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The No. 1 Magazine for Electronics & Computer Projects

VOL. 20 No. 10 OCTOBER 1991

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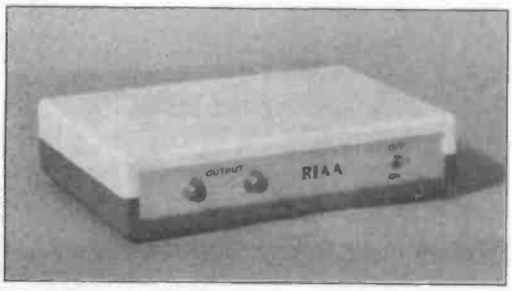
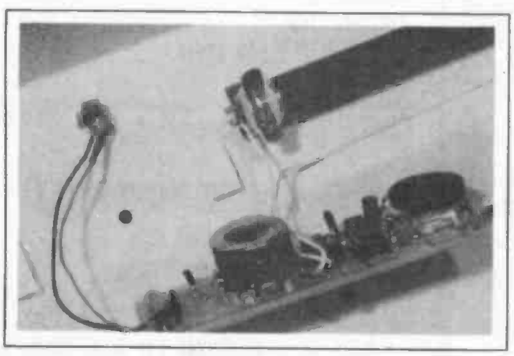
ABC

The No 1 Magazine for Electronic & Computer Projects

ISSN 0262 3617

PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .





Projects

Series

Features

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Our November '91 issue will be published on Friday, 4 October 1991. See page 611 for details.

NEXT MONTH

ELECTRONIC DARTS SCORER

This article describes the design and construction of a microprocessor controlled darts scorer similar in specification and performance to commercially available units. The Darts Scorer has the following features: players scores displayed on individual 3-digit l.e.d. displays; home and away players scores entered via common keypad; facility to recall previously entered score; individual start scores can be entered for each player (to allow handicapping); correct facility available for incorrectly entered scores; functions as a digital clock when not being used for darts.

The construction of this unit should give the reader a useful insight into the design and construction of a typical "embedded" microprocessor application

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The series is designed as a resource from which ideas can be drawn as required. Where practical work is suggested, this will use simple equipment. For later levels, some specialised components will be needed but every effort has been made to keep costs to a minimum by using home-made parts wherever possible.

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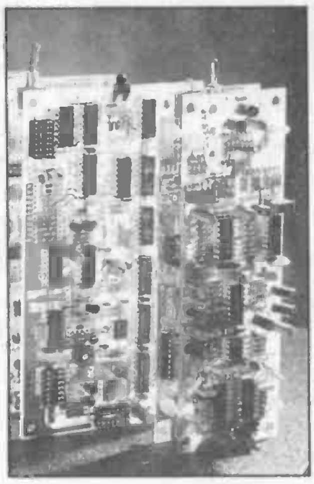

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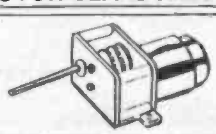

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ALL KITS HERE HAVE BEEN FEATURED IN EE AND ARE SUPPLIED WITH MAGAZINE ARTICLE REPRINTS. SEPARATE REPRINTS ALSO AVAILABLE PRICE 80p EACH INCLUSIVE P&P. KITS INCLUDE CASES, PCB's HARDWARE AND ALL COMPONENTS (UNLESS STATED OTHERWISE) CASES ARE NOT DRILLED OR LABELS SUPPLIED UNLESS STATED.

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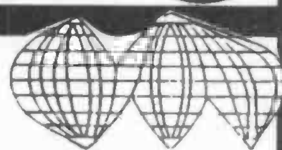

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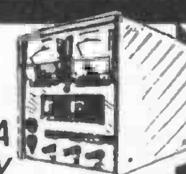
KIT REF 840 **£19.86**



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EE NOV 86

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KIT REF 563 **£71.47**

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EE NOV '87

A very popular project which picks up vibrations by means of a contact probe and passes them on to a pair of headphones or an amplifier. Sounds from engines, watches and speech travelling through walls can be amplified and heard clearly. Useful for mechanics, instrument engineers and nosey parkers!

KIT REF 740 **£20.01**

4 CHANNEL LIGHT CHASER
EE Jan '90

A 1000W per channel chaser with zero volt switching, hard drive, inductive load capability, mic sound sensor and sophisticated 'beat' detector. Chase steps to music or auto when quiet. Variable speed and mic. sens. LED mimic on front panel. Switchable for 3 or 4 channels. P552 output. Ideal for rope lights, pin spots, disco and display lighting.

KIT REF 833 **£32.13**

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EE MAY '87

A mains powered Ioniser with an output of negative ions that give a refreshing feeling to the surrounding atmosphere. Negligible current consumption and all-insulated construction ensure that the unit is safe and economical in use. Easy to build on a simple PCB.

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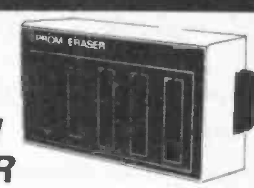

EPROM ERASER
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Safe low-cost unit capable of erasing up to four EPROM's simultaneously in less than twenty minutes. Operates from a 12V supply. Safety interlock. Convenient and simple to build and use.

KIT REF 790 **£28.51**

LIGHT RIDERS
EE OCT '86

Three projects under one title – all simulations of the Knight Rider lights from the TV series. The three are a lapel badge using six LEDs, a larger LED unit with 16 LEDs and a mains version capable of driving six main lamps totalling over 500 watts.

KIT REF 559 CHASER LIGHT	**£15.58**
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KIT REF 815
Including headphones **£45.95**

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EE MAR '90

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KIT REF 835 **£17.16**

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The No.1 Magazine for Electronic & Computer Projects

VOL. 20 No. 10 OCTOBER '91

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IN THE MAIL

It is nice to know that many of our projects are very popular with readers, and that some projects get a wider recognition. Our recent feature *Better Use of Dry Cells* and the associated project *Dry Cell Recharger* triggered off some interest from *The Mail on Sunday* newspaper and a short piece appeared in the 18th August issue. This followed a discussion by *The Mail on Sunday* with our contributor Alan Tong and also with Mike Tooley. Alan was pictured holding a range of cells alongside a heading proclaiming "Battery men shocked by an £8 gadget."

For those that mised it, here is a snippet of what they said:– "A schoolboy project is causing fury in Britain's £250 million battery industry.

A 21-year-old graduate is claiming he has produced a gadget that will do what the industry has always said was impossible or dangerous. . . . *Recharge ordinary, disposable batteries.* Alan Tong, from Enfield, North London, has designed a charger which he says will recharge an ordinary battery safely up to 20 times. Do-it-yourself plans appear in the magazine *Everyday Electronics* showing how it can be made for about £8."

As we go to press other national media are showing interest in the project.

QUESTIONS

Incidentally two questions about the *Dry Cell Recharger* have been asked time and time again. They are – "Can 9V (PP3 type) batteries be recharged?" and "Who can supply the 4.5V transformer?" The answer to the second question is easy – Electromail can supply and full details are given in this month's *Shop Talk*.

The first question is not quite so easy to answer: There is no doubt that batteries (as opposed to cells) can be recharged but this is not usually very successful and the amount of energy stored on recharge is not worthwhile (mainly due to the construction of the cells within the batteries). As we said in the first article – "A word about using PP3 9V batteries, don't. PP3's are the least efficient source of battery power. Avoid buying equipment that uses them."

It is also worth knowing that mains power is 5,000 times cheaper than batteries so a mains adaptor is a worthwhile investment when you can use one.

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We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply must be accompanied by a **stamped self-addressed envelope or a self addressed envelope and international reply coupons.**

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot however guarantee it and we cannot accept legal responsibility for it.

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

We regret that **we cannot provide data or answer queries on projects that are more than five years old.**

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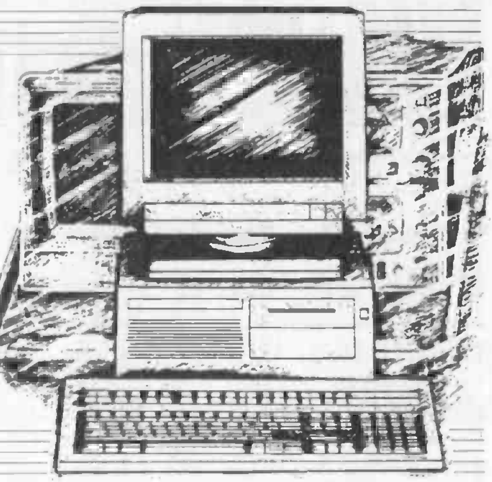
Constructional Project

PC-SCOPE INTERFACE

JOHN BECKER



How a PC-compatible computer can be used as one of the most versatile items of workshop test equipment.

THIS interface enables any PC-compatible computer to be used as an oscilloscope. It samples and stores waveforms of any shape and speed up to around 1MHz. The computer reads the memory store and plots the waveform within a screen window.

There is a choice of display modes, formatted wide or medium window, and high speed unformatted. The software is written in GW-Basic and may be used with colour or monochrome screens. Waveform frequency and amplitude are also calculated by the software and displayed on screen.

Three panel controls vary signal input and gain levels, and select the sampling rate. The effective input frequency range is around 1Hz to 500kHz, though waveform frequencies to either side of the range will still produce display results.

INPUT AND ADC

The block and circuit diagrams for the project are shown in Fig. 1 and Fig. 2. In Fig. 2, the input signal is brought into the pre-amp and buffer stage around IC10. The signal is a.c. coupled by capacitor C5 and its level controlled from nil to maximum by VR3. Signals having a peak-to-peak voltage of up to 16V a.c. may be input. This limit is imposed by the working voltages of C3 and C5. VR1 varies the gain of the preamp from x1 to x11, and VR2 presets the midway output bias level. Operating from a 5V d.c. power line, IC10 has a maximum output swing from approximately 1.5V to 4.5V.

From IC10, the signal goes to pin 11 of the high speed flash analogue-to-digital converter (ADC) IC6. This is a 6-bit ADC which is capable of almost instantaneous conversion at rates of up to 15MHz. Unlike many ADCs which require several clock pulses to complete the conversion, IC6 basically requires just one, although the transfer of the converted data to the output register is only carried out on the next conversion pulse.

The ADC has two current-controlled reference level inputs, at pins 9 and 10. VR4 and VR5 preset the upper and lower limits respectively and are adjusted to suit the maximum output swing from the preamp. No harm will be done if the input signal level exceeds the reference levels, although the resulting binary output code will be erroneous. They may be set for zero resistance if preferred, broadening the reference levels to 0V and +5V.

Contents of the ADC's conversion register are only presented to the outputs B1-B6 when the chip is enabled by the correct logic levels on pins 5 and 6. Binary 10, high and low respectively, enables the output. Any other code puts the outputs into a high impedance state, removing their effect from other devices which share the same lines. Pin 5 is held permanently high. Pin 6 is under control from other parts of the circuit and during sampling mode is held low, so routing the outputs to the 2048-byte memory IC4, and to the 8-channel gate IC7.

CLOCKING AND COUNTING

ADC conversion, memory addressing and writing are triggered by the combined clock generator and counter around IC1. Fig. 3 shows details of the oscillator section, the basic rate of which is set here to 3.2768MHz by the crystal.

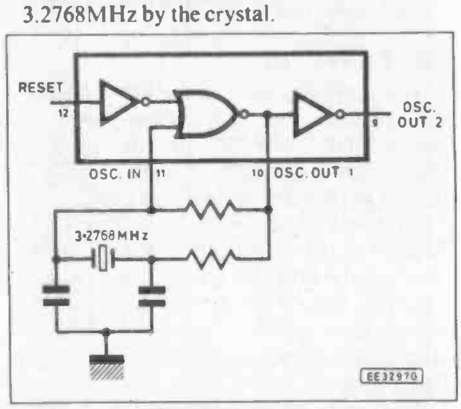
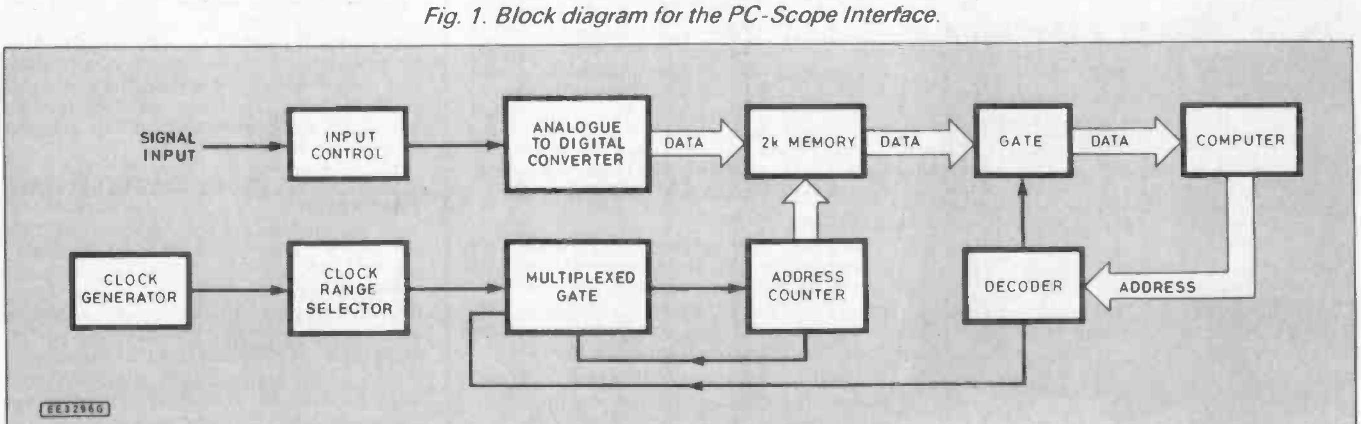


Fig. 3. Oscillator section of the 74HC60 14-stage counter i.c.

The oscillator drives a 14-stage binary ripple counter in which each stage successively divides the clock frequency by two. Stages Q4-Q14, though excluding Q11, are available as outputs. Switch S1 is wired to select any one of them, plus the original 3.2768MHz clock. Q14 produces the lowest frequency output, of 200Hz. The full range of output frequencies will be seen in line 50 of the software listing.

From S1, the selected clock rate is in-

Fig. 1. Block diagram for the PC-Scope Interface.



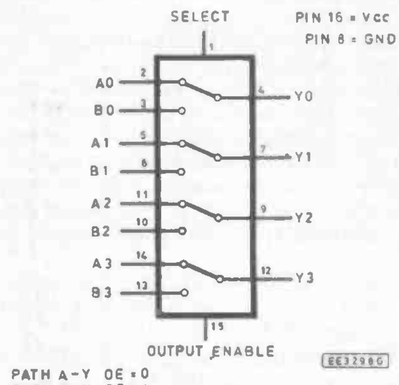
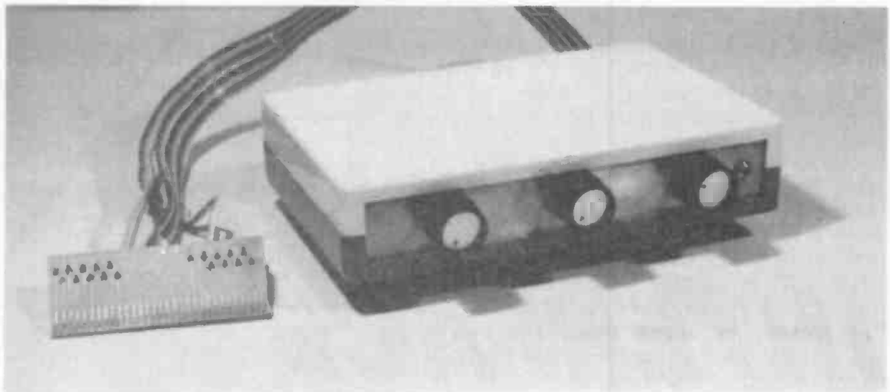
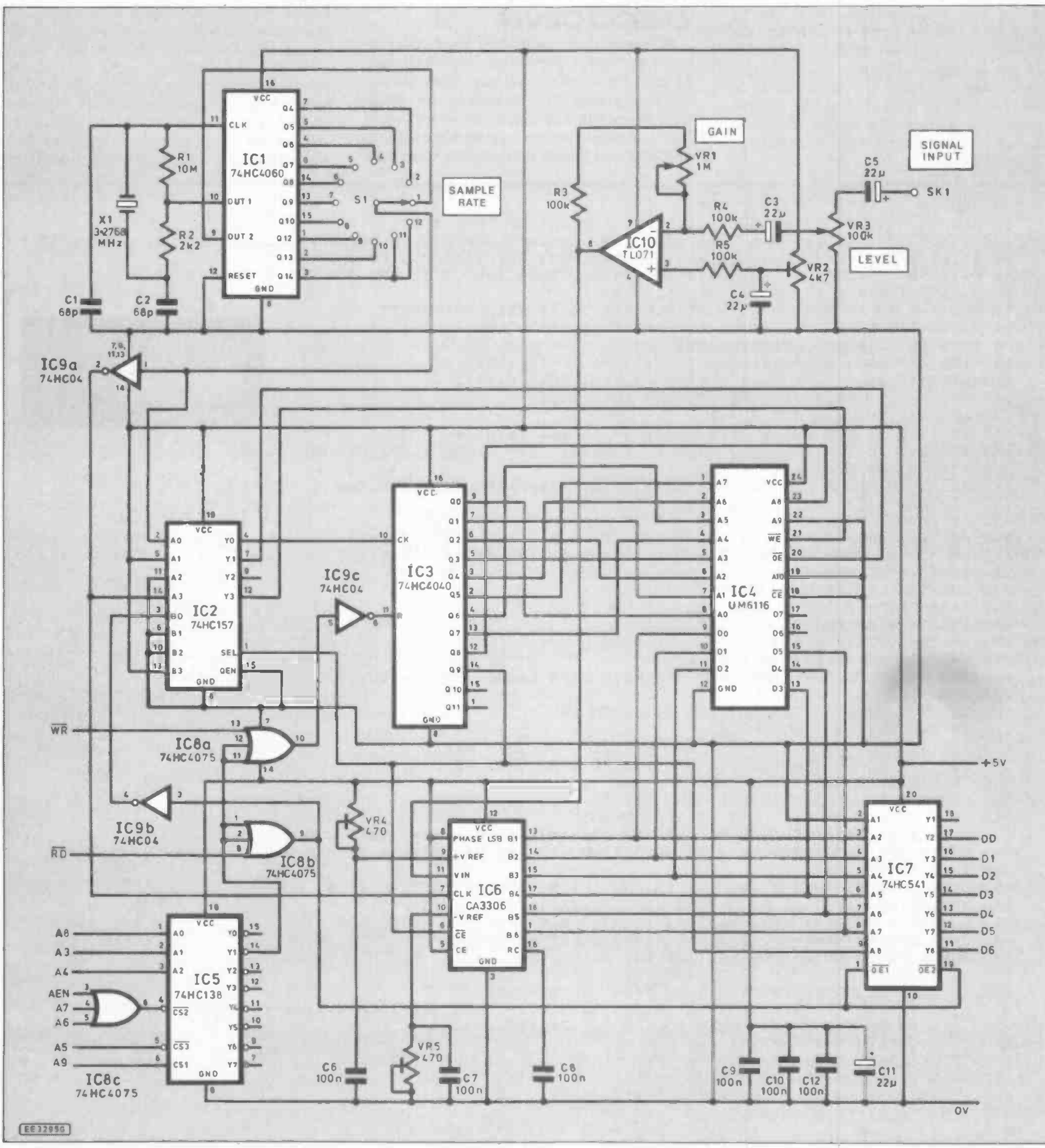


Fig. 4. Switching logic details for the 74HC157.



verted by IC9a and is fed to IC6 pin 7 as the ADC conversion pulse. Uninverted and via path A0-Y0 of the multiplexed gate IC2 (see Fig. 4), the clock is also fed to the 12-stage binary ripple counter IC3. On receipt of the negative-going edge of each pulse on clock input pin 10, the count within IC3 is stepped on by one place. The first nine outputs of IC3, Q0-Q8, are connected to the memory IC4 as its

Fig. 2. Complete circuit diagram for the PC-Scope Interface.



address lines. Q9 controls the path-block routing of gate IC2, provides a sync point for monitoring by the computer via IC7, and controls the active chip enable pin 6 of ADC IC6. Outputs Q10 and Q11 are not used.

The inverted clock signal from IC9a is also routed via IC2 path A3-Y3 to control the read/write operation of the memory. A low level on IC4 pin 21 sets the memory into write mode. Provided that the output enable (OE) pin of IC4 is simultaneously high, data presented from the ADC will be recorded at the address location set by counter IC3, overwriting any data previously stored at the same address. By using opposing phases of the clock pulse, synchronisation of the counter clocking and memory writing is timed so that the address is stable during the write function.

When the counter's Q9 output goes high, IC2 is set so that outputs Y0-Y3 are connected to paths B0-B3 instead of A0-A3. In this configuration, path B3-Y3 takes IC4 pin 21 low so holding the memory in read mode. Path B1-Y1 takes IC4 pin 20 high, so opening the memory's D0-D5 data outputs. The clock input to counter IC3 is now via path B0-Y0, opening it to triggering under computer control in conjunction with a dedicated decoding circuit.

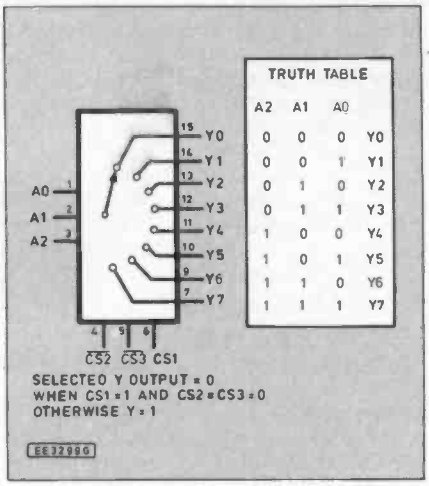


Fig. 5. Switching logic details for the 74HC138 3 to 8 line decoder.

DECODING

PC-compatible computers have three or more expansion sockets any of which can be used for interface circuits. They are all on a common bus consisting of data, address, power and synchronisation lines. The expansion sockets can be accessed via any of 32 addresses between hex locations $0300-$031F (decimal 768-799). Several extension cards can be used in parallel simultaneously, accessing them via different and dedicated addresses. This oscilloscope interface has basically been designed for accessing at address $0300, though it will also respond to address calls at $0301-$0307. Additionally, the p.c.b. has been designed to allow a simple wiring change to be made allowing other addresses within the $0300-$031F range to be used.

Decoding of the address bus is performed by IC5 and IC8c. The binary equivalent of $0300 is 1100000000 therefore, reading left to right, address lines A9-A0 must reflect this logic. The computer's address enable line AEN must also be low for the address to be valid. AEN and address lines A7 and A6 are ORed by IC8c. When all three lines are low, so too will be the output of IC8c. The combination of IC8c output low, A5 low and A9 high is the only one which will enable IC5 to respond to address codes on its A0-A2 inputs. Fig. 5 shows the chip's logic details.

When IC5 is disabled its Y0 -Y7 outputs are all set high. When enabled, the output selected by the logic on IC5 A0 -A2 will go low. Y1, as used and shown in Fig. 2, will go low when computer lines A3 and A4 are low and A8 is high. Since computer

LISTING ONE: MAIN PC-SCOPE PROGRAM

```
10 REM EE PC SCOPE 03FEB91 S58
20 SCREEN 0:COLOR 15,4:SCREEN 1:COLOR 1,2:KEY OFF:DIM S(12),T(12)
30 PRINT" [d] d/a [s] sync [+] edge [w] window":LOCATE 2,28:PRINT"[h] hold"
40 L=768:M=90:T=M-32:S=M+32:F= 5:G=F+300:WW=2:W=1:SY=0:P=1:FF=F+1:GG=G
50 DATA 3276800,204800,102400,51200,25600,12800,6400,3200,800,400,200
60 DATA 0,1,2,4,8,16,32,64,256,512,1024
70 FOR A=1 TO 11:READ S(A):NEXT:FOR A=1 TO 11:READ T(A):NEXT
80 S$(0)="SYNC OFF ":S$(1)="SYNC ON  ":G$(0)="-":G$(1)="+"
90 LOCATE 5,2:PRINT G$(P);S$(SY)
100 FOR A=F TO G STEP 50:LINE (A,T-1)-(A,T-5),1:NEXT
110 LINE (F,T-1)-(G+1,T-1),2:LINE (F,S+1)-(G+1,S+1),2
120 LINE (F,T)-(F,S),2:LINE (G+2,T)-(G+2,S),2
130 LOCATE 18,2:A=0:OUT (L),0
140 IF (INP(L) AND 64)=0 THEN A=A+1:IF A<1100 THEN 140
150 FOR B=1 TO 11:IF A>T(B) THEN NEXT:PRINT "**    CHECK SWITCH":GOTO 130
160 VV=S(B):WW=B:LOCATE 18,2
170 PRINT"SWITCH POSITION";WW:PRINT:PRINT" SAMPLING RATE";VV;"Hz     "
180 Z$=INKEY$:IF Z$="" THEN 300
190 IF Z$="d" THEN D=(D+1) AND 1
200 IF Z$="+" THEN P=(P+1) AND 1:LOCATE  5,2:PRINT G$(P);S$(SY)
210 IF Z$="s" THEN SY=(SY+1) AND 1:LOCATE 5,2:PRINT G$(P);S$(SY)
220 IF Z$<>"h" THEN 260
230 LOCATE 5,29:PRINT"HOLDING"
240 Z$=INKEY$:IF Z$="" THEN 240
250 LOCATE 5,29:PRINT"        "
260 IF Z$<>"w" THEN 180
270 W=(W+1) AND 1:IF W=0 THEN 180
280 FOR A= FF TO 105:LINE (A,T)-(A,S),0:LINE (A+200,T)-(A+200,S),0:NEXT
290 GOTO 180
300 IF SY=0 THEN C=(INP (L) AND 63):GOTO 360
310 IF P=0 THEN A=1:GOTO 330
320 FOR A=1 TO 200:C=(INP (L) AND 63):IF C<36 THEN NEXT
330 FOR B=A TO 200:C=(INP (L) AND 63):IF C>28 THEN NEXT
340 IF P=1 THEN 360
350 FOR A=B TO 200:C=(INP (L) AND 63):IF C<36 THEN NEXT
360 FF=F+1:GG=G:IF W=1 THEN FF=105:GG=205
370 LINE (FF-1,T)-(FF-1,S),2:LINE (FF ,T)-(FF ,S),0:IF D=1 THEN 430
380 N=0:Y=255:C=C+T:FOR A=FF TO GG:B=(INP (L) AND 63)+T:IF B>N THEN N=B
390 IF B<Y THEN Y=B
400 LINE (A+1,T)-(A+1,S),0:LINE (A,M)-(A+1,M),3:LINE (A,C)-(A+1,B),1:C=B
410 NEXT:LINE (A,T)-(A,S),0:LINE (A+1,T)-(A+1,S),2
420 LOCATE 3,2:PRINT"PEAK MAX";64-(Y-T);" MIN";64-(N-T):GOTO 130
430 C=(C AND 32)*2+T:J=C:N=0:Y=0:KK=FF:KL=0:YK=FF:YL=0
440 FOR A=FF TO GG:B=(INP (L) AND 63)
450 IF B>36 THEN C=S:IF J<>C THEN Y=Y+1:YL=YK:YK=A
460 IF B<28 THEN C=T:IF J<>C THEN N=N+1:KL=KK:KK=A
470 LINE (A+1,T)-(A+1,S),0:LINE (A,J)-(A,C),1:J=C:NEXT:LINE (A+1,T)-(A+1,S),2
480 IF SY=0 OR Y=0 OR N=0 THEN LOCATE 3,2:PRINT"                        ":GOTO 530
490 IF P=0 THEN V=(YK-FF)/Y
500 IF P=1 THEN V=(KK-FF)/N
510 X=1000000!/VV:X1=1000000!/(X*V)
520 LOCATE 3,2:PRINT "FREQUENCY";INT(X1);"Hz     "
530 LINE (A,T)-(A,S),0:GOTO 130
```

address lines A0-A2 are not used, IC5 will respond to any call within the eight code block $0300-$0307.

Output IC5 Y1 controls two inputs of the two OR gates IC8a and IC8b. The computer has separate write and read lines which are brought to the other respective inputs of the two OR gates. When a write or read call at any address between $0300 and $0307 is called by the computer, the OR gates respond accordingly. IC8a's output goes low in response to a correctly addressed write call, causing the output of the NAND gate IC9c to go high, so resetting counter IC3.

Several functions are controlled by calling a read operation via the selected address. The call sets IC8b's output low. This causes gate IC7 to open its outputs onto the computer data bus. Memory IC4 is already in read mode and so the computer reads its contents via IC7.

Simultaneously, IC9b output goes high and is fed via IC2 path B0-Y0 to the clock input of IC3. At this point, IC3 ignores the positive-going change. However, when the read call ends and the clock input level falls, the counter is clocked on one place by the negative-going edge. Data from the next memory location is then ready for reading on the next read call.

To ensure synchronisation between sampling blocks, the computer monitors the status of IC7 output D6. Although the memory and counter can only be accessed by the computer when gate IC2 is open on the B0-B3 paths, IC7 can be read at any time. The end of the sampling routine is signified by IC3 Q9 output going high. When, via IC7, the computer registers this change it then starts its data retrieval. Repeatedly reading via $0300, it alternately inputs the memory data and steps the counter. At the end of the reading routine, which may be of any length up to the full 2048 steps, the computer writes to $0300, resetting the counter. Consequently, IC3 Q9 goes low and the next batch of signal data is input, converted and stored. When Q9 goes high again, data is once more available for reading.

SOFTWARE

GW-Basic is the most widely used of the Basic languages available for PC-compatibles and is the dialect in which the software is written. The computer must be loaded with the GW-Basic control software package before Listing One can be run.

The listing is applicable to computers with colour or monochrome screens, though for the latter it may be necessary to omit the colour command statements. The program can be readily translated into other dialects as long as they allow access to the expansion sockets.

The expansion socket address location is held in variable L, shown in line 40 as 768 ($0300). After an initialisation routine, the sampling starts at line 130 in which the address 768 is written to, resetting the counter. The unit will respond to this command irrespective of the status of gate IC2.

Signal sampling takes place at the rate set by S1. The time it takes between the counter being reset and its Q9 output going high is monitored by the computer via IC7's D6 output, counting the number of read calls made until D6 goes high. Relating this number to the data in lines 50 and 60, the computer determines the position to which S1 is set. From this knowledge, subsequent input signal frequency calculations can be made and displayed.

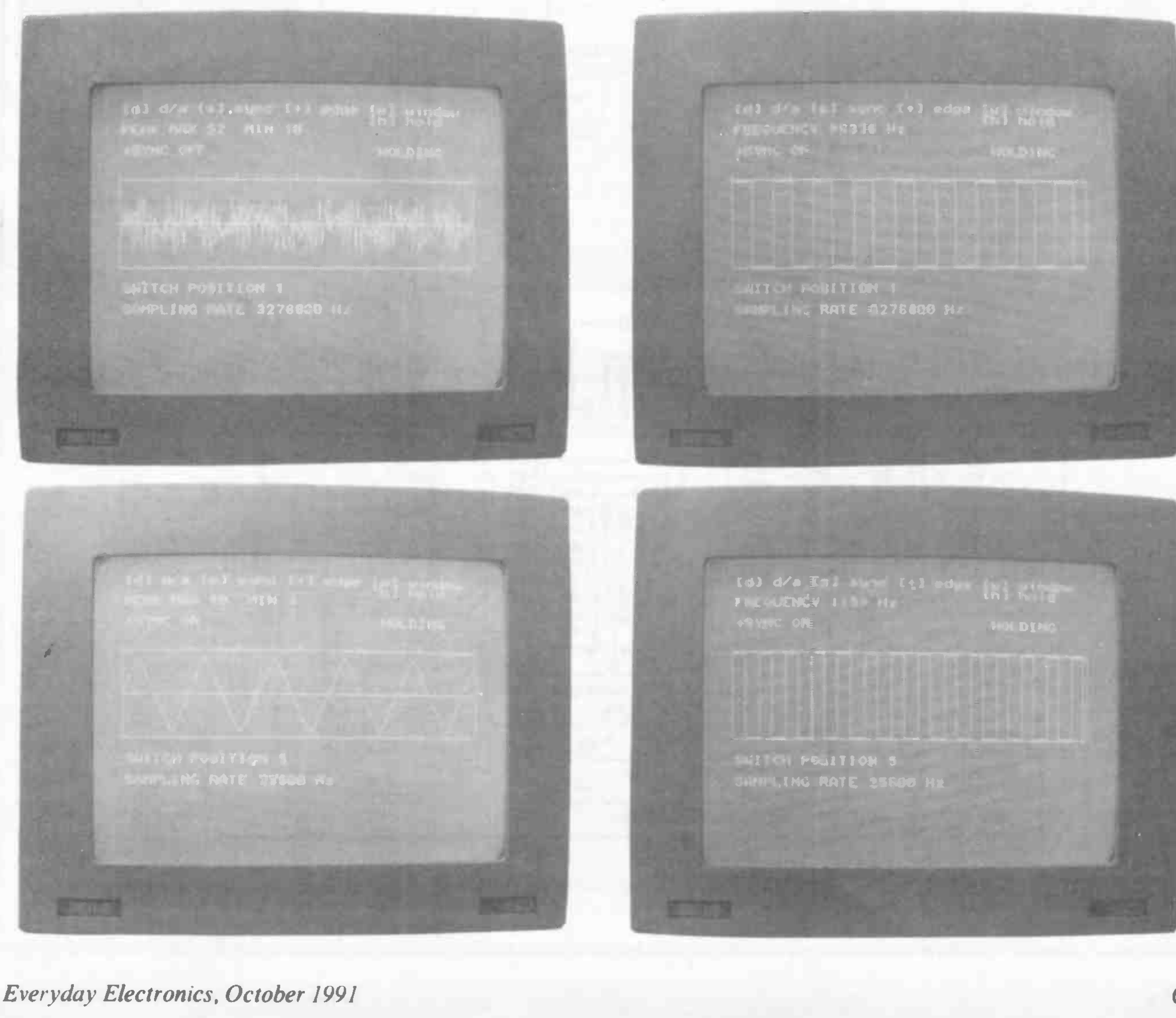
DISPLAY

Several display modes can be keyboard controlled while the program is running. Keyboard inputs are monitored in line 180. Pressing key "d" toggles the program between displaying the waveforms in analogue or digital format. Key "+" alternates the signal trace sync polarity between positive and negative edges, and key "s" turns sync on and off. The waveform trace may be frozen or run continuously by pressing key "h". Screen window size is controlled by key "w".

In all these keying instances, the opposite action of that previously triggered is set. Changes to any of the keyboard-entered factors may be made at any time, though they will only be acted upon immediately prior to each data input batch.

Drawing of the waveform data on screen begins at line 300. Action is taken in respect of synchronisation requirements. If sync is called for, the incoming data is searched until the nearest level relative to positive or negative triggering is found. Following sync assessment, data is repeatedly input and line-plotted on screen according to its amplitude and relative timing.

Examples of screen waveforms when operated in analogue and digital mode, with sync switched in and out.



PC-SCOPE INTERFACE

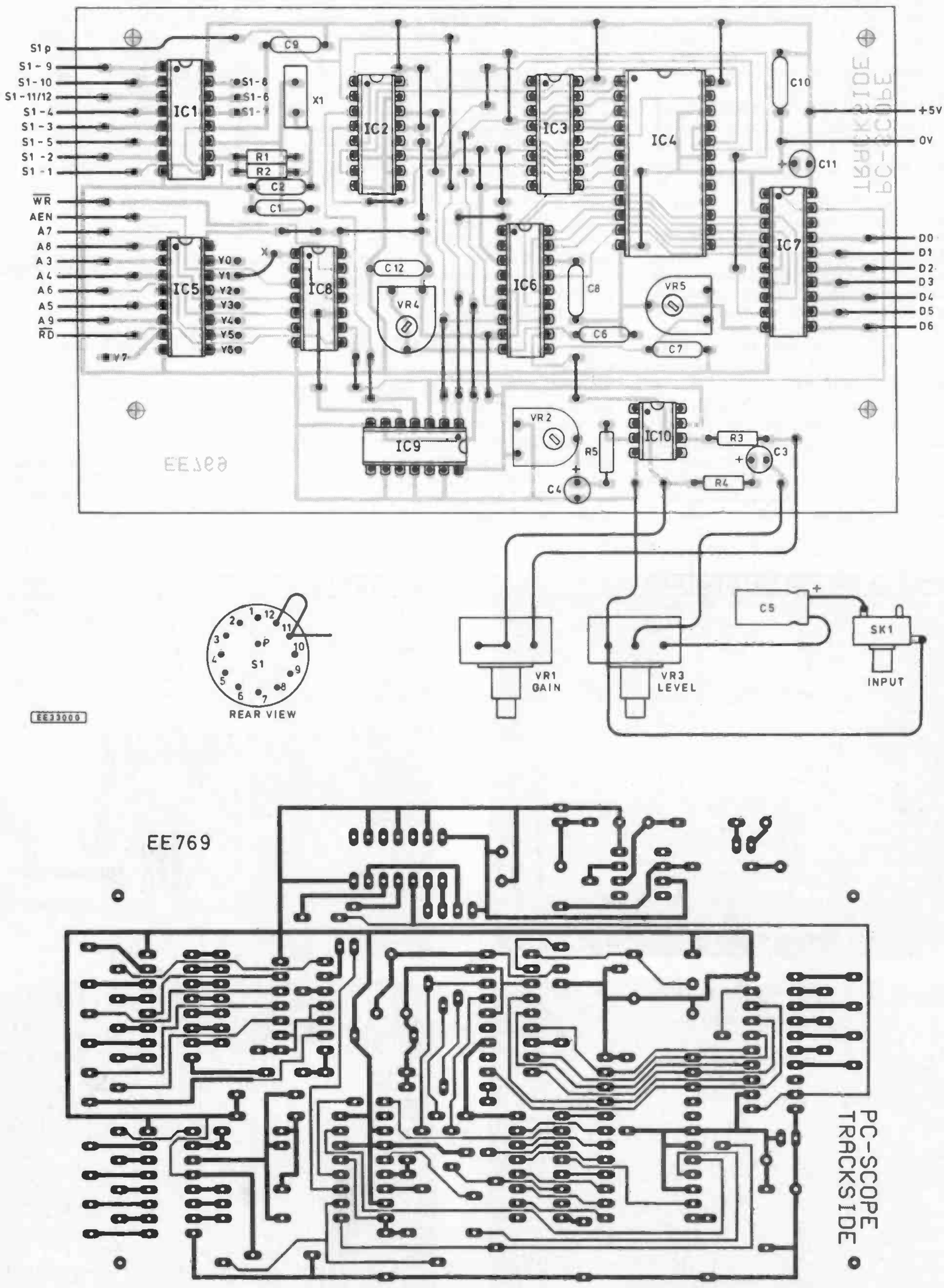


Fig. 6. Printed circuit board component layout, interwiring to off-board components and full size copper foil master pattern details.

COMPONENTS

Resistors
R1 10M
R2 2k2
R3 to R5 100k (3 off)
All 0.25W 5% carbon film

Potentiometers
VR1 1M lin. rotary
VR2 4k7 min. horiz. preset
VR3 100k lin. rotary
VR4, VR5 470 min. horiz. preset (2 off)

Capacitors
C1, C2 68p polystyrene (2 off)
C3 to C5, C11 22μ radial elect. 16V (4 off)
C6 to C10 100n polyester (5 off)

Semiconductors
IC1 74HC4060
IC2 74HC157
IC3 74HC4040
IC4 UM6116
IC5 74HC138
IC6 CA3306
IC7 74HC541
IC8 74HC4075
IC9 74HC04
IC10 TL071

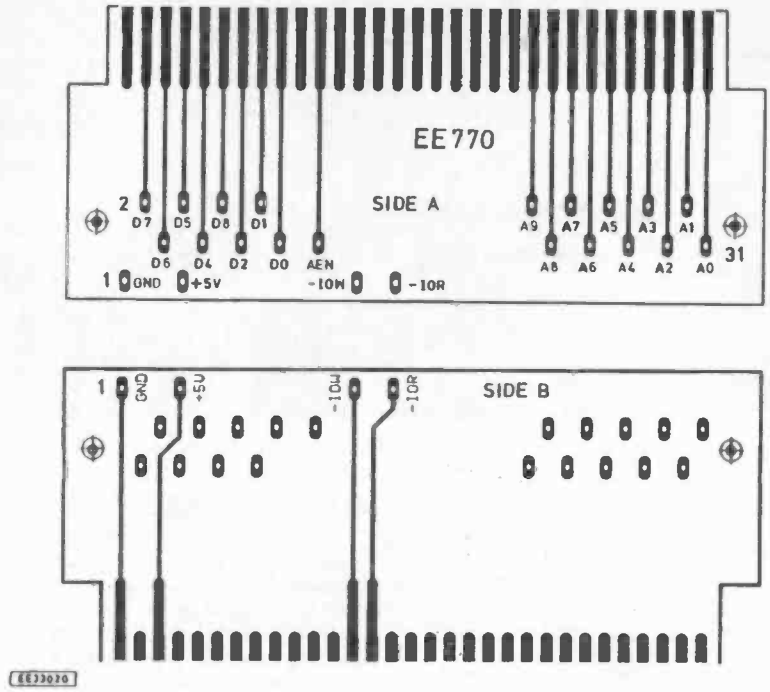


Fig. 7. Full size copper foil master patterns for the double-sided interface plug.

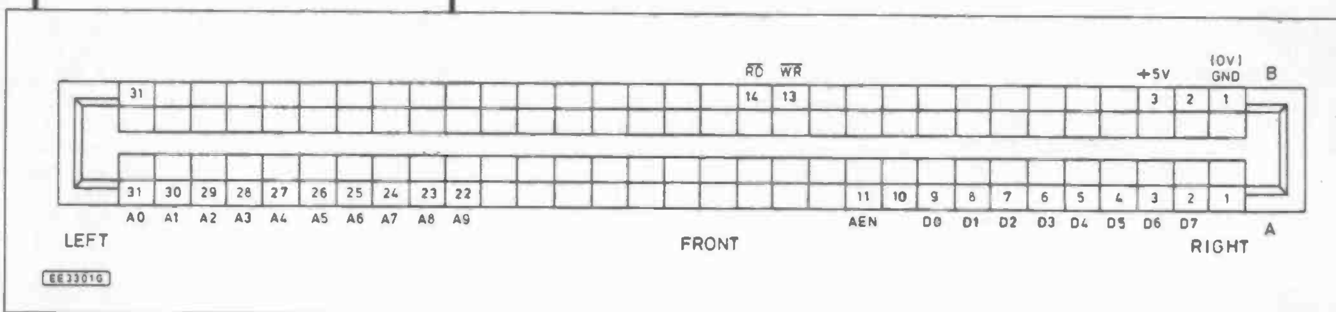
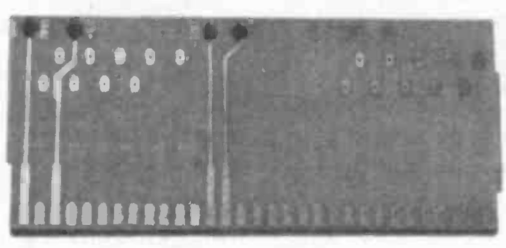


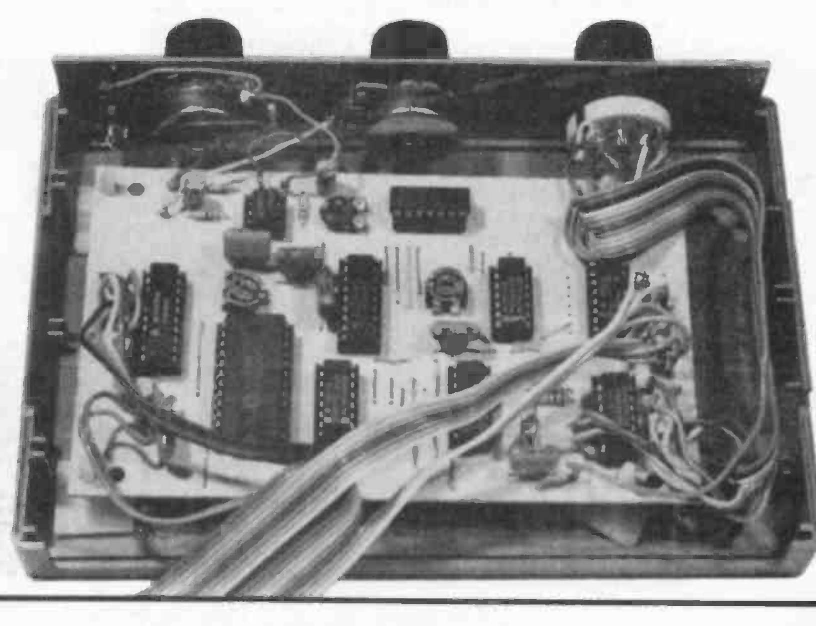
Fig. 8. PC expansion socket for the Amstrad 1640. For other PC's consult computer manual (see text).

Miscellaneous
S1 1P 12W rotary switch
X1 3.2768MHz crystal
I.C. sockets – 8-pin d.i.l., 14-pin d.i.l. (2 off), 16-pin d.i.l. (4 off), 18 pin d.i.l., 20-pin d.i.l., 24-pin d.i.l.; 3.5mm jack socket; knobs (3 off); plastic case 180 x 120 x 40mm; p.c.b. supports (4 off); ribbon cable (1 metre 20-way).

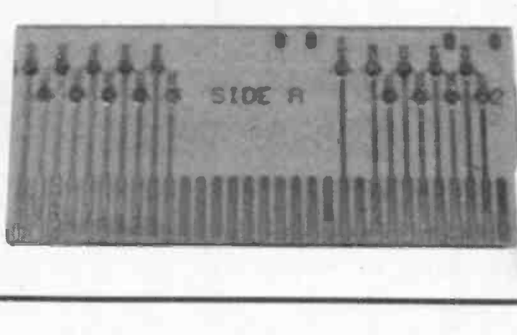
Printed circuit boards available from the *EE PCB Service*, order codes EE769, EE770.

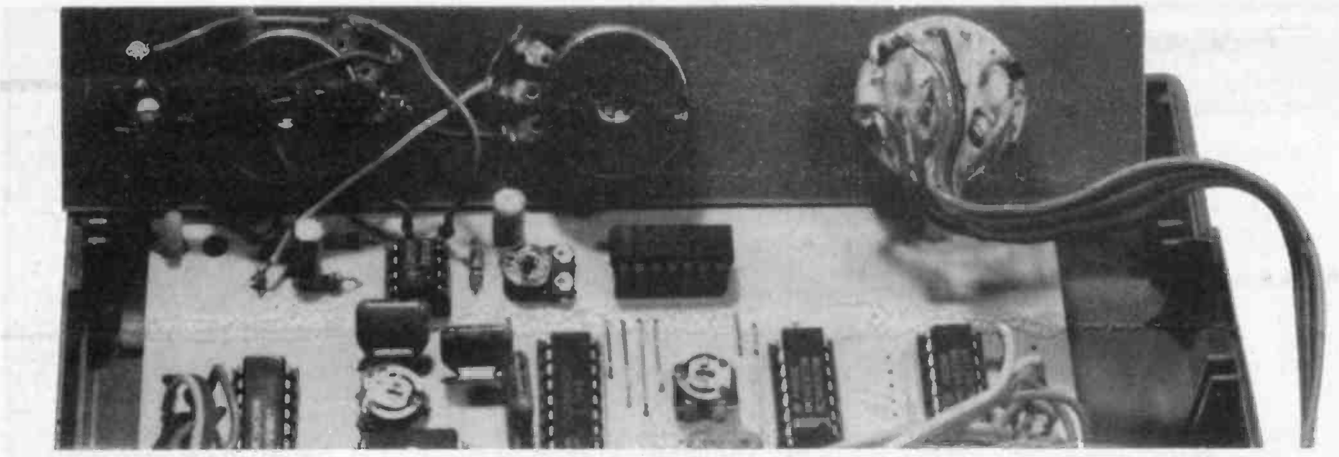
Approx cost guidance only **£32**





(above right) Interface expansion plug side B.
(right) Layout of components inside the control case.
(below) Interface expansion plug side A.





Wiring to the front panel control components. Note that the electrolytic capacitor C5 is wired directly between the Level control VR3 and the Input socket SK1.

In digital mode, the lines are drawn as vertical logic pulses of equal amplitude. In analogue mode they are plotted angularly and, being sampled waveforms, consist of a number of joined steps. Any signal may be plotted in either mode, with or without sync, irrespective of its type.

Frequency calculations are only made and displayed in digital mode and with the sync on. They will not be precise frequency values and should be regarded only as a guide. Displayed waveforms must be clearly defined for a reasonable frequency assessment to be made. Maximum and minimum amplitude factors are displayed only in analogue mode. They relate to the input values in decimal but may be expressed as voltages by simple calculation against the reference levels set on the ADC chip.

The timing factors quoted in line 60 apply to computers running at the same system speed as the Amstrad 1640 with which the prototype was proved. They are used to determine which setting of clock rate switch S1 has been selected, and hence affect the calculation of the input signal frequency. For machines running at other system speeds the factors will need changing, though will bear the same relationship to each other as shown in line 60. The correct factors can be readily found by comparing the calculated frequency displayed on screen with a known frequency source. They do not affect the correct operation of the rest of the program. The factors in line 50 are not affected by the computer system speed but relate to the unit's 3.2768MHz crystal clock.

An alternative routine may be used in place of the main program to give a faster sampling and display rate without the formatting frills written into the full display routine. By using Listing Two the unit will be read at the fastest practical rate, though will still be limited by the sampling rate set by S1. Data is displayed in a very simple format across the screen. The screen is cleared prior to each data batch being displayed.

ASSEMBLY

There are two p.c.b.s for the project. The main control board is shown in Fig. 6 and is mounted in a box external to the computer. The second board, shown in Fig. 7, is simply a double-sided plug which is inserted into any of the computer expansion sockets to carry the wiring to the main board. The computer manual should be consulted for the correct orientation of the board in its chosen socket. Fig. 8 shows the orientation for the Amstrad 1640.

The unit is powered by the computer's +5V supply, delivered via the interface plug board.

Inter-track link wires on the component side of the main board should be soldered in first. Note especially the links under the IC4 and IC8 positions.

The link between points Y1 and X alongside IC5 sets the decoded address to the $0300-$0307 block. To code the unit for other address blocks point X may instead be linked to any one of Y3, Y5 or Y7, coding for $0308-$030F, $0310-$0317 and $0318-$031F respectively. Points Y0, Y2, Y4 and Y6 should be ignored.

Sockets should used for all i.c.s and should be inserted next, followed by the presets and then the remaining components. Strict attention must be observed when soldering any part of the board, but especially so in those areas where tracks pass between i.c. pins. A fine-tipped soldering iron and thin solder wire (22 s.w.g.) should be used.

Inter-board wiring is best made using ribbon cable, allowing a maximum length of about one metre. Much greater lengths could cause logic signal problems for the computer, especially those operating at higher system speeds. Check all soldered joints with a magnifying glass.

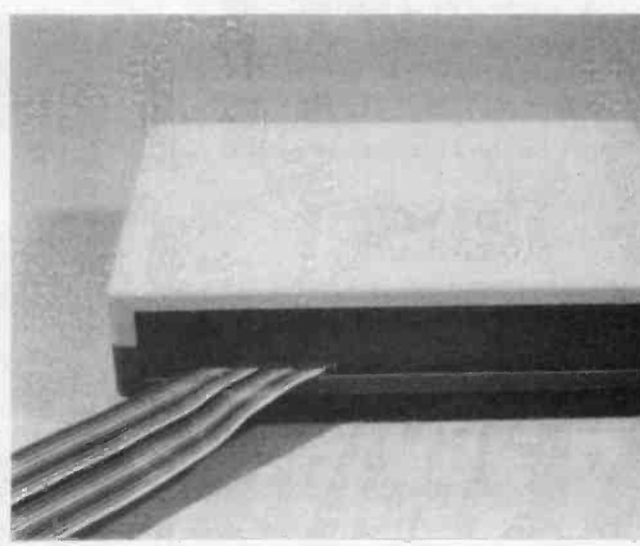
TESTING

Before inserting i.c.s or plugging into the computer, with a multimeter set on a low resistance range, check that no shorts exist between adjacent tracks on the plug-in board. Additionally check that no short exists between the +5V and 0V power lines. Still without i.c.s in place, plug the unit into the computer and switch on. If the screen does not display its normal response, immediately switch off and recheck the boards.

When satisfied, plug in the i.c.s, load GW-Basic and either the main routine or the shortened version. Set S1 to position 4, VR3, VR4 and VR5 for minimum resistance, VR1 for maximum resistance, and VR2 midway. Feed into the unit a sine or triangle wave signal of, say, 1kHz at 2V peak-to-peak, and run the program, changing the settings of the panel controls to suit the observed display. Increase the signal until its upper and lower peaks are flattened by the clipping action of the op.amp. Now adjust VR2 until the clipping is symmetrical.

Decrease the signal level until peaking just below the clipping level. Minutely adjust in turn both VR4 and VR5 to preset the ADC reference levels. The amplitude of the screen trace should increase as the relative conversion span changes. Increase the resistances until waveform clipping is again apparent, then back off the presets slightly until the clipping disappears. Minor adjustments may be beneficial once users are familiar with the unit's operation. □

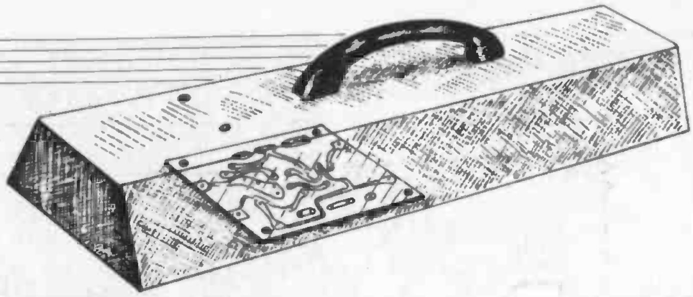
Rear of the completed unit showing the entry/exit slot for the multicoloured expansion plug cable.



LISTING TWO: FAST SAMPLING

```
10 REM PC SCOPE FAST SAMPLING
20 SCREEN 0:COLOR 15,4:SCREEN 1:COLOR 1,2
30 J=0:D=40:OUT (768),0
40 IF (INP(768) AND 64)=0 THEN 40
50 CLS:FOR A=1 TO 256:B=INP(768) AND 63:J=J+2
60 LINE (J-2,D+C)-(J,D+B),1:NEXT:C=B:NEXT:GOTO 30
```

Constructional Project



UV EXPOSURE UNIT

RICHARD WORTHINGTON

An inexpensive method of producing your own printed circuit boards (up to 100mm × 250mm), with a built-in safety feature. Can also be used to drive 8W 12in fluorescent lighting tubes, from 12V supplies.

PROBABLY the main disincentive from making you own p.c.b.s must be the cost of the ultra-violet exposure unit that is needed for fast and consistent results. However, now that the first ever surface-mount projects are appearing, there surely can't be a better time to get started.

This project therefore describes a safe and inexpensive UV Exposure Unit, suitable for the production of traditional or SMD printed circuit-boards up to 100mm by 250mm in size. It's easy to build, and runs off a 12V d.c. supply such as NiCad batteries, a lead/acid battery or a mains adaptor.

HOW IT WORKS

The basic method of use is illustrated in Fig. 1. It would probably be difficult to build a device similar to commercial UV exposure units; to make the casing would require carpentry or metal-working skills for a start, then there's the problem of glass cutting, plus the usual mains safety considerations.

So, a different and more simple approach is used here: First, the unit is placed on top of the p.c.b. overlay transparency and photo-resist board. Tilt switches sense when the unit is stationary and horizontal — this feature ensures that it is impossible to accidentally view the UV fluorescent tube when lit. A warning buzzer then sounds for ten seconds, before the fluorescent tube illuminates, exposing the area beneath the unit to ultra-violet light.

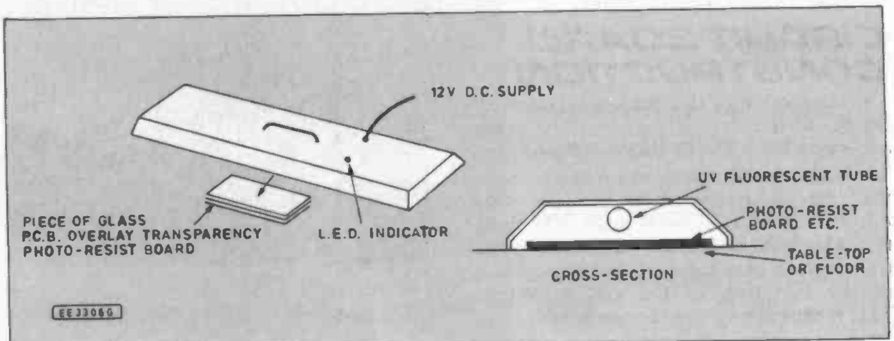


Fig. 1. Demonstrating the simplicity of using the unit. Once the photo-resist board "sandwich" is made up, the unit is placed over it and it is exposed to ultra-violet light.

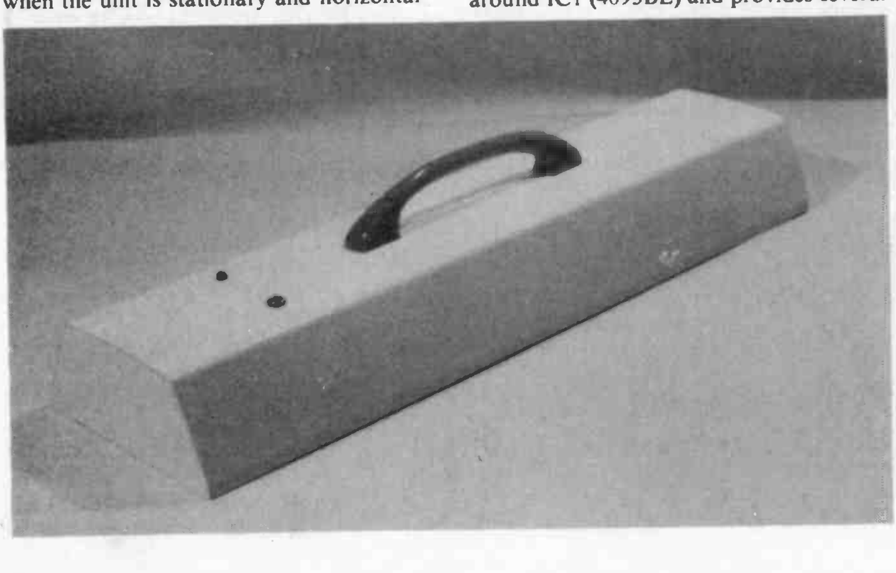
CIRCUIT DESCRIPTION

The circuit, shown in Fig. 2, consists of two main sections; the first is based around IC1 (4093BE) and provides several important safety features. The second section, based around transformer T1, generates the high voltage necessary to run the fluorescent tube.

To begin, when the unit is placed on a horizontal surface, such as a tabletop or the floor, all four mercury tilt switches "close". IC1a input is pulled low, so its output (pin 3) goes high and capacitor C1 slowly charges via resistor R2.

Meanwhile, since both inputs of IC1c are high, its output is low and the audio oscillator (based on IC1d) is free to operate. Oscillation is possible due to the hysteresis of IC1d (Schmitt trigger); the chosen values for R3 and C2 give a frequency of several hundred Hertz. There is, therefore, an audible advance warning of when the fluorescent tube is about to light.

Eventually, as C1 charges up, the voltage at IC1b input reaches two thirds of the positive supply voltage. At this point IC1b changes state, its output now going low so that transistor TR1 conducts. The audio oscillator ceases, l.e.d. D3 lights, and the second section of the circuit (the UV fluorescent tube driver) is activated. If, however, the unit is picked up or knocked over, one or more tilt switches will "open", C1 discharges via D1, and the fluorescent tube instantly switches off.



TRIGGER CIRCUIT

The second section uses a familiar blocking oscillator circuit to supply the UV fluorescent tube – this part of the circuit could be built on its own to drive an ordinary 8W fluorescent tube if required; simply omit TR1 and everything to the left of it, making a connection from +12V to R6.

Initially, capacitor C3 charges up until TR2 conducts. As current starts to

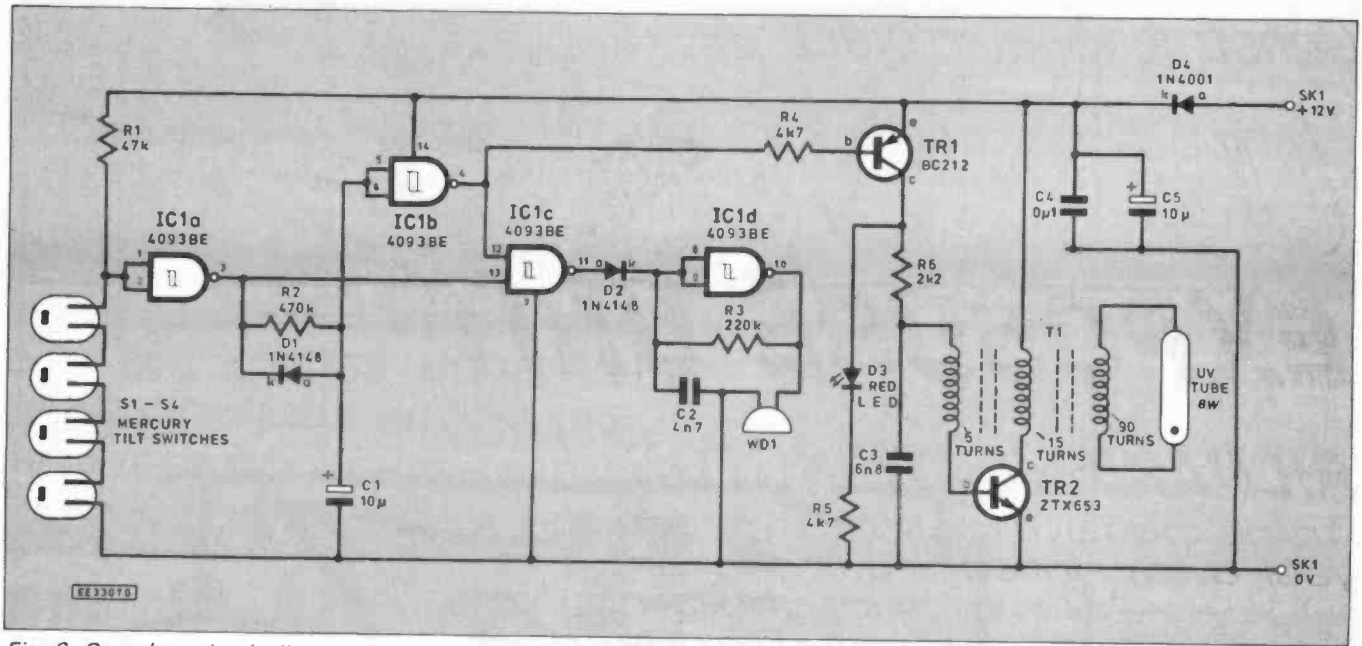
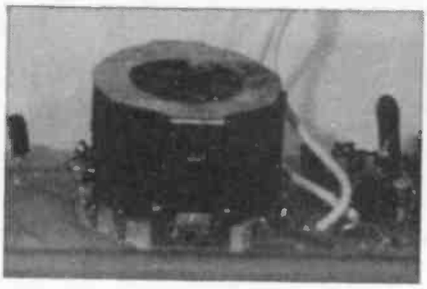


Fig. 2. Complete circuit diagram for the UV Exposure Unit. To drive an 8W 12in. fluorescent lighting *tube, omit TR1, take D3a R6 to +V line and discard all components to the left of TR1.*

flow through the collector coil winding, a pulse is induced in the base winding. This reverses the direction of charge on C3, switching off TR2 until C3 can recharge via R6, the process then repeats. The frequency of oscillation depends on the time constant of C3 and R6. A third "step-up" winding supplies the UV fluorescent tube.

CIRCUIT BOARD CONSTRUCTION

Construction of this project is relatively simple with most of the circuitry being accommodated on the single-sided printed board (p.c.b.) shown in Fig. 4. This board may be purchased from the *Everyday Electronics PCB Service*, code 768. It is probably best to begin by assembling the transformer (see Fig. 3), making certain of the direction of the coil windings. The remainder of the circuit-board construction is quite straightforward — but remember to leave sufficient length in the leads of tilt switches S1 to S4, and check that the ends with the contacts will be lowermost when the unit is fully assembled (see Fig. 6).



The completed trigger transformer T1.

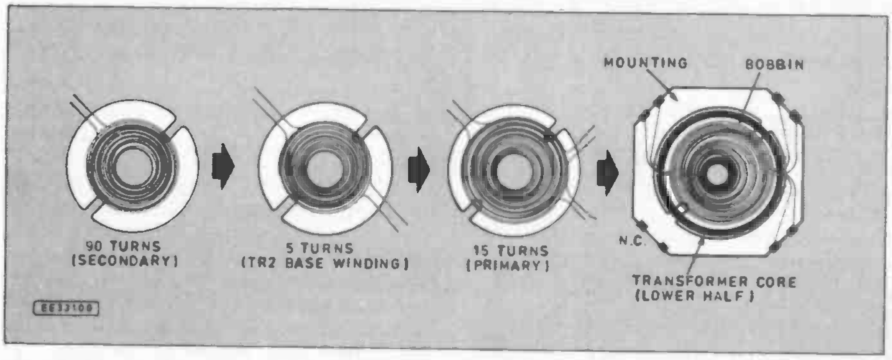


Fig. 3. Ferrite pot-core transformer winding details. Each winding is held in place by a layer of insulation tape. (below) The UV tube and circuit board installed in a piece of white angular "guttering".

COMPONENTS

See SHOP TALK Page

Resistors

R1	47k
R2	470k
R3	220k
R4, R5	4k7 (2 off)
R6	2k2

All ¼W ± 5% carbon film

Capacitors

C1, C5	10µ elect. 12V (2 off)
C2	4n7 polyester
C3	6n8 polyester
C4	0µ1 polyester

Semiconductors

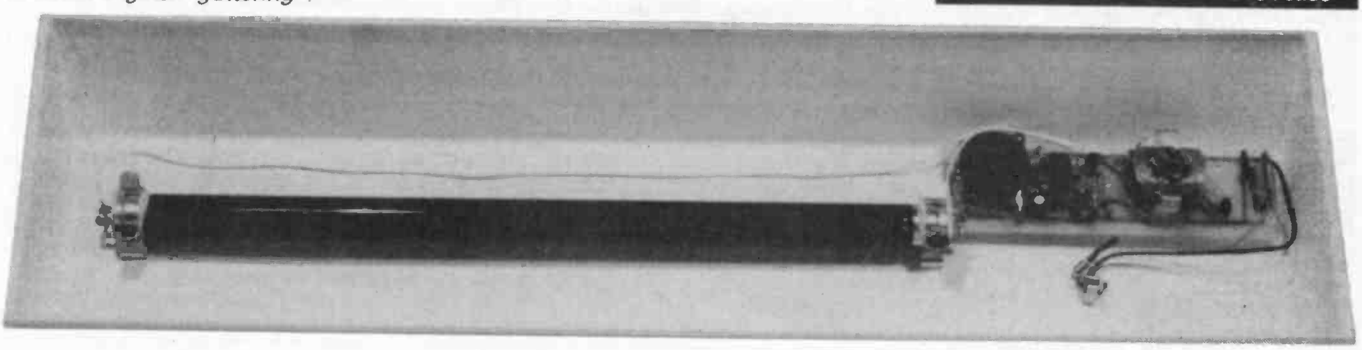
D1, D2	1N4148 signal (2 off)
D3	Standard red l.e.d.
D4	1N4001 1A 50V rec.
TR1	BC212 *pnp* silicon
TR2	ZTX653 *npn* silicon
IC1	4093BE quad 2-input NAND Schmitt

Miscellaneous

T1	B65671 LR26 transformer core, plus bobbin & mounting
S1 to S4	mercury tilt switch (4 off)
WD1	piezo sounder

Printed circuit board available from the EE PCB Service, order code EE768; 12 inch 8W UV fluorescent tube plus mounting clips; suitable casing and handle (see text); 2.5mm or 3.5mm jack socket, 14-pin i.c. socket, connecting wire, 32s.w.g. enamelled wire for winding T1.; 1mm solder pins; glue; solder etc.

Approx cost guidance only **£20** *excl. case*



The piezo sounder, WD1 can be mounted in the centre of the tilt switches, supported by a small cube of wood or plastic. Also, note that the p.c.b. layout is designed for BC212, BC212A or BC212B as transistor TR1 (i.e. case style TO92c); transistor types BC212L, BC212LA and BC212LB use TO92e instead.

Next, before wiring in the completed p.c.b. or connecting the UV fluorescent tube, it is worth making a quick check for correct circuit operation; a 9V or 12V power source will do for now. Short out S1 to S4 and piezo transducer WD1 should sound for roughly ten seconds, ceasing at the same time as the l.e.d. (D3) lights.

The supply current should not significantly exceed approximately 500mA — otherwise disconnect the power recheck the direction of the transformer windings. A multimeter, set to an a.c. range or 500V or more, and connected between points C and D, can be used to confirm correct operation of the fluorescent tube driver. Once testing is complete, remove the shorting link from S1 to S4.

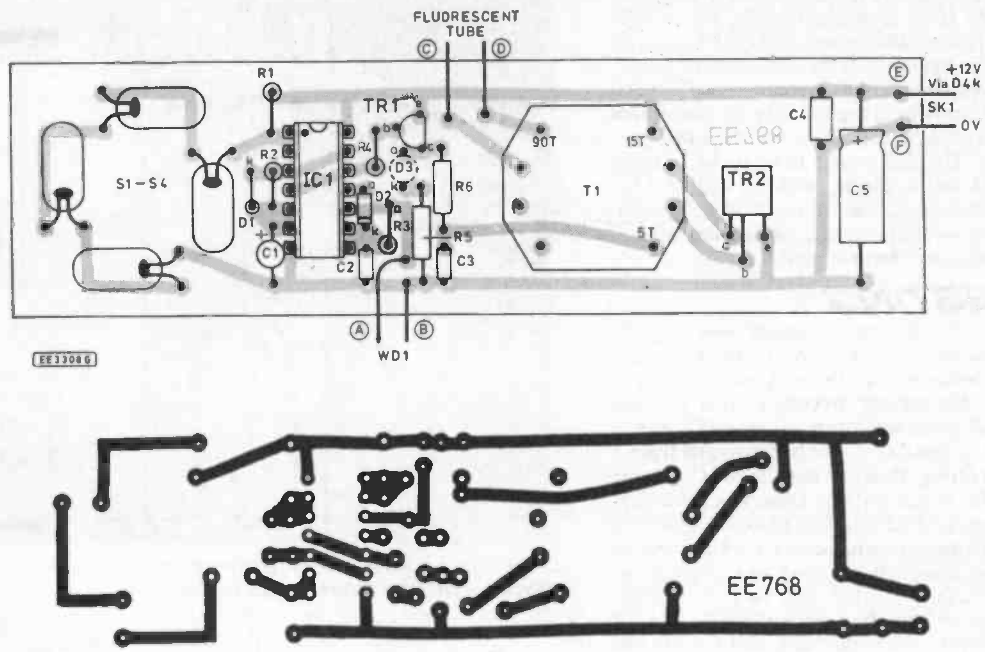
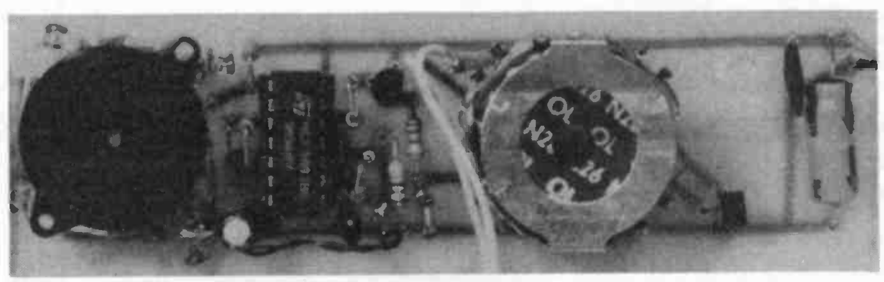


Fig. 4. Printed circuit board component layout and full size copper foil master pattern. The completed board is shown below; the mercury switches are beneath the warning buzzer.



MECHANICAL CONSTRUCTION

This leaves just the mechanical construction, which depends on the enclosure chosen for the unit. The prototype used a casing consisting of 45cm of (new) plastic guttering — yes, guttering. Not the grey, semicircular type, however; the modern sort is white (a better reflector of UV) and has a more angular cross section – apart from being much better looking, it's an ideal shape for mounting circuit boards! Alternatively, a piece of aluminium sheet, about 45cm by 18cm, can be bent to the same shape.

Whichever method is used, the ends of the casing will, of course, need to be closed off. For the prototype two pieces of scrap plywood were sawed and sandpapered to the correct shape, glued in place with impact adhesive, and painted white to match the casing (matt paint gives better results than gloss).

Next, four holes are drilled in the casing — for the l.e.d., the power socket and the handle. If the l.e.d. is mounted directly on the reverse of the circuit board, then just a hole of 5mm diameter is required (i.e. no l.e.d. mounting clip). A 2.5mm or 3.5mm jack socket is ideal for the power connection.

The fixings for the UV fluorescent tube itself consist of two metal clips, generally sold as "tool clips" or "Terry clips". The specified UV tube fits the half-inch size,

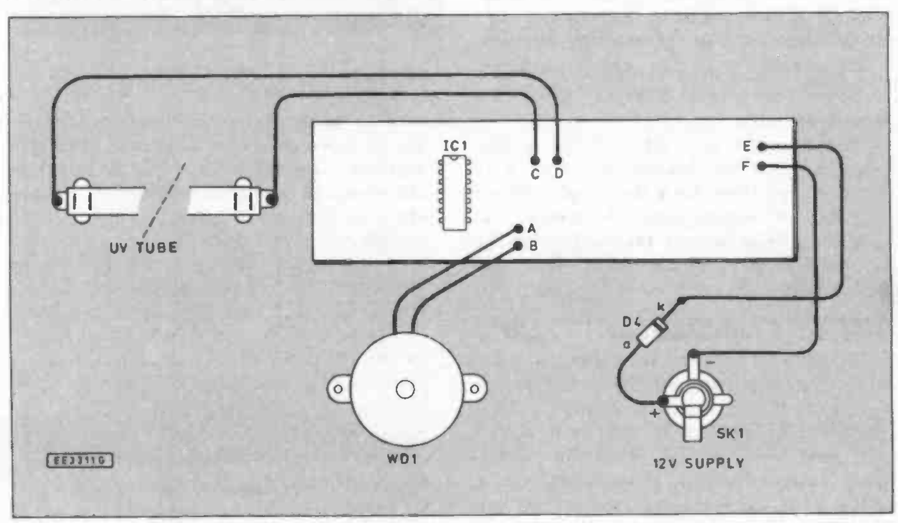
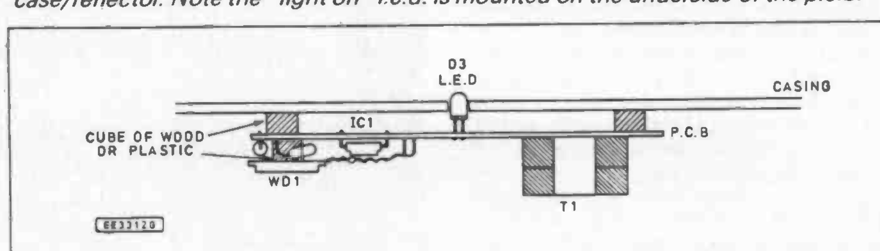
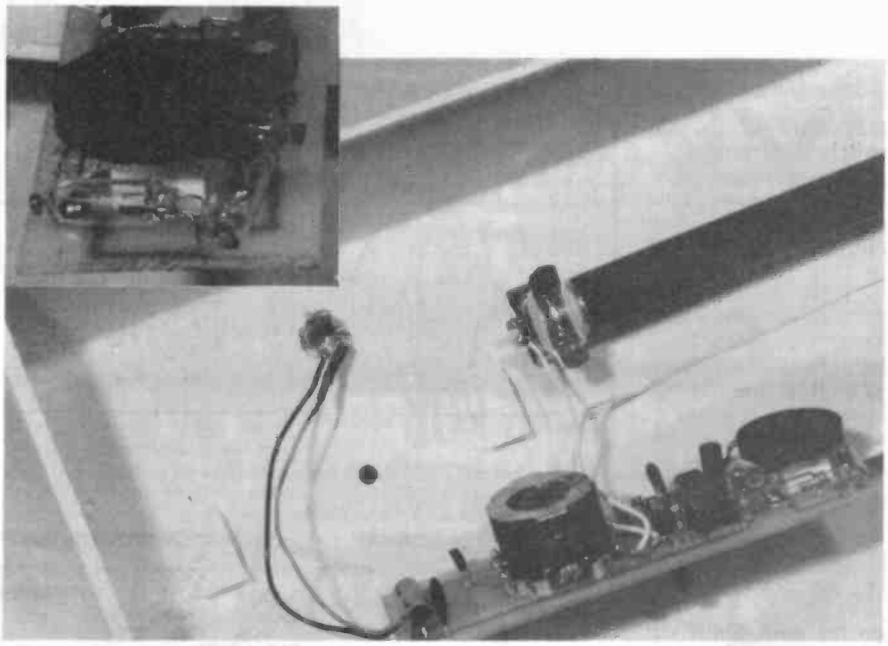


Fig. 5. Interwiring from the p.c.b. to the off-board components.

Fig. 6. Cross-section showing one method of mounting the circuit board in the case/reflector. Note the "light on" l.e.d. is mounted on the underside of the p.c.b.





Close-up showing wiring to power-in socket and one end of the tube. Inset shows mercury "tilt" switches below buzzer.

which should be securely bolted *(using nylon bolts)* or glued to the casing. An elastic band looped across the top of each clip reduces the chance of the tube breaking free, in the event of the unit being dropped.

Commercial units typically have a metal reflector behind the UV tube, so aluminium foil could be used here for the same purpose. The foil would have to be securely glued to the casing, with no chance of it touching the circuit; this would help to ensure even illumination, particularly if large p.c.b.s are to be produced.

TESTING

Finally, the unit is tested with the UV fluorescent tube in place. Ultra-violet light can be harmful to the eyes, so this complicates the testing procedure. If a conventional fluorescent tube — also 12 inch 8 watt, or similar — can be borrowed from a light fitting, then this may be used for some of the initial testing. Otherwise, the suggested method is to first place the unit on a flat surface, resting across a white sheet of paper. Prop up one end very slightly, so that some reflected light will be visible, scattered from the paper surface.

Connect the power and wait for the end of the warning tone. A violet coloured light should then be visible on the paper adjacent to the unit, probably increasing in intensity after a second or two, as the UV tube lights fully.

If nothing is seen (though the earlier tests, without the fluorescent tube, were satisfactory), then check the supply voltage and the tube connections. **The most important thing is to always take care with the potential dangers of ultra-violet light and high voltages.**

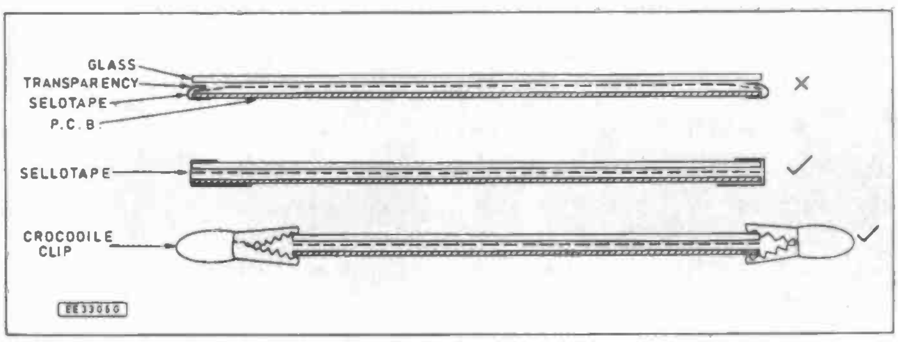


Fig. 7. Cross-section "sandwich" showing suggested method of preparing the photo-resist board for exposing the UV.

PCB PRODUCTION

The topic of creating your own p.c.b.s is well covered in many articles and books — for example: the *Guide to Printed Circuit Boards* (EE April 1987) or *How to design and make your own P.C.B.s* (from the EE *Direct Book Service*). Here, therefore, is just a brief outline of the use of this UV Exposure Unit, starting out with a p.c.b. foil pattern from an article:

1. First of all, the foil pattern is photocopied onto clear film. Photocopy shops can be expensive for this, but the results should be satisfactory.

2. For the next stage, you'll need the completed UV Exposure Unit, photo-resist board, a piece of glass, plus the p.c.b overlay transparency. (The glass, which should be about 100mm wide, can be borrowed from an old picture frame.)

Cut out the transparency so it is slightly smaller than the photo-resist board, taking care not to damage the photocopied image. Remove the light-proof protective covering from the photo-resist board, keeping the board out of bright light. Check that the piece of glass is clean, then sandwich the transparency — **correct way up** — between the glass and the board. Remember, it is vital to keep the transparency flat against the photo-resist board: probably the best method is either to Sellotape the edges of the glass and the board together, or to keep the glass and the board held together by a couple of crocodile clips (see Fig. 7).

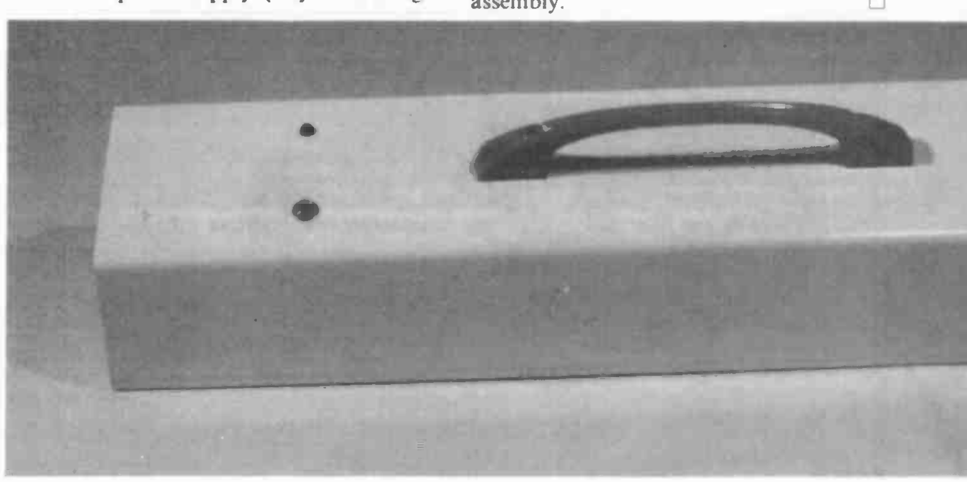
3. Place the "sandwich" of glass/transparency/photo-resist board on a flat surface such as a tabletop, or the floor. With the UV Exposure Unit placed on top of this "sandwich", connect up a suitably rated 12V power supply (If you're using NiCads, you'll need about nine "C" or "D" cells). After an exposure time of about 10 to 15 minutes, disconnect power then remove the photo-resist board (again, avoid bright light).

4. The board can be developed using sodium hydroxide, available from most ironmongers, and commonly sold as "caustic soda"; add about two teaspoons to one pint water, stirring until completely dissolved. The resulting solution will dissolve unwanted regions of the photo-resist coating and, as soon as the bare copper surface is visible in these areas, development is complete. The board should be washed under the cold water tap after this.

5. Ferric Chloride (Iron (III) Chloride) is used to etch away the unwanted copper regions. The dilution is about 250g ferric chloride to one pint water, and etching takes about twenty minutes. This time can be reduced, if necessary, by warming the solution. **(NOTE: Avoid eye, mouth or skin contact with sodium hydroxide or ferric chloride.)** Wash the board under a tap again.

6. The board should now show the desired pattern of copper tracks, but they are still coated with photo-resist. This is easily removed by exposing the whole board to UV, then immersing it in sodium hydroxide solution a second time. Once again wash it under a tap.

7. Finally, all that remains is to drill the holes, using a 1mm bit, and give the board a final cleaning before the start of assembly. □



Special Series

MAGNETIC RECORDING

Part 1: What is Magnetism?

VIVIAN CAPEL

Life today would be difficult to imagine without magnetic recording: No audio or video recorders; no computer disks; no payphone cards; no bank cash cards or magnetic security pass cards. In spite of its universal use, magnetic recording and the principles of magnetism are still little understood by most people. In this short series we hope to answer some of the questions most often asked about Magnetic Recording.

LIFE TODAY would be difficult to imagine without magnetic recording. Audio and video cassette recorders make a major contribution to our entertainment. Even the long-playing record and the compact disc would be very difficult to produce without it as each side or at least each track would have to be recorded in one "take" directly on to the master, as in the old days of 78's. There could be no subsequent editing or mixing.

Floppy computer discs and hard drives would be unheard of, and there would be no payphone cards or magnetic security pass cards. These are just domestic uses, many industrial processes would likewise suffer without magnetic data recording and other applications.

Yet in spite of its universal use, magnetic recording, or even the principles of magnetism are little understood, certainly not as well as those of electronic circuits. In this series we hope to redress the balance a little, and give the reader a grasp of just what is involved in "magnetic recording".

PRODUCING A MAGNETIC FIELD

It is fairly common knowledge that a magnetic field is produced when an electric current flows in a circuit. This field causes the rotor in an electric motor to turn when a current is passed through it, and it induces a voltage in an adjacent coil if it is passed through a winding of a transformer.

It is also accepted that a current is a flow of electrons along a conductor from a point where there is a surplus, the negative pole, to one where there is a deficiency, the positive. Now inside the atom, electrons are constantly orbiting the positive nucleus as satellites, so in effect we have minute electric currents circulating continually around the centre of the atom.

According to the above principle, each electron should and in fact does generate a tiny magnetic field as it orbits. In addition, the atoms spin, and this also produces a magnetic field. These magnetic-generating electron motions are called ***magnetic moments.***

So all atoms produce internal magnetic fields, however, the total field or moment of the whole atom is the vector sum of all the individual ones. In most cases, the different planes of orbit and spin cancel out so that the total field is zero. These materials are said to be ***diagmagnetic,*** that is they have no detectable external magnetic properties.

With other materials some of the internal fields coincide and reinforce each other. These produce magnetic fields outside the atom or molecule and are called ***paramagnetic.*** The individual molecules or atoms are thus like very small individual magnets each having a North and South pole.

Now another well-known fact is that opposite poles attract, whereas like poles repel each other. So, in any conglomeration of paramagnetic molecules, the poles of each little magnet tries to find an opposite one, which it does, with the result that they form into rings, each ring consisting of a complete magnetic circuit.

Now the effect of this is that no field escapes, all fields are confined inside the lump which therefore exhibits no external magnetic field. If though the material is placed in an external magnetic field, it causes the rings of atoms to break up and form straight lines along the applied lines of magnetic force. Their magnetic fields now appear externally and actually reinforce the applied magnetizing force, so making it stronger.

What happens when the external force is removed? That depends on the material. If it is magnetically ***soft***, most of the atoms breathe a sigh of relief and form up into rings again. If it is magnetically ***hard,*** most of the atoms stay in line, and a *Permanent magnet* is created.

Often, a sharp physical shock will "loosen" some atoms and they will go back into ring formation. That is why you should never give a permanent magnet a hard knock, it will very likely lose a lot of its magnetism.

Materials that are magnetically hard are often physically hard too, and magnetically soft ones are physically soft, but there are exceptions.

POLES APART

The magnetic field consists of lines of force that exit from one end of a magnet called the North pole and form a loop around the outside, to enter the other end which is the South pole. Inside the magnet the line of force continues through the material back to the exit point thus making a complete circuit.

Externally, the lines take the shortest path from pole to pole, but they mutually repel each other so they tend to balloon out with some lying close to the magnet and others at increasing distances from it. They can never cross, so unlike a reel of cable or ball of string started at the wrong end, they never get tangled up.

The poles of a magnet can be configured to direct or concentrate the field in a certain desired area, and the magnet itself can be shaped to have a similar effect. Thus, although the "natural" shape for a magnet is a straight bar, a common version is the horseshoe having poles that are physically close, thereby concentrating the field between them. The same effect is achieved in a recording head as we shall see in a later article.

The names given, the North and South poles, can be a little misleading though. More accurately they are North-seeking, and South-seeking poles. That is they are attracted to the earth's magnetic poles that

Table of Magnetic Properties

Property	*Symbol*	*Formula*	*CGS unit*	*Ratio*	*MKS unit*
Flux	ϕ		Maxwell	10^8:1	Weber
Field Strength	H		oersted	12.5:10^3	Ampere-metre
Coercivity	H_c		oersted	12.5:10^3	Ampere-metre
Flux Density	B		gauss	10^3:1	tesla
Permeability	μ	$\frac{B}{H}$			
Reluctance	r	$\frac{L}{\mu a}$	*(L = length; a = area)*		

are near the geographic north and south respectively.

As opposite poles attract, this means that the magnetic pole near the earth's geographic north in the Arctic is really a magnetic *South* pole, and the pole near the geographic south in the Antarctic is the magnetic *North*. This is an example of one of those little-known facts about magnetic behaviour.

What perhaps is better known is that the magnetic and geographic poles do not exactly coincide. In England, compass needles point some 16 degrees West of true North which is nearer NNW.

As a Bar magnet is a string of molecular magnets aligned end to end, it follows that the magnet can be broken in half to form two magnets, whereupon each has its own North and South poles. These too can be halved and further divisions made theoretically down to molecular length.

The interesting fact is that the strength of the magnet is not diminished, each section has the same number of lines of force passing through it as the whole, providing the cross-section area remains the same. Furthermore, if two equal magnets are joined end-to-end, the strength is not increased. The lines merely link end-to-end to give the same number as for one. So there is no such thing as a formula for magnets in series!

FLUX

Having got some idea of the basics of magnetism the time has now come to absorb a few technical definitions and expressions. Unfortunately many long-used terms have been changed so that older ones are encountered and are often still used, as well as the new ones, which makes it rather confusing. To be able to understand any description involving magnetism one really needs to be familiar with both systems and be able to convert one to the other.

The old system was the CGS, being based on the centimetre, gramme and the second. The new is the MKS, which uses the metre, the kilogramme and second. The MKS is clumsier, more difficult to understand, and definitely no improvement, but then, many of us think that about the whole metric system anyway.

Firstly, those lines of force or flux as they are also called. The symbol is ϕ and the CGS unit is the ***Maxwell*** which simply denotes one line of force. The MKS unit is the ***Weber***, defined as the force that produces an e.m.f. of one volt, when it is reduced to zero at a uniform rate across a coil of one turn in one second.

You can see why MKS units are considered more clumsy! To convert, one Weber equals 10^8 Maxwells. This illustrates another difference, that MKS units are usually much larger and so often have to be fractionalized.

One useful fact resulting from the combination of the above information is that the induced voltage across a coil of a given number of turns produced by a known flux of known frequency can be calculated. A fall from maximum to zero takes place in a quarter of a cycle so the frequency is 0.25Hz.

As this is impractically low we can multiply it by 100 to give 25Hz, and reduce the flux by the same factor to give the expression that a flux of one million lines of force or Maxwells (0.01 Webers) will produce one volt in a single turn at 25Hz. In a more practical coil of 100 turns the required flux is 10,000 Maxwells or 0.0001 Webers.

FIELD STRENGTH

The stronger the magnetic field, the greater the number of lines there will be in a given area. The symbol is ***H***, which refers to ***field strength*** in air (strictly a vacuum), and it describes the number of lines of force passing through a surface which is perpendicular to the direction of the lines.

The CGS unit is the ***oersted*** which straightforwardly is one line of flux per cm^2. The MKS unit is the ***ampere-metre***, the conversion being 1,000 ampere-metres to 12.5 oersteds.

Thus, the MKS unit is actually smaller in this case because of the larger area involved. Field strength H particularly describes an *applied* field from a magnetic source, to distinguish it from the resulting field it *induces* in a magnetic substance.

The term ***flux density***, symbol ***B***, is used to describe the field induced in a material by an applied field. As with field strength it is defined by the number of lines of force passing through a surface of given area perpendicular to the direction of those lines. The CGS unit is the ***gauss***, defined as the flux induced by a field of one oersted which as we have seen is one line of flux per cm^2.

The MKS unit is the ***Tesla*** which is a flux of one Weber per m^2, which is 10^8 lines of flux per m^2. Few induced magnetic fields extend over metres so we can reduce this to the more practical CGS unit based on the cm, by equating one Tesla to 10,000 gauss.

In some situations the flux density in air may be required such as when comparing the density with and without the presence of a magnetic substance. In such case the flux density is equal to field strength, and $B = H$.

PERMEABILITY

Permeability is the magnetization capability of a paramagnetic substance, and the symbol is μ. When a magnetizing field is applied to such a substance, a large number of its ring formations straighten out to produce an external field which is stronger than the applied one. The applied field can thus be considered as a sort of trigger.

In the case of ferrous metals the permeability can be several thousands which means than the induced fields are several thousand times greater than the applied one. This isn't really a case of something for nothing, the resulting fields were there all the time but concentrated within the molecular rings. By breaking the rings and straightening them out, the internal lines of force are merely compelled to seek an external path to complete their circuit.

The permeability is thus the ratio between the applied field H and the induced field B: so $\mu = \frac{B}{H}$ or to find the induced field, $B = \mu H$.

In air, the field resulting from an applied force is just the force itself, no more or no less, so the permeability is one. Non-magnetic (diamagnetic) materials impede or resist the passage of lines of force, so the field within or through them is less than one.

This magnetic resistance is termed ***reluctance***, because the material is reluctant to let the lines of force through. The symbol is usually r and the formula is: $r = \frac{L}{\mu a}$ where L is the length and a is the area of the material. The permeability of the substance, being on the bottom line results in a low reluctance for high permeabilities and a high reluctance for low ones.

SATURATION

The action of the applied magnetizing force is as we have seen, to make some of the internal molecular magnets break circle formation and line up to produce an external field. When the applied field is increased, more molecules line up, and the induced field becomes stronger. With high permeability materials, a small increase of the applied field produces a large increase in the induced field because the increase is multiplied by the permeability.

At a certain point, all the molecules in the material are lined up, and any further increase in magnetizing force cannot produce any more flux in the induced field. The material is then said to be ***saturated***. However, as saturation point is approached with nearly all the molecules affected, the induced field increases at a reducing rate. The magnetization characteristic thus becomes curved toward saturation point.

When the magnetizing force is removed, the induced field does not drop to zero even with a "soft" magnetic material. While most of the molecules re-form into circles, some seem to like their new straight-line position and they stay there. So a certain amount of the induced field remains. The remaining magnetism is termed the ***remanence*** and the ability of a material to retain magnetism is called its ***retentivity***.

The only way to bring a material at normal temperature to zero level after being magnetized, is to subject it to a reverse magnetic field. As it refuses to give up all its acquired magnetic flux peacefully it must be coerced.

The reverse field required to bring a material from saturation down to zero is thus termed its ***coercivity***. The unit is the oersted or the ampere-metre, the same as for the initial magnetizing field, but the symbol is H_c.

Well, with that insight into matters magnetic and the terms and units used to describe them, we are ready to explore the technicalities of magnetic recording.

WHY USE BIAS

Magnetic recording tape consists of a polyester base on which particles of a "hard" magnetic material are deposited and held by a binder. They are needle-shaped, having a length of between 0.1µm to 0.5µm, and are oriented lengthways along the tape.

These become magnetic ***domains***, each of which are magnetized by the record head to a level corresponding to that of the audio signal present at the instant of passing. When passing again in the replay mode, the external fields existing around each domain induce voltages in the head windings which correspond to the original audio signal.

This sounds nice and simple, but there are complications (aren't there always?). The problem is that the induced magnetic flux B is not proportional to the applied force H over its magnetization range. As the force increases, the induced flux rises gradually to start with, then it increases in a linear manner to a point where it slows down to the saturation level.

The characteristic curve so formed is the same for both magnetic polarities, so the South curve is a mirror image of the North curve but below the zero line as shown in Fig. 1. It can be seen that if a sine wave with excursions either side of zero were to be recorded against this characteristic there would be severe distortion at the regions near the zero points.

The curve in Fig. 1 illustrates the amount of flux induced in the material when it is first magnetized by an applied force. It is therefore known as the ***initial magnetization curve.***

It is not the whole story though, as we saw earlier, some flux remains (*remanence*) when the applied force is removed. To bring it to zero we have to apply a reverse force. It can then be magnetized in the opposite direction to saturation whereupon the applied field must be reversed again to bring it back to zero. Then the cycle can be re-started although not from the same point as before.

If all that seems rather obscure, the best thing is to follow the process through with the aid of Fig. 2. As with Fig. 1, the horizontal axis is the applied force *H*, and the vertical, the resulting induced flux *B*.

We start at the centre *a*; the applied force *H* is increased and the induced flux *B* follows suit, although with the previously noted curve at the commencement. It continues to point *b* which is the saturation level. This in fact is the initial magnetization curve of Fig. 1. Now force *H* is gradually reduced to nothing and the induced flux *B* also falls, but not to zero. Instead it achieves the level of *c*.

Force *H* is reversed, and *B* continues on down from *c*, until it does hit the zero line at *d*. Force *H* continues in the reverse direction, and *B* starts to reverse too, finally reaching saturation at *e*. Now force *H* is again reduced, and *B* once more falls back toward zero, but it only reaches *f* when *H* gets to zero.

Now *H* presses on in forward gear again, bringing *B* to zero at *g*. Here it is at its starting point, but at the expense of some forward field *H* to overcome its previous negative value, so, *g* is displaced along the *H* line as can be seen.

Continuing in the forward direction, *H* quickly induces *B* up to the saturation point *b* again. This is the true completion of the cycle, and further excursions follow the same path. It is known as the ***hysteresis loop***, but not we hope because it caused readers hysterics trying to follow it!

D.C. BIAS

With such a devious response to the magnetizing force it may be wondered how on earth a linear recording can possibly be made. Well, as we all know, it can, and we shall now see how it is done. The simplest method is by using ***d.c. bias***, and this can take two forms.

The first is ***d.c. bias from zero***. A direct current is passed through the record head, and the audio signal is superimposed on it. It thus increases and decreases the d.c. on alternate positive and negative half-cycles.

If the d.c. bias is set to the halfway point on the initial magnetization curve, the tips of the half-cycles will avoid both the bottom curve just above zero, and the top curve just below saturation. They thus use only the straight portion and a linear recording can be made as seen in Fig. 3.

A question that may be asked is why do we use the initial magnetization curve here instead of the hysteresis loop? Well, for this type of recording, the individual magnetic domains are magnetized to the required level to represent some point on the audio waveform, and are not thereafter demagnetized. So, the initial magnetization curve applies. The situation is different with the next type of bias which is ***d.c. bias from saturation***.

With this, the tape is magnetized to saturation by a d.c. current through the erase head which always precedes the record head, or by a permanent magnet. The d.c. bias through the record head is of opposite polarity to the saturation, so it partially demagnetizes the tape. As before, the audio is superimposed on the bias. So, the recording is made by varying the amounts of *demagnetization* instead of *magnetization* as with the first method.

What advantage is that? This, the curve which is thereby used is the demagnetization portion of the hysteresis loop, that is *b, c, d, e* of Fig. 2. It can be seen that this part of the curve has a longer straight portion than the initial magnetization part, *a, b*. So a larger audio signal can be recorded than with the d.c. bias from zero method. This can be shown if we reproduce just that part of the loop with an applied sine wave as shown in Fig. 4.

This then is the usual method employed when d.c. bias is used. But there is a snag. The number of magnetic molecules passing the head per unit of time is constantly varying as it is impossible to manufacture a tape with an equal number across its width at all points. They have all been brought to saturation, but a fixed number will be demagnetized for a given value of d.c. bias. So the remainder at saturation will be the original varying number minus a certain fixed number, hence the saturated remainder will also be a varying number.

This procession of saturated molecules of varying number past the playback head produces noise as the number fluctuates. So d.c. bias gives a high background noise, and is therefore unsuitable for hi-fi sound. It is used for many portable recorders in which tape noise is not important.

A.C. BIAS

To overcome the noise problem, a totally different method of biasing is used for high quality reproduction. An a.c. wave several times the frequency of the highest audio frequency, is generated by a sine-wave os-

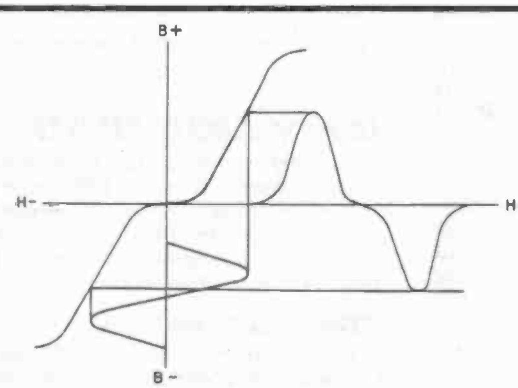


Fig. 1. Initial magnetisation curve. A recorded waveform crosses the non-linear portions and is severely distorted.

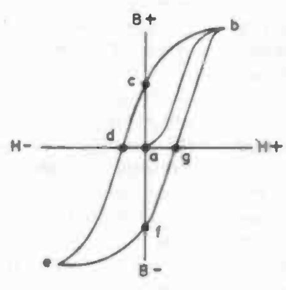


Fig. 2. Hysteresis loop. After initial magnetization a-b, the flux falls from saturation when field is removed b-c, then requires a reverse field to restore it to zero, c-d; further applied reverse field builds up to saturation point e; then a removal causes drop e-f. A forward field now reduces the flux to zero, f-g; whereupon increased forward field raises the flux to forward saturation, g-b.

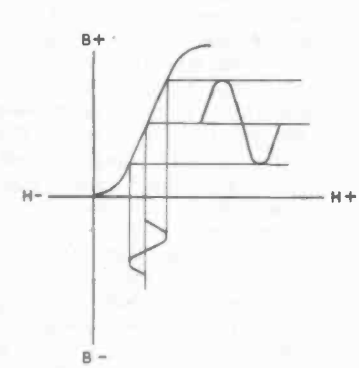


Fig. 3. D.C. bias from zero puts the operating point at the centre of the straight part of the initial magnetisation characteristic.

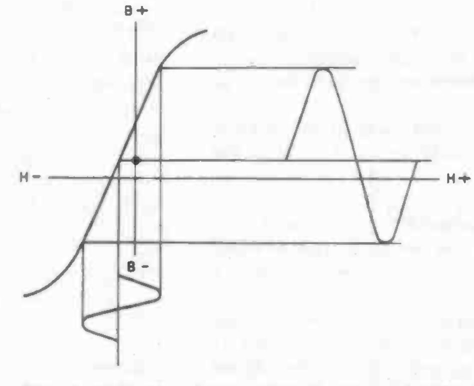


Fig. 4. D.C. bias from saturation uses the "back" of the hysteresis loop by biasing a previously saturated tape. The straight portion is much longer than that of the initial magnetisation curve.

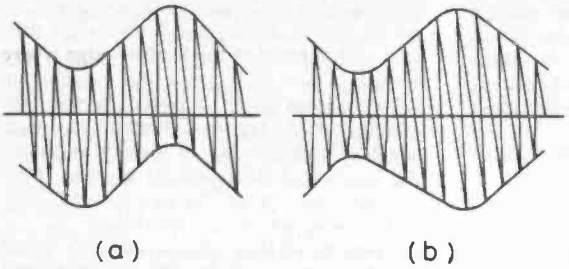


Fig. 5a. An audio frequency superimposed on h.f. wave as with a.c. bias. The amplitude of the h.f. does not change.

Fig. 5b. A modulated wave. THe h.f. amplitude changes with the audio. This generates plus and minus sidebands which interact with the audio frequency and produce intermodulation distortion. Modulation of the bias waveform must thus be avoided.

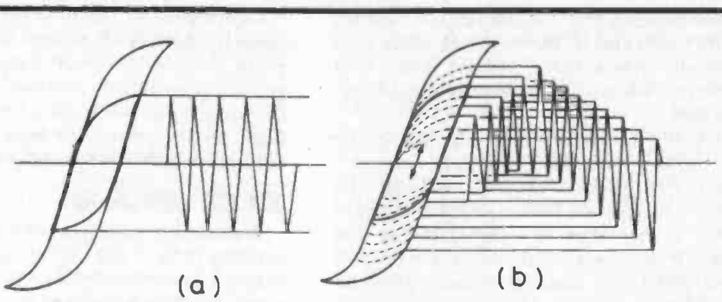


Fig. 6a. RF waveform produces a mini loop within the main hysteresis loop.

Fig. 6b. Mini recording loop moves up and down in sympathy with the audio modulations leaving the trailing gap edge magnetized with instant value corresponding to audio signal.

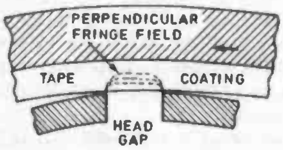


Fig. 7. The perpendicular field at the trailing edge tries to change the longitudinal magnetic orientation achieved in the gap. Short magnetic zones are more affected than long ones, so short-wavelength high-frequencies are partly erased while long-wavelengths are unaffected.

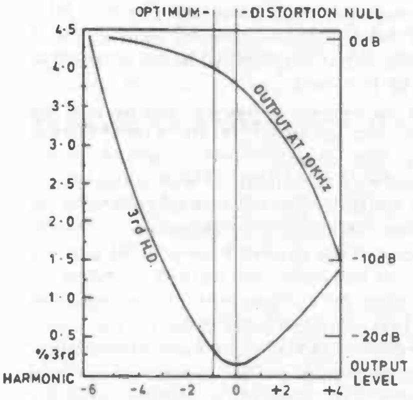


Fig. 8. Third harmonic distortion and 10kHz response plotted against bias level. Bias level for minimum distortion produces h.f. loss. Optimum for low distortion and good h.f. response is just below minimum distortion point.

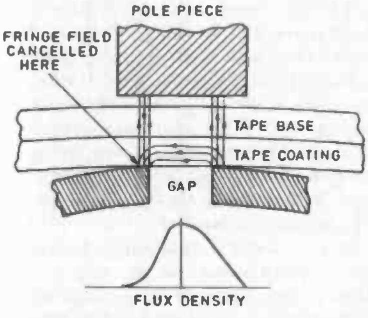


Fig. 9. Crossfield bias. An auxiliary signal field established between the head and a pole piece behind the tape. The direction of the flux reinforces the head flux at the leading edge but cancels it at the trailing edge. This eliminates the perpendicular field and so permits higher frequencies to be recorded. The assymetrical flux distortion across the gap is shown.

cillator in the recorder, and the audio is superimposed on it.

At this point it is necessary to note the distinction between *superimposition* and *modulation*. In the case of superimposition, the high frequency bias carries the lower frequency audio on its back as it were, on both its positive and negative halves. At no time does the amplitude of the bias signal itself change, see Fig. 5a.

With modulation, the amplitude of the high frequency carrier does change, being squeezed at some points and stretched at others by the modulating signal, see Fig. 5b. This produces extra frequencies known as sidebands, which are the sum and difference of the carrier and modulation frequencies.

If the bias frequency is allowed to affect the recording amplifier, modulation can occur, which, if the bias frequency is low enough, could produce a spurious sideband within the audio range. To avoid this, the bias frequency is kept as high as possible and filters are usually included to keep the bias out.

MINI LOOP

But now back to the recording process. Just how the a.c. method works has been a matter of some dispute, and various explanations have been offered. Some of these have used the initial magnetization curve as a basis of the theory, but as individual particles are both magnetized and demagnetized several times during the recording process, the hysteresis loop must be involved.

The first thing to appreciate is that the record head gap is very wide compared to the magnetic particles for reasons we shall explore in a later article. So as they cross the gap, the particles are subject to several cycles of a.c. bias and so go through a number of successive magnetizing and demagnetizing cycles before leaving it. They thus follow several hysteresis loops except that the amplitude of the bias is insufficient to drive the particle to saturation point, in fact it is kept well short of saturation. We could therefore call it a ***mini loop.***

Now the effect of superimposing audio on the bias is that the whole of the mini loop moves up and down in sympathy with the audio variations, within the main hysteresis loop. This is shown at Fig. 6a where a steady a.c. bias is producing a mini loop at a central position within the main one. In Fig. 6b audio is shown superimposed on the bias causing the mini loop to move up and down within the main loop.

When a particle eventually leaves the influence of the head gap, it remains magnetized to a level corresponding to some point on the loop that it reached at the instant of departure. We will call this the *final flux point*. It could be any part of the loop and it does not matter which, but all particles that follow leave the gap magnetized to the same point.

When the mini loop is stationary (when there is no audio signal), all successive particles are thus magnetized to the same degree. But when the mini loop moves vertically, the final flux point moves with it. Hence the magnetic level of successive particles varies according to the position of the mini loop which in turn is determined by the audio signal.

So we have magnetic domains along the tape having levels of flux equivalent to the audio waveform. Note that the bias itself is not recorded and it leaves no trace on the tape. It is merely a vehicle, providing a rapidly cycling loop that can be moved up and down, tracing varying levels of flux along the tape as it does so.

FRINGE FIELD

The portions on either side of the gap in the recording head are magnetic pole pieces, so the flux flows from one side of the gap to the other. However, the gap contains a shim of non-magnetic material which offers a high reluctance, so the flux is diverted around the outside of the gap and so through the tape where it is wanted.

The flux path is thus roughly hemispherical. It emerges from one side of the gap perpendicularly to the tape, swings around to run along the tape parallel to the gap, then turns again to enter perpendicularly at the other side. The needle-shaped magnetic particles are longitudinally orientated and so are readily magnetized by the bias field over the central area of the gap. They go through several hysteresis cycles and acquire their final magnetization level just before the trailing edge of the gap where the applied field becomes perpendicular. This is known as the **fringe field**, see Fig. 7.

Now the perpendicular field tries to change the magnetic orientation. Long magnetic zones have a high coercivity, are quite stable and resist the change, but short ones do not. Long zones correspond to long sound wavelengths which are associated with bass frequencies, whereas short zones are recorded by the short-wavelength high frequencies.

So, the high frequencies tend to be erased by the perpendicular fringe field whereas the bass ones are unaffected. This is one of the reasons for the limitation of high frequency response with magnetic recording.

HOW MUCH BIAS

The technical descriptions of recording tapes often include a bias specification consisting of a plus or minus dB value. This is because different tape coating formulations have different optimum bias requirements. Recorders usually have an internal adjustment whereby the bias level can be set, and some decks have a user control.

If the bias is set too low, the straight portions of the mini-loop hysteresis cycle are restricted and large amplitude audio signals will encroach on the curved parts. The result is non-linear recording and distortion. If the setting is too high, the mini loop lengthens, and so large audio swings drive it toward saturation points which also result in distortion.

It follows that there is a value that gives minimum distortion, and indeed distortion measurements show a gradual increase either side of a low point. It would seem then that this is the obvious optimum point, but there is another factor. As the bias level is increased so obviously does the flux density, and as the lines of force start out as a perpendicular fringe field, this means an increase in the fringe field at the trailing edge of the head-gap.

As we have seen, this field has the effect of erasing higher frequencies (h.f.). So, any increase in bias produces a loss of treble or high frequency response. The bias can thus be adjusted either for minimum distortion, or decreased a little from this point to give a better h.f. response at the expense of a small increase in distortion.

As the distortion null point is not sharp, a useful increase in h.f. can be obtained with only slightly increased distortion. If even more h.f. is required it can be obtained with more distortion by reducing the bias further.

The bias should not be *increased* beyond the distortion null point as this will both increase distortion and reduce h.f. Fig. 8 shows typical distortion and h.f. loss curves set against bias.

CROSSFIELD BIAS

An ingenious method of avoiding h.f. loss due to the fringe field is to employ a secondary magnetic field set up between the record head and a pole piece situated at the back of the tape. Both sides of the gap are part of the same pole, which is North on one half-cycle and South at the other when the bias oscillation reverses.

Now the polarity across the gap is always opposite, so this means that the fringe field on one side of the gap is reinforced by the secondary field, while that on the other is cancelled, being of opposite polarity. Reference to Fig. 9 will make this clear.

Polarity is arranged so that reinforcement takes place at the leading edge where the fringe field is harmless because the tape there still has to be recorded by the gap. The important region is the trailing edge; there cancellation occurs thereby eliminating the fringe field and its erasing effect on high frequencies. The asymmetrical flux distribution is also shown in Fig. 9.

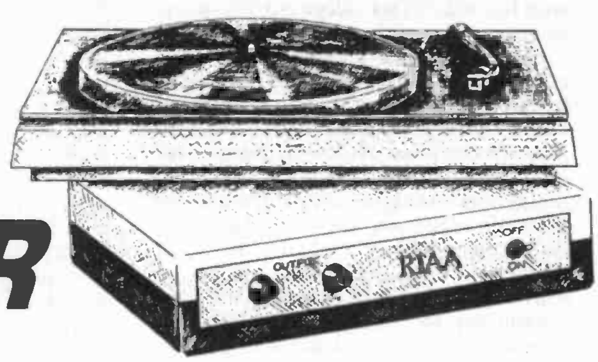
Another version uses a separate head for bias positioned behind the tape, and slightly offset from the recording head. This has a similar effect in eliminating a fringe field.

The *crossfield bias* system began to appear on some open reel tape recorders just before the audio cassette became popular and open reel machines disappeared from the domestic scene. The physical layout of the compact cassette though made it virtually impossible to implement.

Had it been considered at the design stage, it would very likely have been possible to make a cassette with cut-away portions to accommodate a pole-piece behind the tape just as for the drive spindle. This would have achieved an improved high frequency response, and lower distortion as the bias could then have been set to the distortion null.

Since then though, improvements in tape formulation and record heads have achieved an acceptable high frequency response thereby reducing the attractiveness of the crossfield system. We will explore the record and playback heads next month.

Constructional Project



RIAA PREAMPLIFIER

ROBERT PENFOLD

An inexpensive stereo pre-amp that will allow the use of a record deck with most audio equipment

I SUPPOSE that the gramophone record has had its day, and will probably be totally replaced by cassette tapes and compact discs at some time in the future. On the other hand, with countless millions of records now in circulation, and with much of the material they contain never likely to be reissued on cassette or compact disc, there is no immediate prospect of gramophone records becoming museum pieces.

There will be a need for record playing equipment for some time to come. Hi-fi amplifiers generally have an input for a record player, but this is something that is absent on some audio equipment.

This preamplifier project was inspired by a letter from a reader who required a preamplifier to enable a record deck to be used with a stereo radio cassette unit. However, there now seems to be an increasingly large amount of low cost audio equipment that does not have a built-in record deck or an input for one, and this preamplifier should enable any such equipment to be used with a record deck.

One obvious proviso is that the audio unit must have some form of spare input ("Aux", "Tuner", etc.) that the preamplifier can drive. Also, this preamplifier is only designed to operate with a magnetic pick-up, and will not operate with any other type. The output from a normal moving coil cartridge is too low to drive this preamplifier properly, but as this type of cartridge tends to be very expensive there would be something of a mismatch if one was used in an inexpensive audio system. The unit will not work with ceramic or crystal pick-ups, but these seem to be something of a rarity these days.

RIAA EQUALISATION

The output from a magnetic pick-up is quite low, and is mostly at a level of about 2 to 10 millivolts r.m.s. during volume peaks. This is far lower than the signal level most "Aux" and similar inputs are designed to receive. These vary somewhat in sensitivity, but generally something in the region of 200 millivolts r.m.s. to 2 volts r.m.s. is needed in order to drive them. An RIAA preamplifier must therefore provide a substantial amount of voltage gain.

There seems to be a common misconception that magnetic cartridges have an output characteristic that necessitates the use of equalisation in order to give a flat frequency response. This is not strictly true though, and a magnetic cartridge is fully compatible with the method of groove modulation used for gramophone records. Equalisation is needed, but only in order to counteract the tampering with the frequency response that is used during the recording process.

This manipulation of the frequency response takes the form of treble boost and bass attenuation. The treble boost provides a very basic form of noise reduction. Complementary treble cut must be used in the playback equipment in order to give an overall flat frequency response, and this reduces "hiss" type background noise. This "pre-emphasis" (the treble boost) and "de-emphasis" (the treble cut) is a standard noise reduction technique that is used in radio, tape recording, etc.

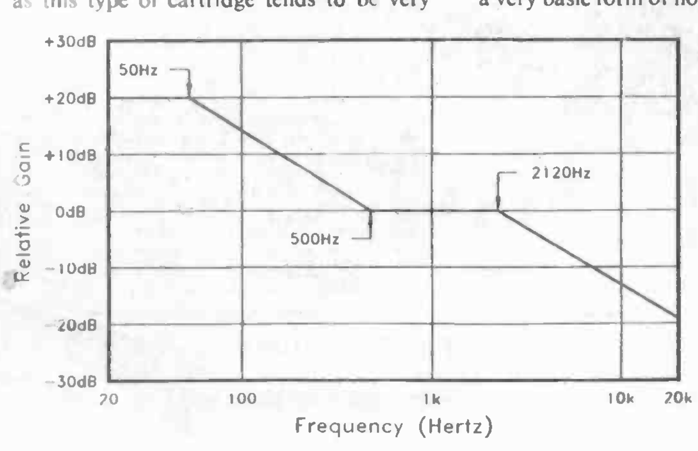


Fig. 1. The "ideal" or correct replay equalisation characteristic for an RIAA preamplifier.

The attenuation of the low frequency response is needed in order to prevent excessive groove modulation on strong bass signals. Remember that with a constant recording level, each halving of frequency results in a doubling of the groove modulation. Using attenuation of the bass frequencies prevents excessive groove modulations without having to cut back the modulation at other frequencies (which would severely reduce the signal to noise ratio).

The correct equalisation characteristic for an RIAA Preamplifier is shown in Fig. 1. There is a 6dB per octave roll-off above 2120Hz, and a 6dB per octave boost below 500Hz. In other words, above 2120Hz a doubling in frequency results in a halving of gain, while below 500Hz a halving of frequency results in a doubling of the voltage gain.

The response flattens out at 50Hz, and this avoids the problems with "rumble" that could otherwise occur. Also to counteract rumble, but of the sub-audio variety, the response is rolled-off below 20Hz. However, this attenuation is normally provided by the coupling capacitors anyway, and does not require any additional components. In practice the frequency response of Fig. 1 cannot be easily achieved. It is possible to obtain a close approximation though, and this requires only a fairly simple circuit.

THE CIRCUIT

The full circuit diagram of the RIAA Preamplifier appears in Fig. 2. As the unit is for stereo operation it consists of two identical amplifiers. The one based on IC1 and IC2 handles the left hand channel, while the one based on IC3 and IC4 handles the right hand channel. Each preamplifier is based on two operational amplifiers used in the non-inverting mode. Operational amplifiers are well suited to an application of this type as they enable the required voltage gains and input impedances to be easily set, and they also make it easy to incorporate the equalisation into the circuit.

The basic non-inverting amplifier circuit is shown in Fig. 3a. R1 and R2 bias the input of the circuit to about half the supply voltage, and also set the input impedance. The latter is equal to the parallel resistance of these two resistors. The voltage gain of the circuit is equal to (R3 + R4)/R4.

Equalisation can be incorporated into the circuit by adding a capacitor in parallel with one of the feedback resistors. In Fig. 3(b) there is a capacitor (C4) in parallel with R3, and this provides a 6db per octave roll-off above a certain frequency.

The reactance of a capacitor, which is effectively its resistance to a.c. signals, is frequency dependent. Each doubling of frequency provides a halving of the component's reactance. At low frequencies the reactance of C4 is too high to have a significant shunting effect on R3, but above a certain frequency the shunting of C4 starts to roll-off the response. The initial attenuation rate is quite low, but it soon reaches the full 6dB per octave.

Returning to Fig. 2, and the left hand channel circuit, R1 and R2 set the input impedance of the circuit at 50k. This is a good match for most magnetic pick-ups. Some have a recommended load impedance of 100k, and this can be obtained by using 200k resistors for R1 and R2 (as well as R8 and R9 in the right hand channel). IC1 provides a voltage gain of about eleven times, which should ensure sufficient output from the unit to drive any normal audio equipment. However, if necessary the gain of the circuit can easily be raised or lowered by altering the values of R4 and R11.

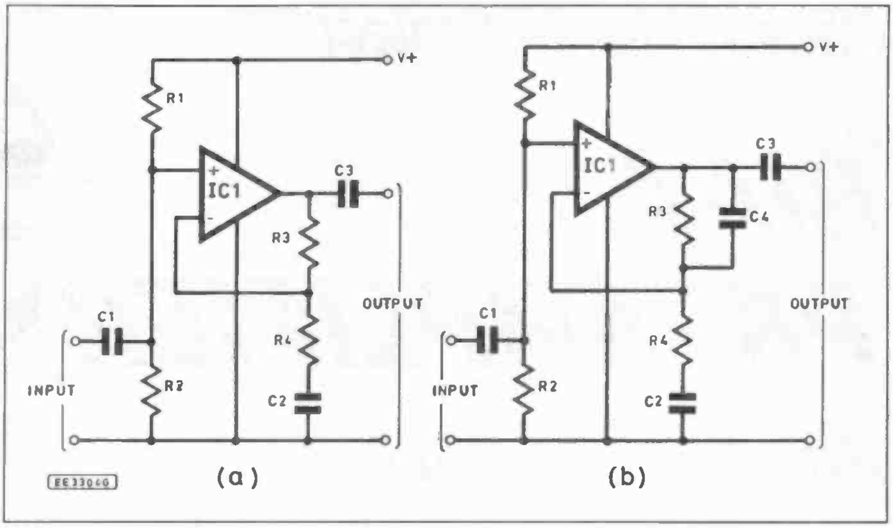


Fig. 3(a). The basic non-inverting amplifier circuit. (b) A non-inverting amplifier with simple equalisation.

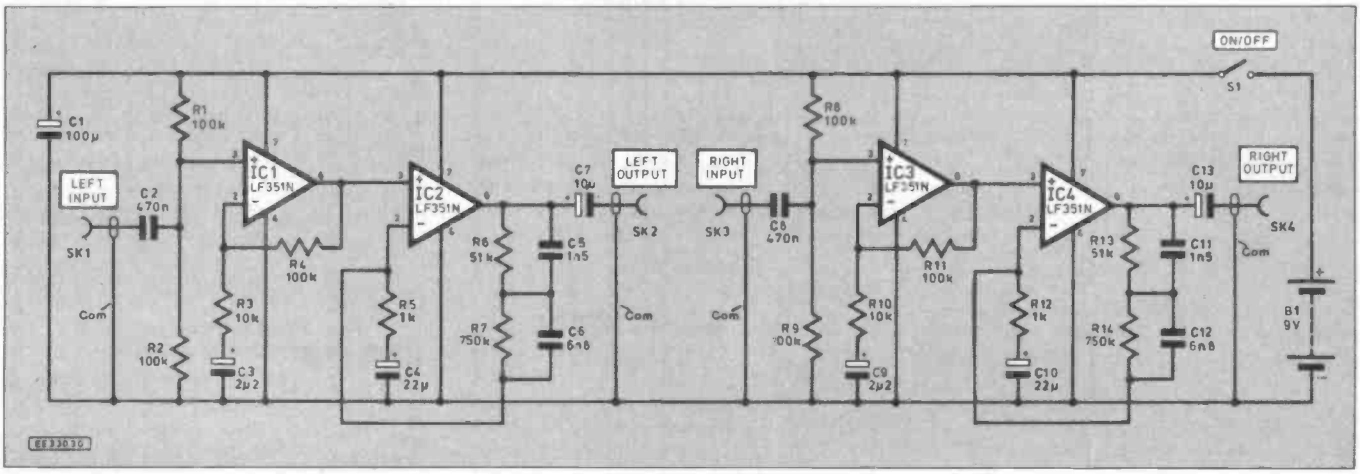


Fig. 2. The full circuit diagram for the RIAA Stereo Preamplifier.

COMPONENTS

Resistors
R1, R2, R4, R8, R9, R11 — 100k (6 off)
R3, R10 — 10k (2 off)
R5, R12 — 1k (2 off)
R6, R13 — 51k (2 off)
R7, R14 — 750k (2 off)
All 0.6W ±1% metal film

See SHOP TALK Page

Capacitors
C1 — 100µ axial elect. 10V
C2, C8 — 470n polyester (2 off)
C3, C9 — 2µ2 radial elect. 63V (2 off)
C4, C10 — 22µ radial elect. 16V (2 off)
C5, C11 — 1n5 polyester (2 off)
C6, C12 — 6n8 polyester (2 off)
C7, C13 — 10µ radial elect. 25V (2 off)

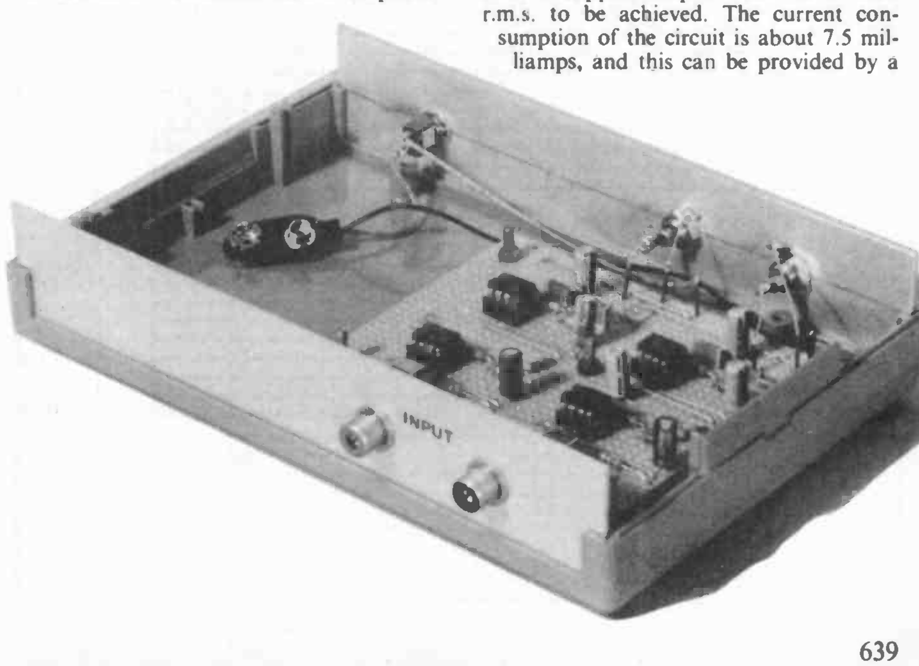
Semiconductors
IC1, IC2, IC3, IC4 — LF351N bifet op. amp. (4 off)

Miscellaneous
SK1, SK2, SK3, SK4 — Phono socket (4 off)
S1 — s.p.s.t. sub-min toggle switch
B1 — 9 volt (PP3 size)
8 pin d.i.l. i.c. holder (4 off); 0.1 inch pitch stripboard 31 holes x 36 strips; case approx 180 x 120 x 40mm (see text); battery connector; wire; solder; fixings; etc.

Approx cost guidance only **£15**

Further voltage gain is provided by IC2, together with the equalisation. At low frequencies the voltage gain of the circuit is set by R6, R7, and R5 at just over 800 times. At frequencies above about 50Hz C6 shunts R7 and rolls off the response at 6dB per octave. This continues until about 500Hz, where R6 prevents any further drop in gain. Above approximately 2120Hz C5 starts to shunt R6 significantly, and reintroduces the 6dB per octave roll-off. A single equalisation capacitor cannot be used due the flat response that is needed from 500Hz to 2120Hz. The required "kinked" response requires the use of at least two C-R circuits.

Power for the circuit is provided by a single 9 volt battery. This just about permits unclipped output levels of 2 volts r.m.s. to be achieved. The current consumption of the circuit is about 7.5 milliamps, and this can be provided by a



small (PP3 size) 9 volt battery. If the unit is likely to receive a great deal of use a higher capacity type, such as a PP9, would probably give significantly lower running costs.

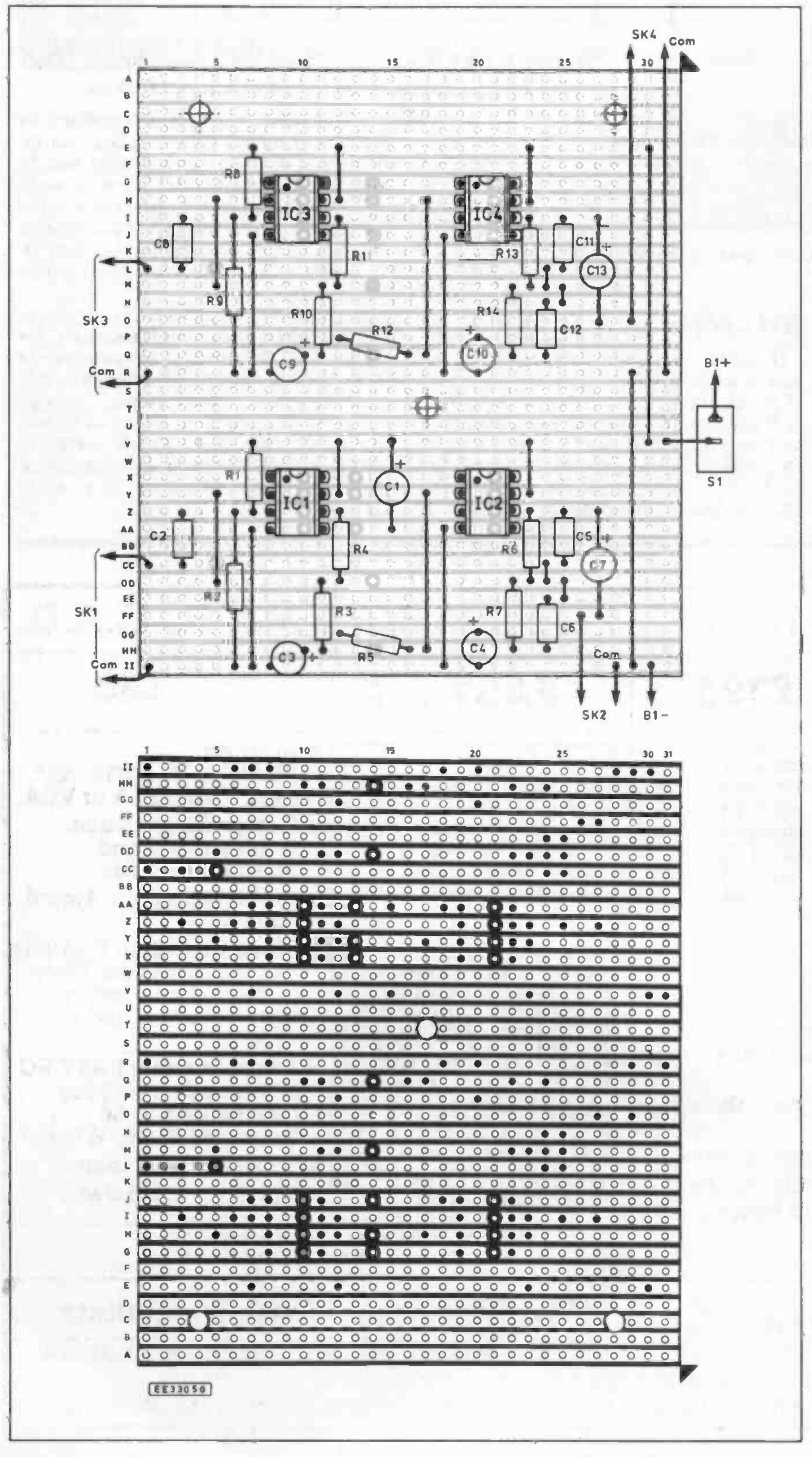
CONSTRUCTION

Apart from the controls, battery, and sockets, the components all fit onto the component panel. The layout of components and details of breaks required in the underside copper tracks is shown in Fig. 4.

This is a 0.1 inch pitch stripboard which has 31 holes by 36 copper strips. Stripboard is not sold in this size, and board of the correct size must be cut down from a larger piece using a hacksaw.

Cut along rows of holes, and then file any rough edges to a smooth finish. Then drill the three mounting holes, which are 3.3 millimetres in diameter. These will accept 6BA or metric M3 mounting bolts. Next the twenty eight breaks in the copper strips are made. A special tool for this purpose is available, but a twist drill bit of about 5 millimetres in diameter will also do the job quite well. Be careful to fully cut through each strip, but do not cut into the board any deeper than is really necessary.

Fig. 4. Stripboard component layout and details of breaks required in the underside copper tracks.



The board is then ready for the components, link wires, and solder pins to be added. The solder pins are fitted at points where connections to the off-board components will eventually be made. The single sided type are all that is needed in this case. Tin the tops of the pins with a generous amount of solder. The integrated circuits have f.e.t. input stages, but these are not of the MOSFET type, and consequently they are not especially vulnerable to damage by static charges. Despite this I would still recommend the use of holders for the integrated circuits.

COMPONENTS

If the polyester capacitors are to readily fit into the layout they should be a printed circuit (vertical) mounting type having 0.3 inch (7.5 millimetre) lead spacing. C5, C6, C11, and C12 should preferably have a tolerance of five per cent or better, but in practice ten per cent types should give perfectly acceptable results.

Resistors R6, R7, R13, and R14 have unusual values, but 750k and 51k are in the E24 series of values, and are now stocked by most component retailers. However, values of 680k and 47k should give perfectly acceptable results if there are any supply difficulties.

The link wires are made from 22 s.w.g. tinned copper wire, and must be quite taut in order to ensure that they do not accidentally come into contact with each other or component leadout wires. Alternatively, they can be insulated with pieces of p.v.c. sleeving.

CASE

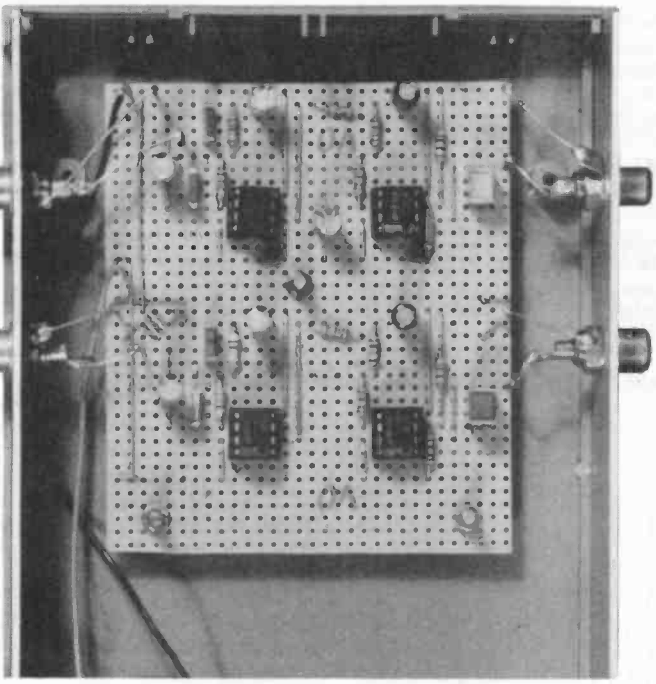
There is some advantage in using a case of all metal construction for a circuit of this type. It can be earthed to the negative supply rail and will then screen all the components and wiring from mains "hum" and other electrical noise. However, provided the unit is not operated very close to any obvious sources of electrical noise (mains leads, loudspeakers, etc.), there should be no real problems with stray pick up even if a plastic case is used.

The prototype is housed in a plastic case having aluminium front and rear panels. Its outside dimensions are 180 by 120 by 40 millimetres, and this is sufficiently large to comfortably accommodate everything. If you use a high capacity battery a case having a larger height dimension might be required though.

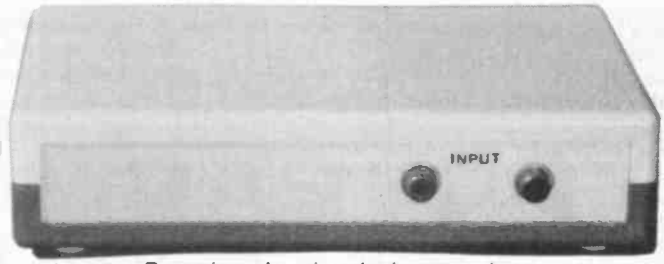
It is preferable to choose a layout that keeps the wiring between the sockets to the board as short as possible. I achieved this by having the input sockets on the rear panel, the output sockets on the front panel, and the component panel mounted between them on the base panel of the case.

The board itself can be used as a template when marking the positions for the mounting holes in the base panel of the case. Some extra nuts or short spacers should be used over the mounting bolts, between the case and the board. If a metal case is used, this keeps the connections on the underside of the board clear of the casing so that short circuits are avoided.

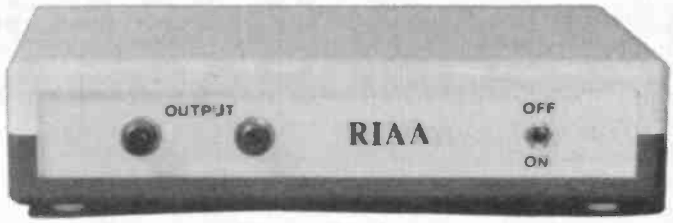
Even with a plastic case the extra nuts or spacers should be included. Otherwise there is a strong possibility of the board being distorted and cracking as the mounting nuts are tightened. Phono sockets are now the most common type on audio equipment, but you can obviously use a different type of connector if it will fit in better with your other audio equipment.



The completed circuit board showing the short wires soldered to the input and output sockets.



Rear view showing the input sockets.



Front panel showing the phono output sockets.

To complete the unit the battery clip and hard wiring is added. Provided the input wiring is quite short there is no need to use screened leads. On the prototype the wiring is all so short that I simply used pieces of 22 s.w.g. tinned copper wire, rather than the more usual multi-strand p.v.c. insulated connecting wire. The latter can be a bit awkward to deal with if very short lengths are involved.

IN USE

In use the unit simply connects between the output of the record deck and the input of the amplifier (or whatever). The record deck will probably be fitted with a screened lead and plugs that can be connected to SK1 and SK3. A screened lead will be needed in order to couple the output from SK2 and SK4 to the input of the amplifier.

In common with most preamplifiers of this type, there will be a so-called "warm-up" period of a few seconds after switch-on before the preamplifier starts to work properly. This is actually the time it takes for the capacitors to reach their normal operating charges, and for the d.c. levels in the circuit to settle down at their correct levels.

It is unlikely that the unit will have inadequate voltage gain, but if necessary, R4 and R11 can be increased in value (say to about 220k) in order to boost the gain. It is more likely that a high output cartridge will cause clipping and severe distortion on volume peaks. If this should occur, try making R4 and R11 lower in value (about 47k) in order to reduce the gain of the circuit. □

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The two companies mentioned below have large stocks of Easiwire solderless wire wrapping systems, as used to build all our *Simple Model Series* projects. They have agreed to make these available to EE readers who purchase complete kits of components for the projects, **INCLUDING** printed cards to cut out and assemble for each model. If you are prepared to buy *any four* of the six model kits that kick off the series then you can get your Easiwire **FREE**.

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- Centurion Tank (Oct '91) .... £4.95 plus £1 p&p ☐
- Mini Microwave (Nov '91) .... plus £1 p&p ☐
- Christmas Novelty (Dec '91) .... plus £1 p&p ☐

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Ex Date ....

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Address ....

....

....

Simple Model Series

FLASH! BLEEP!! WHIRR!!!

CENTURION TANK

OWEN BISHOP

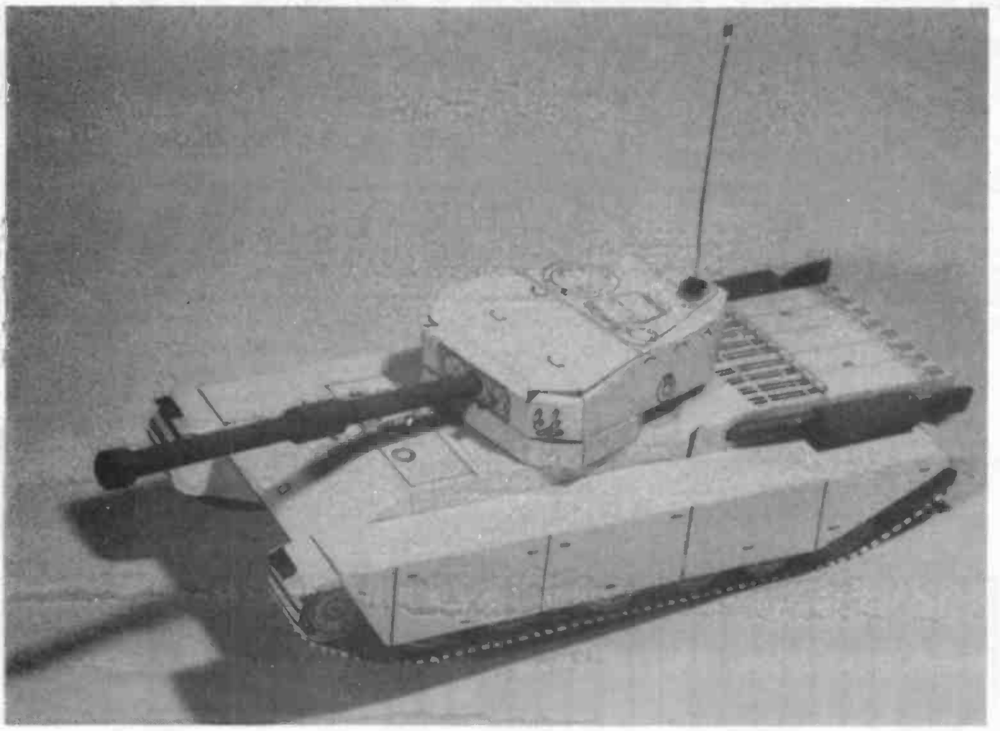
PROJECT 4

A novel series which combines two hobbies in one – electronics and model-making. Simple electronics circuits combined with easy-to-assemble models that cover a wide range of interests.

THIS is a cardboard model of the very successful Centurion heavy cruiser tank, developed at the end of World War 2, just too late to take part in that conflict. Since then it has been in service with the armies of Australia, Britain, Canada, Denmark, India, Iraq, Israel, Jordan, Kuwait, Libya, Lebanon, Netherlands, New Zealand, South Africa, Sweden and Switzerland.

The Centurion first took part in combat in Korea in 1950 and was regarded as the best tank in the field, including those of US and USSR design. It has fought in Kashmir (1965), in the Middle East (Six Day War 1967, and in 1973), and in Vietnam (1968). As well as being a superb fighting vehicle, the Centurion was designed with flexibility in mind. Versions of it have been adapted for other tasks including a bridgelayer, an armoured ramp carrier, and an armoured recovery vehicle.

The model is based on the Mark 5 Centurion built from 1952 until 1959, mainly by Vickers-Armstrong, until it was replaced by later versions up to Mark 13. All versions have a similar appearance and specifications, though later versions have increased cross-country and road ranges, improved armaments and additions such as infra-red night-fighting equipment. The model is constructed to 1/35 scale, one of the scales commonly used for military modelling in plastic.



Centurion Specifications, Mark 5

Crew	4
Battle weight	50813kg
Overall length	983cm
Hull length	755cm
Max road speed	34.6km/h
Vertical obstacle	91cm
Maximum gradient	60 per cent
Maximum trench	335cm
Cross-country range	52.3km
Engine	Meteor Mk IVB
Cylinders	12

The electronics provides realistic sounds of gunfire, both of the 20-pounder main armament and one of the 0.30 Browning machine-guns. The sound effect is initiated by touching the antenna which is mounted on the turret. If the turret is pointing ahead or to the right at that time, a burst of machine gun fire is heard.

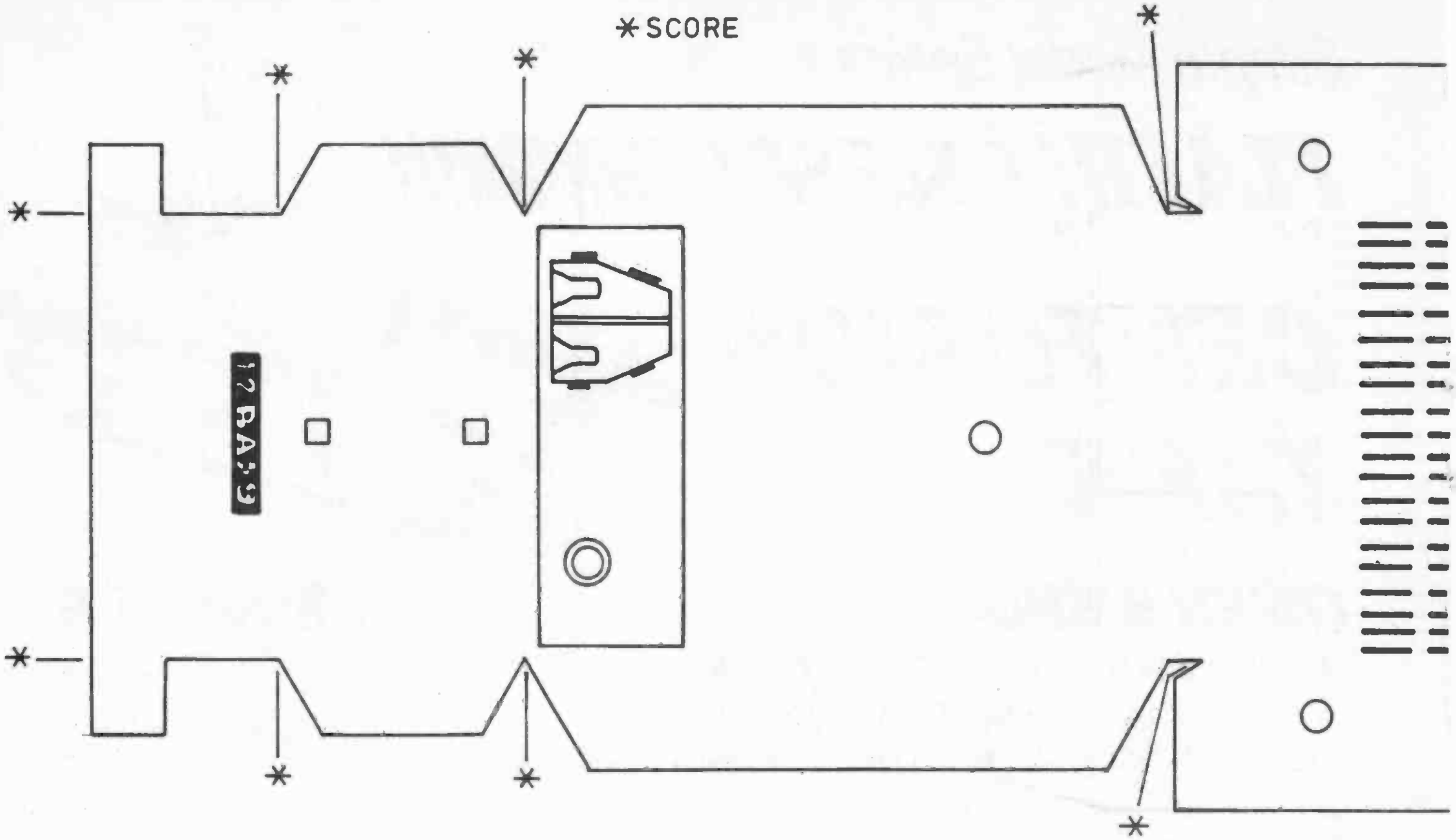
If the turret is pointing to the left, the 20-pounder fires and a red flash erupts from its barrel. This circuit can be fitted into almost any tank built on 1/35 scale from a plastic kit. Or it could provide background sounds for 20th Century military diorama.

ASSEMBLING THE MODEL

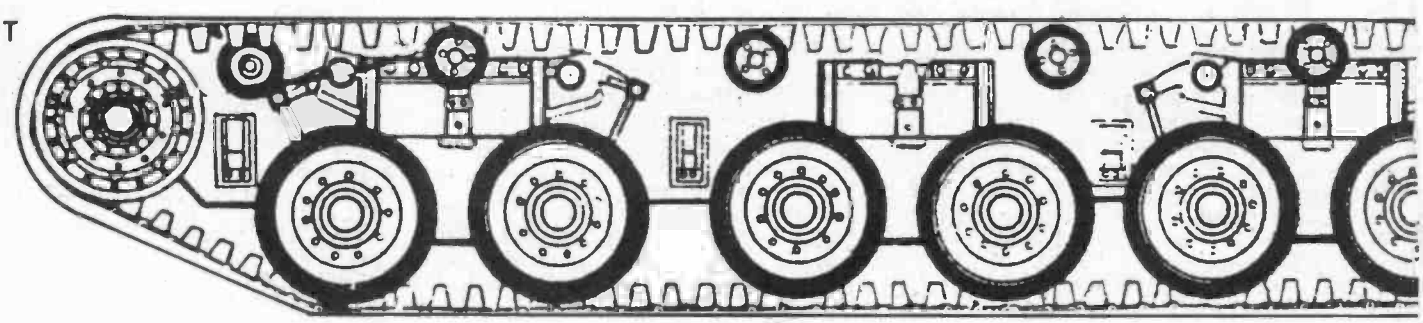
Begin assembly with the track sections. Cut out and glue the sides of the track assemblies together in pairs using spacers at the top and bottom of each side.

Next cut out the hull. This is made from thin card to enable it to be folded neatly into the required shape. Before folding it, score along all fold lines, noting that two of the lines must be scored on the reverse side of the card since two of the folds are "concave". At this stage cut out, score and fold bridges of thick card; four of these have 10mm "legs" and four have 20mm "legs". Glue the body to one of the track assemblies. At the same time glue the bridges inside the body to strengthen it. The four bridges with longer "legs" are used to support the top of the body, the longer "legs" being needed to ensure firm attachment to the track assemblies.

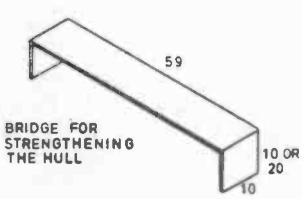
The tracks are cut from thin flexible card.



FRONT

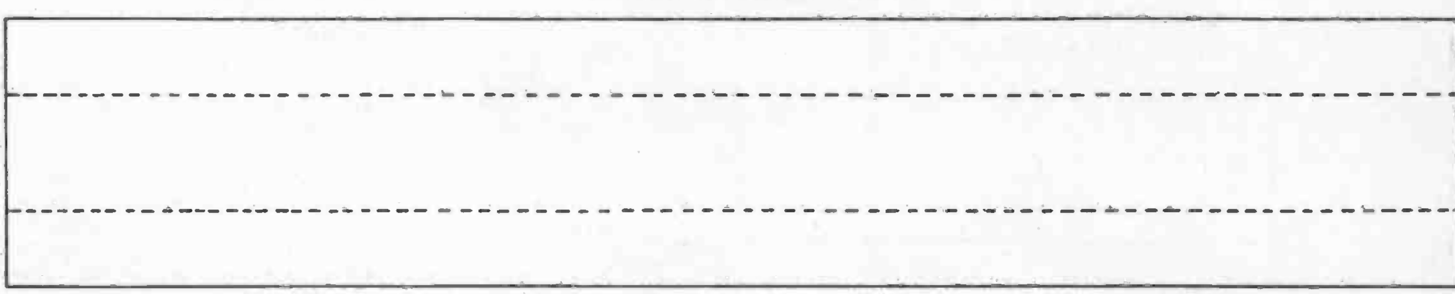


CUT 2

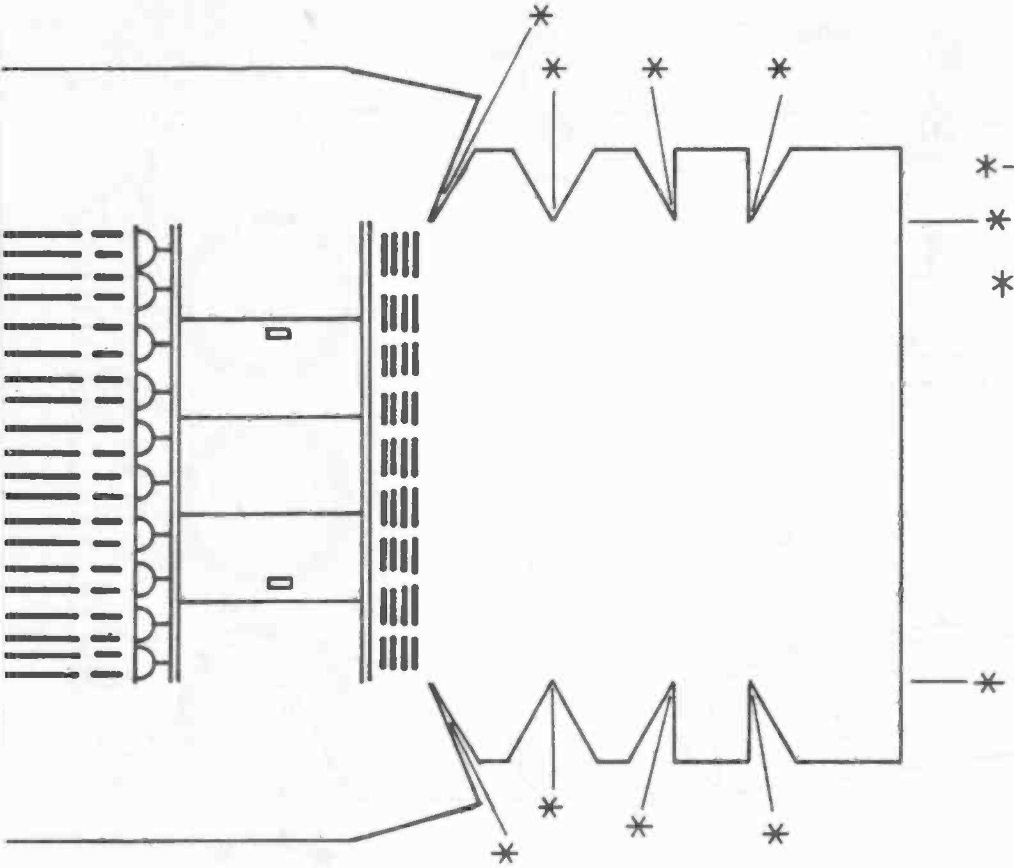


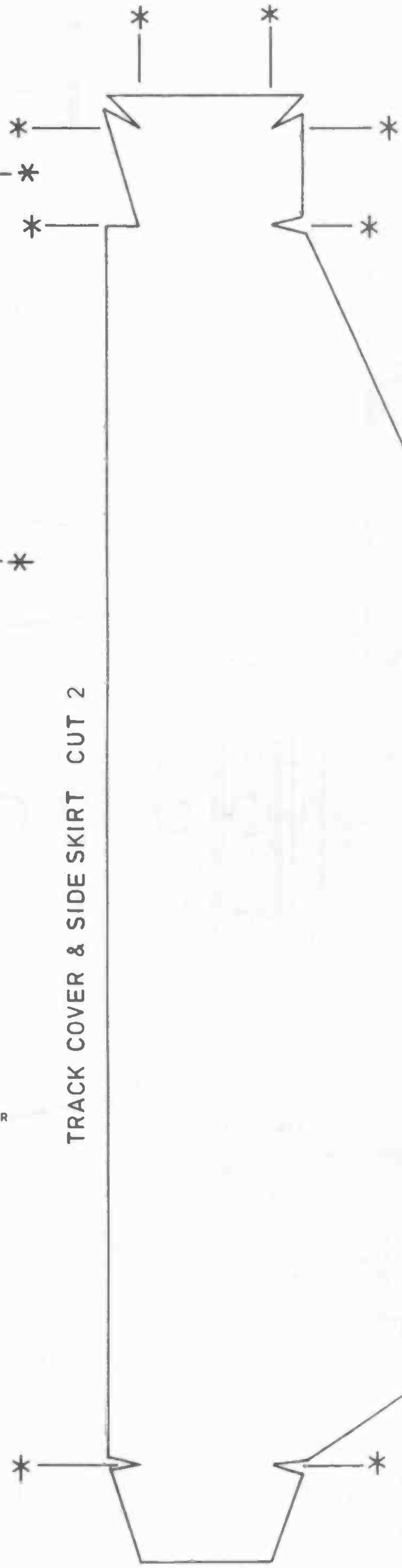
CENTURION TANK

TRACK SPACER CUT4

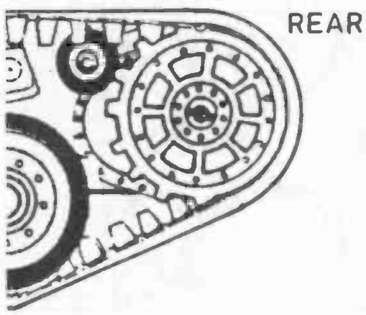


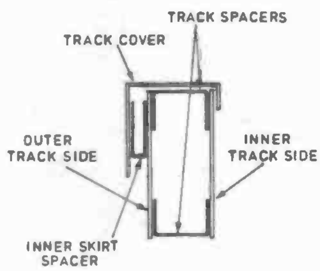
TRACK CUT 2

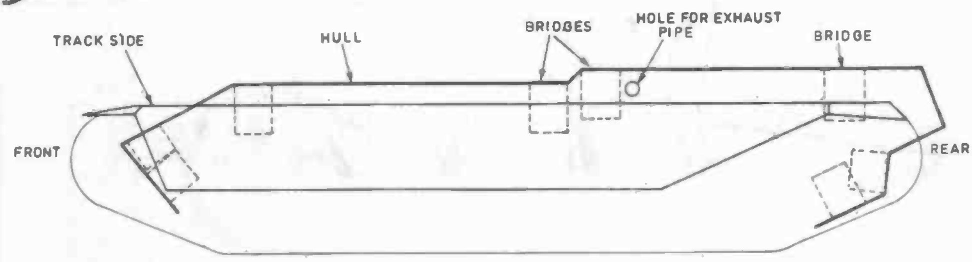




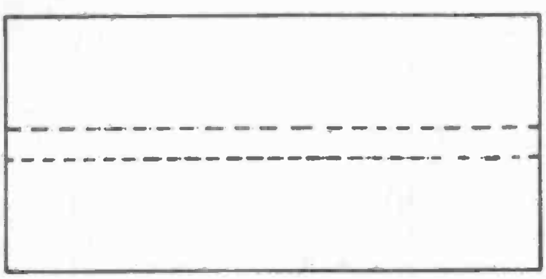
TRACK COVER & SIDE SKIRT CUT 2

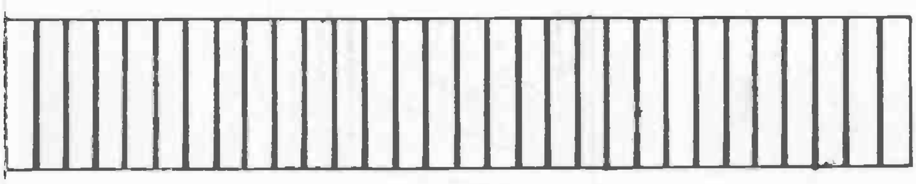


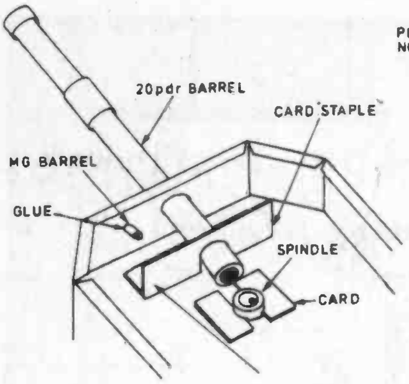


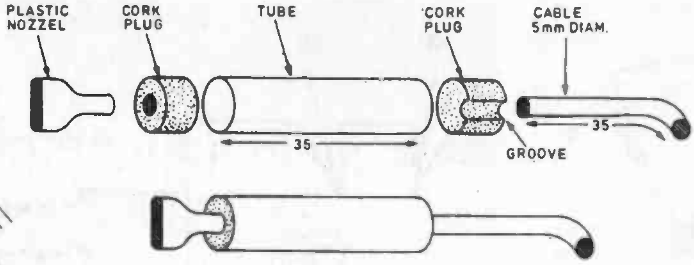


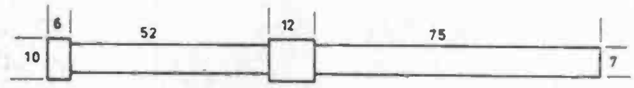
NARROW SPACER BETWEEN TRACK & SKIRT CUT 2

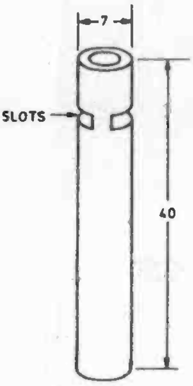




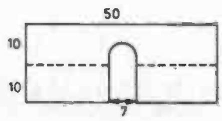


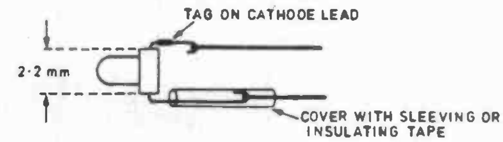


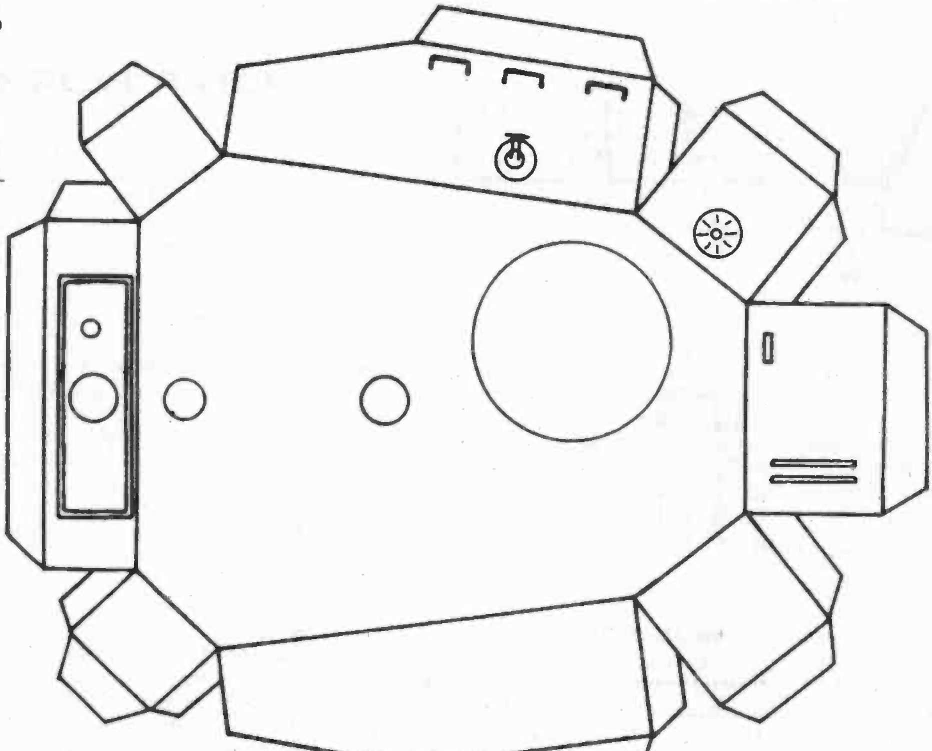




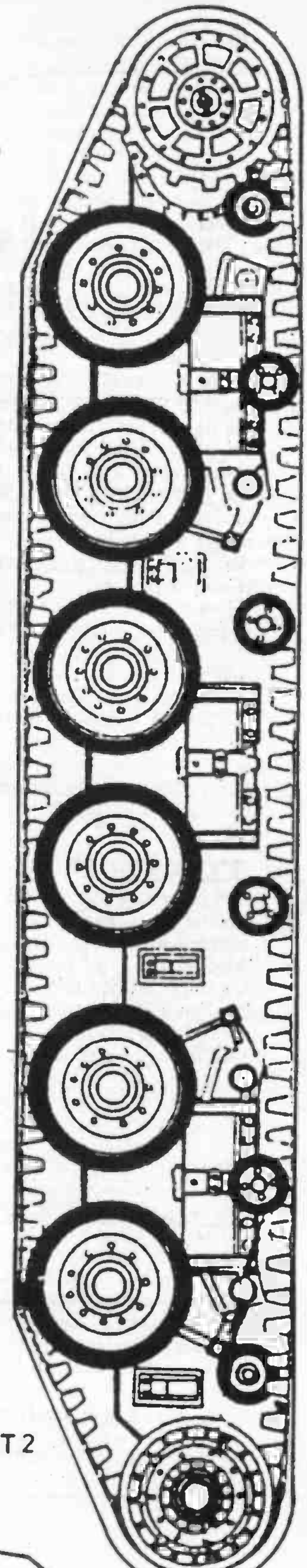
SPINDLE







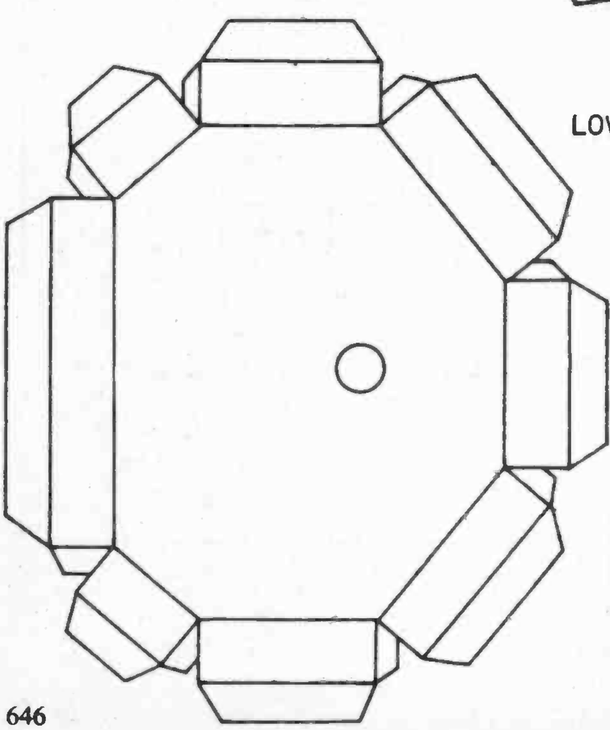
UPPER TURRET

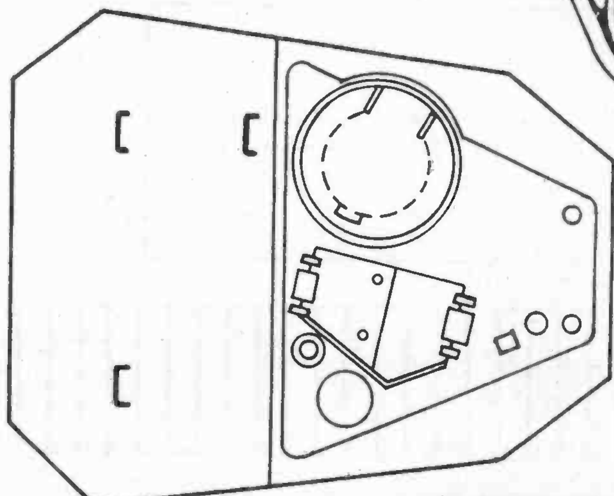


CUT 2

FRONT

LOWER TURRET





TURRET TOP

They are about 1mm wider than the track assemblies. Glue these to the tops of the assemblies at the front ends of the upper spacers; wrap them tightly round the front ends of the assemblies and glue them all along the bottom spacers; wrap them round the rear ends of the assemblies and glue them to the rear ends of the upper spacers.

The track covers and side-skirts are cut out in one piece and folded into shape. Glue them to the upper spacers of the track assemblies. Glue a spacer between the outside of each track assembly and the inside of each side-skirt.

Cut the engine silencers from 10mm diameter tubing. We used light-gauge brass tubing, but the plastic barrels of two used pens or markers could be used instead. The advantage of using brass tubing is that one end of the tubing that is left over can be filed to a sharp circular cutting edge. This makes a cork-borer of exactly the right diameter for cutting out the four cork plugs from a large stopper.

Cut a groove in two of the plugs, and use these for wedging the cable firmly in the front end of the silencer tube. Push the plug fully into the silencer tube so that the plug is recessed about 0.5mm into the tube. Cut two nozzels from sheet polystyrene or similar stiff plastic. Bore a central hole in each of the two remaining plugs and glue the stems of the nozzels into these. Then push these plug into the rear end of the silencer tubes.

TURRET

Paint the silencer assemblies, using matt enamel (e.g. Humbrol) in a camouflage colour, and allow them to dry before gluing them in place on the track covers, with the cables bent round, their ends passing through the holes in the sides of the hull.

The turret consists of an upper and lower part, the upper part having a roof. Cut out, score and fold the upper part. Glue the sides together by means of the tags. The roof is added later, after the circuit has been installed. Cut out, score and fold the lower part. Glue the sides together, then fold the remaining tags inward and glue them to the underside of the upper part.

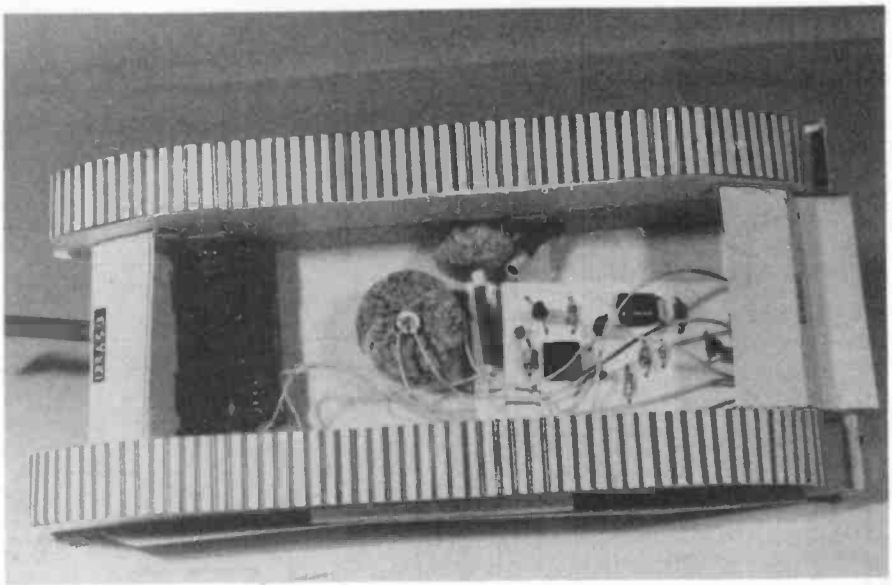
The 20-pounder barrel is a length of polystyrene tube about 6-7mm in diameter. Push short pieces of flexible plastic tubing (we used home wine-maker's siphon tube) over the barrel to form the muzzle rim and the fume extractor. Paint the barrel assembly and allow it to dry before pushing it through the aperture in the front of the turret. It projects 122m beyond the front of the turret. Secure it in place by gluing the cardboard staple to the turret floor. Secured in this way, the barrel inclines slightly upward.

Push a short length of plastic tube about 2.5mm diameter through the front of the turret, to the left of the barrel. This represents the barrel of the machine-gun. Fix it in place with a drop of glue applied from the rear and paint it in camouflage colour.

The turret spindle consists of a 40mm length of plastic tubing, as used for the barrel. Cut two slots in this as shown to grip two rectangles of thick card. When the rectangles are glued to the turret floor, they hold the spindle firmly and prevent it from turning.

TURRET SWITCH

The switch consists of a stationary spring contact and a rotary moving contact, which is mounted on the turret spindle.



Apart from the contacts themselves, the switch is made of wood or cut from a large cork stopper. The stationary contact can be any piece of springy metal; we used a 40mm length of spring curtain rod, with the plastic sheathing removed except at the end where the rod was glued into a hole cut in the support.

Then connecting wire is pushed into the free end of the spring rod, and held in place by a short wedge of sharpened match-stick. The rotary part of the switch consists of a disc cut from a stopper which has a central hole bored to fit tightly on the spindle. The contact is a drawing-pin, with the connecting wire wound several times around the pin before the pin is pushed into the edge of the cork disc. The disc is pushed on to the spindle as far as possible, so that the turret is held firmly against the body. If necessary, a length of PVC insulating tape wrapped around the spindle helps to ensure a tight fit.

While the disc is being pushed on to the spindle, it is twisted so that the drawing pin will come into contact with the spring rod when the turret is turned to the left. Then, with the turret facing ahead, glue the stationary contact support to the bridge, with the spring rod touching the disc. This means that firm electrical contact is made with the drawing-pin when the turret is turned left.

HOW IT WORKS

This circuit is based on a special sound-effects i.c. the UM 3562 (Fig. 1). This can produce three sound effects; machine gun, single-shot, and phaser. The third effect is not used in this model. The desired sound effect is selected by connecting pin 2 either to +3V for single-shot, to 0V for phaser, or leaving it unconnected for machine-gun. The frequency of the machine-gun is controlled by the value of R6

When triggered by a low pulse at pin 4, the output at pin 5 produces the required signal. This is amplified by TR3 to drive the loudspeaker. TR3 consists of two *npn* transistors connected together as a Darlington pair. This gives the device a high gain, in the region of 10,000. If S1 is closed, to put the circuit into single-shot mode, TR3 also flashes the l.e.d.. in the barrel of the 20-pounder.

Normally the circuit is triggered by a simple touch-switch circuit, which uses the Centurion's antenna as its touch plate. This circuit relies for its action on the presence of electromagnetic fields from nearby mains-powered equipment. The field alternates at 50Hz, inducing alternating potentials in the human body. When the antenna is touched, the alternating potentials are transferred to the gate of TR1.

The alternating potential causes the cur-

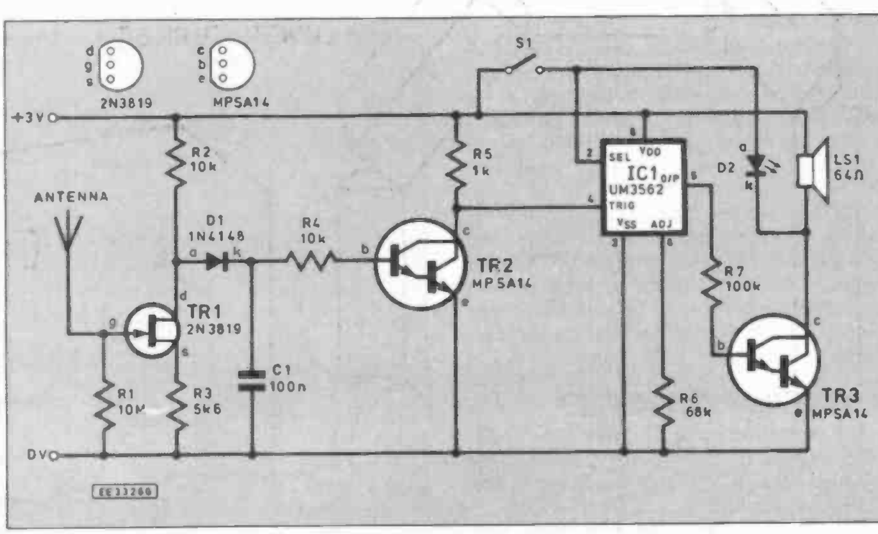


Fig. 1. Circuit diagram for the Centurion Tank sound generator.

COMPONENTS

Resistors

R1*	10M
R2*, R4*	10k (2 off)
R3*	5k6
R5	1k
R6	68k
R7	100k

All ¼W ±5% carbon.

Capacitor

C1*	100n polyester

Semiconductors

D1*	1N4148 silcon signal diode
D2	sub-miniature light-emitting diode, red
TR1*	2N3819 junction f.e.t.
TR2, TR3	MPSA14 Darlington transistor
IC1	UM3562 three-gun sound generator

Miscellaneous

LS1	64-ohm miniature loudspeaker, 38mm diam

1mm socket, black; p.c.b. eyelet terminals (5 off); 8-way d.i.l. socket; tinned copper wire for antenna*

*Indicates parts not required if the alternative trigerring circuit is used.

Materials

Materials for making S1 (see text).

Printed model card — see Shop Talk and Special Offer page plus extra sheets of 250g/m² card or thin buff coloured card (250g/m²) approx half a sheet; medium white card (1mm, 650g/m²) for track assembly inner sides, bridges, etc; thick white card (2mm, 1500g/m²) for circuit card 77.5mm x 40mm; 7mm diam polystyrene tube, approx 200mm; 10mm diam brass or plastic tube, 70mm; Humbrol enamel in camouflage colour; double-sided self-adhesive pads or tape.

Approx cost guidance only **£5**

rent through TR1 to vary and, as a result, the potential at the drain of TR1 rises and falls at 50Hz. As it rises, current flows through D1 and imparts charge to C1. As it falls, current is prevented from returning by the action of D1. Thus, the charge on C1 builds up for as long as the antenna is being touched.

The increased charge on C1 causes a current to flow to TR2, turning it on. This, like TR3, is a Darlington transistor so a small current flowing from C1 is sufficient to turn the transistor fully on. A relatively large current flows through R5, causing a fall in potential at the collector of TR2. Since there is a direct connection to pin 4 of the i.c., this fall triggers the i.c. into action, and the sound effect is produced. When the finger is removed from the antenna, current no longer flows through D1 and the charge on C1 falls, as current leaks away through the base of TR2.

CIRCUIT CARD

Before commencing to build the circuit, note the remarks about the possible substitution of an alternative triggering circuit in the next section.

The circuit is assembled in the usual way (see previous articles in this series for more

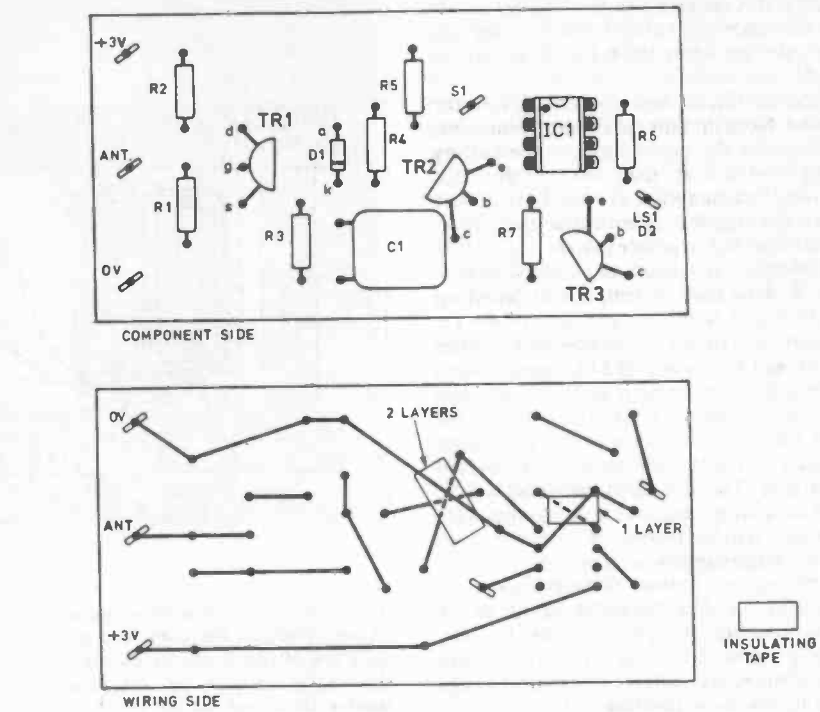


Fig. 2. Circuit card layout and wiring using Easiwire.

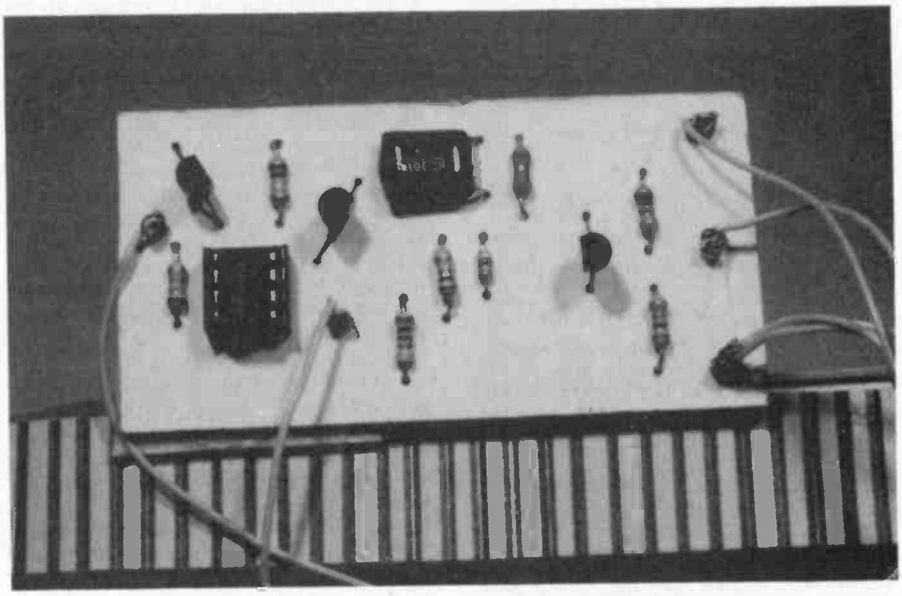
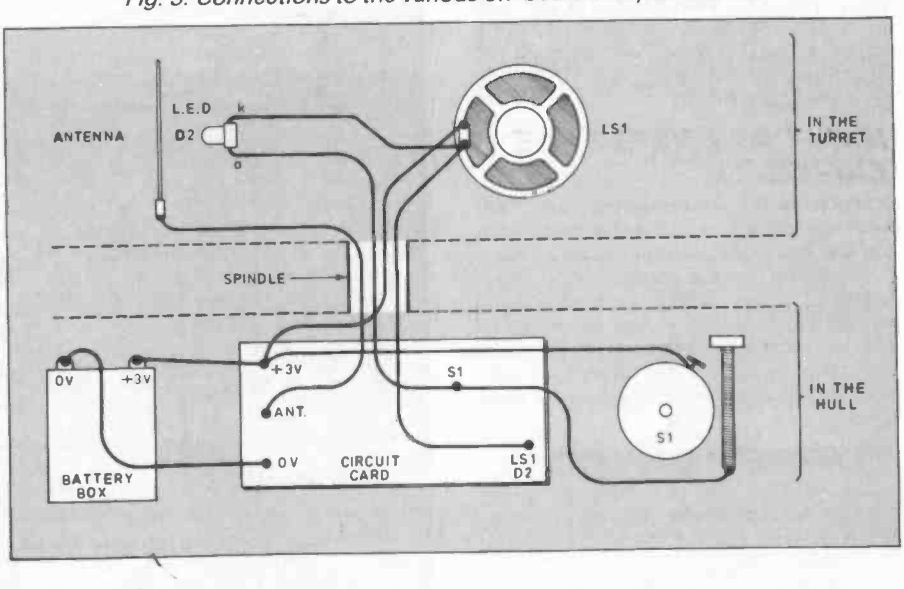


Fig. 3. Connections to the various off-board components etc.



details) by wire-wrapping (Fig. 2). Before wiring, it is advisable to glue the i.c. socket to the card and also to bend over the capacitor and glue the body of this to the card.

Test the circuit before installing it in the model. Note that the maximum permissible voltage for the i.c. is 3.6V, so the battery must have no more than two 1.5V dry cells. Current consumption is very low, 250µA when the circuit is quiescent so there is no need to provide a power switch.

The off-board connections are shown in Fig. 3, these may be temporarily wired up for testing. Check the operation of the i.c. by making a direct connection between pin 4 and the 0V terminal. If S1 is open, a burst of machine-gun firing is heard for as long as contact is made. If S1 is closed, a single shot (the 20-pounder) is heard each time contact is made. The l.e.d. glows at the same time. The volume of the sound will be considerably greater when the loudspeaker is mounted in the turret.

The triggering circuit is tested by touching the trigger terminal, when the machine-gun or single shot should be heard. When all is working correctly, remove the temporary connections and spray the underside of the board with p.c.b. lacquer to help hold the wiring in position.

ALTERNATIVE TRIGGERING

The simple triggering touch-switch may not work unless there is mains-powered equipment switched on in the same room. This is normally no problem but if, for example, the tank is to be used outdoors, or in an out-building that has no mains supply, an alternative trigger circuit should be used. The same may apply if the circuit is being fitted to a tank built from a plastic kit, in which it may not be practicable to run a wire up to an antenna on the turret.

The circuit is modified by omitting R1 to R4, TR1, D1 and C1. It is then triggered by making contact between the base of TR2 and the positive supply. This is similar to the technique used to activate the model computer described last month. The switch contacts are the bare ends of two wires (Fig. 4) located at a convenient place on the model.

The wires are held in position by passing through holes drilled in a block of plastic or cardboard, glued to the inside of the hull or turret wall, with the bare ends projecting a millimetre or two from the model. One wire comes from the +3V supply and the other from the base of TR2. When both wires are touched at the same time by a finger, a small current flows through the finger-tip from the supply to TR2, turning it on and triggering the i.c.

INSTALLING THE CIRCUIT

Assemble S1 as previously described. Glue the rim of LS1 to the rear floor of the

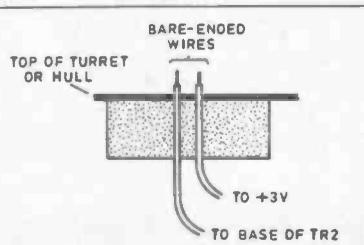
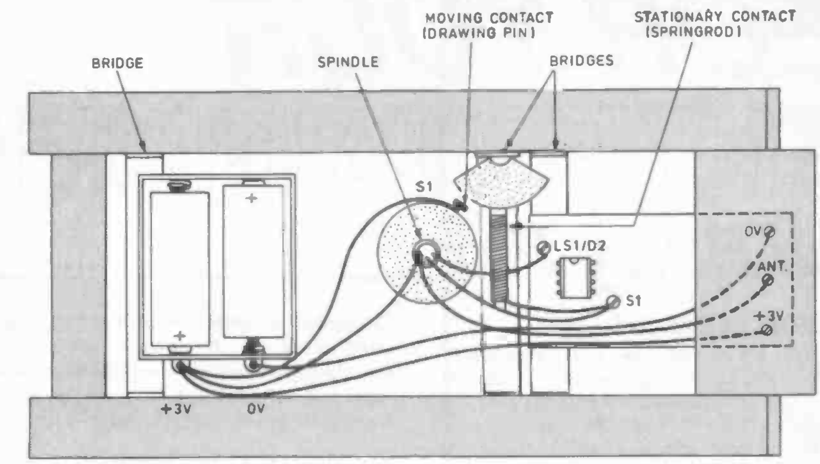


Fig. 4. Alternative triggering arrangement.



EE3327G *Fig. 5. Installation of the circuit card, switch and batteries.*

turret. If the antenna is to be detachable, it is best held in a socket mounted on the roof of the turret, at the rear. The card is best stiffened at this point by gluing a piece of thicker card inside. In the prototype we used a 1mm wander socket, but there are several other types of socket that can be adapted for this purpose. Or the antenna can be permanently mounted in a block of wood or cork glued to the inside of the roof.

A piece of stout tinned copper wire, about 90mm long is needed for the antenna. For the prototype we straightened a wire paper-clip to make this. One end is bent back on itself twice, and squeezed using pliers. This is to make it fit tightly in the socket. The other (upper) end is capped with a small block of rubber to prevent accidental eye injuries. Check that, when the turret roof is finally glued in place, bare metal of the socket cannot come into contact with bare metal of the loudspeaker. If necessary use insulating tape to prevent this.

Cut four lengths of thin insulated flex to run from the turret down into the hull and thread these through the turret spindle. use wires of different colours or mark their ends with differently coloured inks to distinguish them. Thread one of these wires and a shorter wire (from LS1) through the barrel. Twist the ends of these wires around the terminal wires of the l.e.d. Use a collar of p.v.c. sleeving or a piece of insulating tape to prevent short-circuits between the terminal wires

Gently push the l.e.d. a few millimetres into the muzzle of the barrel. Before fixing the circuit board and battery box in place, make the connections to the board as shown in Figs. 3 and 5. Check the operation of the circuit and, if all is working properly, fix the battery box and circuit board to the inside of the hull using double-sided self-adhesive pads or tape. Complete the model by gluing the turret roof in position.

The low power consumption of this circuit means that the cells may be left in the battery box for many hours without appreciable loss of power, but it is advisable to remove the cells if the model is not to be used for several days.

ADDITIONS

The model provides scope for the keen model-maker to add further details. These include the smoke-dischargers on the front corners of the turret, and various bins and storage baskets, as seen on real tanks. It is also possible to cut around the edges of the hatches in the hull and turret so that they open.

A driver and tank commander from a 1/35 scale plastic tank crew kit further increases the realism.

Another authentic addition is the second Browning machine-gun mounted on top of the turret, on the rim of the circular hatch. □

Reference (for photos, scale drawings, history etc.) *Centurion In Action* by Stephen Tunbridge, published by Squadron Signal Publications, Carrolton, Texas (1976) ISBN 0 89747 046 X.

FOR YOUR ENTERTAINMENT

by Barry Fox

Father of Electricity

If you are in London, near Kensington, do be sure to visit the Science Museum for the exhibition *Michael Faraday and the Modern World*. It celebrates the bicenenary of the birth of the father of electricity and runs until the end of this year.

The Royal Institution has loaned original equipment built and used by Faraday. The Science Museum has built working models which, at the push of a button, demonstrate the working principle of all Faraday's major discoveries.

All modern motors and generators rely on Faraday's recognition of the fact that a current flow produces magnetic fields which interact with the field of a magnet to produce a driving force. Faraday's discovery that when two coils are wound on an iron ring, a change in current in one produces a change in current in the other, is the basis of the old–fashioned children's electric shock coil and car ignition.

The same principle lets us step high a.c. voltages from the mains down to safe low voltages, for use in an electric razor, radio set or tape recorder. The national grid relies on transformers to step a.c. voltage up to high levels, so that less power is lost on long transmission lines. This is why Edison's early plans to distribute d.c. failed and Nikola Tesla, backed by George Westinghouse, made a.c. mains the world system.

Faraday started the Royal Insitution's Friday evening meetings for members, at which he often talked. These meetings still continue as Friday Evening Discourses. He also started the Christmas lectures, which are now televised every year. And every year we have the *Faraday Lecture*, a spectacular illustrated talk which tours Britain with sponsorship by the likes of BT, the BBC or STC.

Father of Computing

While at the Science Museum, you can also visit another bicentenary exhibition, *Making the Difference*, on the life and work of Charles Babbage.

Babbage is known as the father of computing, although modern computing was re–invented from first principles in ignorance of Babbage's work. "Pioneers" spent decades re–discovering Babbages's long–forgotten ideas.

Babbage designed mechanical calculating machines, which he called Analytical and Difference Engines, in the mid 19th century. But he never persuaded the Government, under Prime Minister Robert Peel, to put money into building them. "What shall we do to get rid of Mr Babbage and his calculating machine?", asked Peel in 1842.

This followed a row between Peel and Babbage. Then Babbage upset the naval establishment by proving that many of their navigation tables contained mathematical mistakes which had probably steered ships into rocks.

Difference Engine

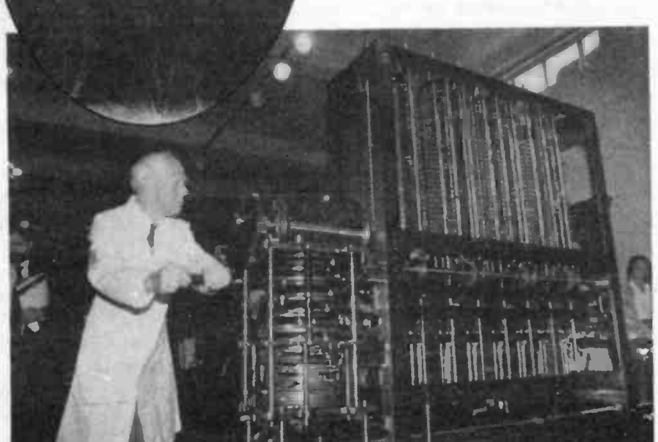
He did not publish details of his engines, but enough information survived in his notes for the Science Museum to spend a year building a full sized Difference Engine. The aim was to try and prove whether it would have worked if Babbage had got the money. So the builders used tools and materials of the type available to Babbage.

The Difference Engine, now finished, consists of around 4000 moving cog wheels (excluding the printing mechanism), and weighs three tons. The operator turns a large handle, making the whole thing work like a giant mangle.

I have to say I was rather disappointed with my visit. Although there are some interesting old relics, most of the information is in small print on large placards. A string of computer companies (ICL, Rank Xerox, Hewlett Packard, Unisys etc) funded the project and there was obvious opportunity to compare the accuracy and speed of a Babbage Engine with the post–war mechanical adding machine, early electronic calculator and modern personal computer. But I found nothing so practical.

Most important, when I visited a couple of weeks after the official opening there was a complete muddle over what Computing Curator Doron Swade acknowledges to be the lynch pin of the whole exhibit – a working demonstration of the giant Engine, given by the engineers who built it and can explain how it works and answer questions. None of the staff knew why the demonstration I had come to attend wasn't happening, where the engineers were or when there would be a demonstration. Afterwards I

Michael Faraday (1791-1867) from a lithograph by T. H. Muire, 1851.
Children from St Marks Catholic School, Hounslow, Middx, watching Faraday's Carbon Arc eperiment.



Charles Babage (1791-1871) from an engraving by Roffe.
Babbage's Difference Machine No. 2 built (full size) by the Science Museum from original designs dating from 1847 to 1849.

spoke with Curator Swade who was clearly appalled, and frustrated by the lack of backup he gets from some of the staff at the Science Museum.

"I have got the Engine built but I have not yet been able to get notices put up to tell people when it will be demonstrated" he admitted.

The engineers claimed that they had been there but been waiting for someone to ask them to give a demonstration. I saw no–one who looked even vaguely like an engineer waiting to be asked to perform. The Engine was securely locked inside a glass case.

Swade has kicked butt and confirms that the situation is this. The Engine should be demonstrated every day, at 11 am and 3 pm. The engineers should wear white coats so that they are easily recognised even when not turning the handle. There should be a notice to tell the public these times and warn of any changes or cancellations. I was left with confidence that if this doesn't happen, it will be over Swade's dead body.

It costs adults £3.50 to get into the Science Museum, after which the special exhibitions like those on Faraday and Babbage are free. Anyone can visit the museum free between 4.30pm and 6pm any day of the week. But the museum does virtually nothing to publicize this happy fact.

Recently, when the Chartered Insitute of Patent Agents tried to interest the Science Museum in staging an exhibition of invention, they were quoted a fee of £750,000 pounds. The CIPA went to the Design Centre instead who did it for a tenth of the price.

I have a distinct feeling that some of the people running, and working at, the Science Museum regard it as sheltered employment.

SHOP TALK

with David Barrington

Dry Cell Charger (Sept '91)

Before we move on to this month's constructional articles we would like to take up a point from last month's *Dry Cell Charger* project. We understand that many readers have been having problems sourcing a suitable mains transformer with a 4.5V secondary winding. The one used in the model was purchased from **Electromail, P.O. Box 33, Corby, Northants NN17 9EL** (☎ *0356 204555*), code 196-381. £3.36 plus £2.85 p&p and VAT.

The 5VA transformer specified in the table (page 553) for "D"-cells is a *minimum* rating. The one used in the designer's model (see above) is rated at 6VA, but has two secondary windings rated at 3VA each. This means that for *"D"-cell* recharging the two secondaries will have to be wired or "strapped" in parallel, i.e. 0V tag to 0V tag and 4.5V tag to 4.5V tag.

UV Exposure Unit

Most of the components required to build the *UV Exposure Unit* are standard items and should be available "off-the-shelf". However, the Siemens ferrite pot core transformer, the glass encapsulated mercury tilt switches and the 12in 8W ultra-violet fluorescent tube are "special" items and may not be available locally.

The pot core B65681 LR26 transformer (stock code 67126R), 8W UV tube (stock code UVT) and the miniature mercury tilt switches were purchased from **Electrovalue Ltd, Dept EE, 28 St Judes Road, Englefield Green, Egham, Surrey TW20 0HB.** (☎ *0784 33603).* Other tilt switches can be used provided they can be accommodated on the board and be adjusted so that the contacts are *closed* when the unit is on a level surface.

The printed circuit board layout has been designed to take BC212, 212A and 212B transistors; types designated with suffix L, LA and LB use a different outline and will have to have their leads bent to fit on the board correctly. The small printed circuit board is available from the *EE PCB Service*, code EE768 (see page 674).

PC-Scope Interface

It is most important that constructors of the *PC-Scope Interface* use the CMOS 74HC types for IC1, IC3 and IC8. Standard CMOS counterparts are too "slow" and unsuited to this high speed circuit.

The A-D Convertor (ADC) chip CA3306 is only currently listed by **Cricklewood Electronics**. The low power CMOS static RAM type UM6116 appears in most component suppliers catalogues. In most cases it is only listed as a 6116 device.

The 3.2768MHz crystal used in the clock/counter stage is fairly common now and should not prove troublesome to locate. It is usually found in catalogues under their "Timing Crystals" section for watches and clocks.

The main printed circuit board and double-sided plug board are both available from the *EE PCB Service*, see page 674. These should be ordered as EE769 (Main board) and EE770 (Expansion plug).

Centurion Tank – Simple Model Series

The model and electronic circuit for the *Centurion Tank*, this month's *Simple Model Series* project, is built on *printed* card, which can be obtained from the EE Editorial Offices for the sum of £2.50 (including postage). The actual wiring of the "electronics" card is by the use of the "no soldering" Easiwire wire-wrapping system.

To help with assembly **Bull Electrical** (☎ *0273 203500)* and **Greenweld Electronic Components** (☎ *0703 236363)* have put together a complete kit, including cards, for the sum of £4.95 plus £1 post and packing.

The above mentioned companies have large stocks of the Easiwire wiring packs and have agreed to make these available to EE readers who order the model kits from them at a "special price" – see page 642. If you purchase any one single kit, an Easiwire pack will only cost £5. However, if you are prepared to order four or more of the listed kits they will supply an Easiwire pack *Free*.

Modular Disco Lighting

Looking at the photographs of the *VU Sound Unit*, this month's *Modular Disco Lighting System* project, the capacitor C2 wired directly across the Sound Input jack sockets appears to be a "metallised polyester film" type. This type is certainly rated at the required 250V and suitable for inclusion here.

The chassis mounting 7-way DIN sockets and plugs are fairly common place and stocked by most component advertisers, but the circular 10-pin video chassis "plug" and matching cable socket may prove difficult to locate. One source is **Electromail.** The case is the **Maplin Blue** case 233, code XY48C.

To some readers, the video sockets and case may appear too expensive an outlay. Alternatives can be used, but, for safety, the case MUST be all-metal and "Earthed".

The full range of bar l.e.d. driver i.c.s LM3914 (linear), LM3915 (log) and LM3916 (VU mode) seem to be popular stock lines and should be easily sourced. The same comment applies to the "common cathode" tricolour l.e.d.

The only current listing we have located for the BC307B transistor is from **Cricklewood and Greenweld Electronics**. An alternative pin-for-pin device is the BC251B.

The double-sided printed circuit board is available from the *EE PCB Service*, code EE767 (see page 674). be sure to order the "log" law potentiometer for VR1.

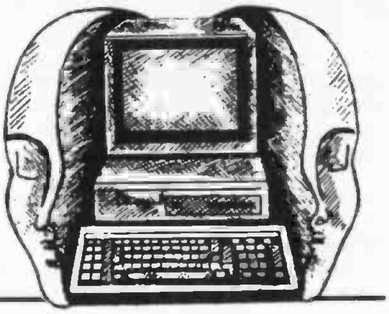
RIAA Preamplifier

We cannot foresee any component buying problems for readers who undertake the construction of the *RIAA Preamplifier* project.

The wideband op. amp LF351N i.c. appears in the listings of most of our component advertisers as an "off-the-shelf" item. The E24 series of resistors now appears in most of our components catalogues and the "odd" values of 750k and 51k should not present any difficulties. As mentioned, you can, of course, use 680k and 47k types.

Remember to keep the leads from the circuit board to the input and output sockets as short as possible.

INTERFACE



Robert Penfold

As PROMISED in last month's *Interface* article, the printed circuit design for the PIO Prototyping Card is included in this month's offering. The top (component) side of the board is shown in Fig. 1, while Fig.2 shows the underside. No component overlay is included, as this is basically the same as the one for the PC prototyping card featured last month. The only difference is the addition of the 8255 chip which fits onto the 40-pin d.i.l. cluster (via a socket). This has the same orientation as the other integrated circuits, which means that pin one is at the top.

My original design required a through-plated board, or the integrated circuits to be soldered on both sides of the board. The design presented here is a modified version which is better suited to DIY construction. It only requires the integrated circuits (or their holders) to be soldered on the underside of the board.

Although pads for the integrated circuits are actually included on the top side of the board, they serve no useful purpose and can be omitted. They are only included because my printed circuit design program insists on pads being present on every copper layer of the board, whether or not anything actually connects to them.

Of course, the printed circuit through-pins should be soldered on both sides of the board. They should also be fitted *before* adding the socket for the 8255, as some of the pins actually fit under the latter.

It is also advisable to solder the pins near the edge connector on both sides of the board, whether or not they actually connect to tracks on both sides. This helps to firmly anchor them in place.

The chip select pin of the 8255 connects to output 0 of the address decoder, placing it at addresses &H300 to &H303 (plus echoes at &H304 to &H307). However, it can obviously be rewired to one of the other outputs if necessary. Port B and the upper nibble of port A are brought out on the 25-pin D-connector, as are the 0V and +5V supplies.

The other twelve input/output lines are brought out to solder pins and can be used with prototype circuits built on the card, or wired to the D-connector, as preferred. The lines that are taken to the D-connector could also be wired to an on-board prototype circuit if necessary, and there is plenty of scope for altering the basic scheme of things to suit the prevailing circumstances.

8255 Programming

The operating mode of the 8255 is controlled by the control register at address &H303. There are three modes of operation called modes 0, 1, and 2. Mode 0 is the most simple, and is the only one we will consider here.

Port A and port B can each be set as eight inputs or eight outputs, but it is not possible to set lines individually as inputs or outputs. Port C can provide split operation, but only on the basis of having one nibble as a four-bit input and the other nibble as a four-bit output.

Bits five to seven of the control register are used to set the required operating mode. Bit seven is set to 1 to enable the operating mode to be changed, and the control register operates in a totally different manner if bit 0 is set to 0. This different method of use is not applicable to mode 0 operation though.

The following table shows how to set the required mode using bits 5 to 7 of the control register:

MODE	*BIT 5*	*BIT 6*	*BIT 7*
0	0	0	1
1	1	0	1
2	1 or 0	1	1

Note that this only applies to port A and the upper nibble of port C. The mode of port B and the lower nibble of port C is controlled by bit 2. This is set high for mode 1 operation, or low for mode 0 use (there is no mode 2 for these ports). In order to obtain mode 0 operation for all three ports it is therefore just a matter of setting bit 7 high, and bits 2, 5, and 6 low (i.e. write 128 decimal to the control register).

The functions of the ports are controlled by bits 0, 1, 3, and 4, which respectively control ports C lower, B, C upper, and A. Setting a bit to 1 sets the corresponding port as an input – setting it to 0 sets the corresponding port as an output.

The following table shows the decimal value needed to set each port as an output. Obviously 0 is always used to set a port as an input:

PORT	*DECIMAL VALUE*
C Lower	1
B	2
C Upper	8
A	16

Remember that bit seven must be set high when writing to the control register. Therefore, the total value written to the control register is 128 plus the values taken from the table for any ports that must be set as outputs. As an example, for mode 0 operation with ports C upper and A set as outputs (ports C lower and B set as inputs), the value written to the control register would be 152 ($128+8+16=152$).

For many applications, such as driving digital to analogue converters, reading sensor switches, etc., mode 0 operation should suffice. For anything more complex one of the other modes might be better, and it is worthwhile getting hold of a copy of the 8255 data sheet if you are going to make more than occasional use of the 8255 card. Maplin Electronic Supplies Ltd. can supply data sheets for all the integrated circuits that they supply, and the 8255 is included in their range.

I had originally planned to include details of A/D and D/A converters for the PC. However, as similar ground is covered in the *PC-Scope Interface* in this issue, I will leave this for the time being.

New DOS For Old

As most PC users will no doubt be aware, a new version of MS/DOS (version 5.0) has recently been released. It radically departs from previous versions of MS/DOS in that an upgrade version is available. This has an installation program which de-installs the existing version of MS/DOS from a hard disk and then installs the new version. The upgrade version of MS/DOS 5.0 normally seems to retail at

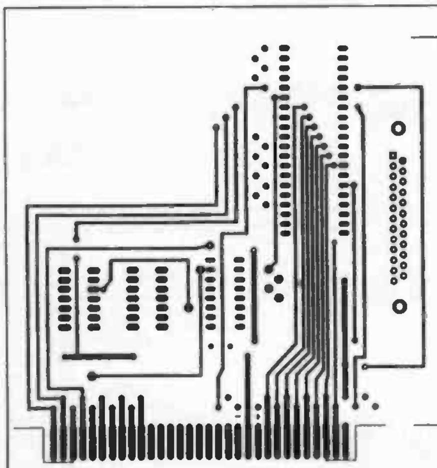


Fig. 1. Track section of the top side of the 8255 PC prototyping card (shown ½ scale).

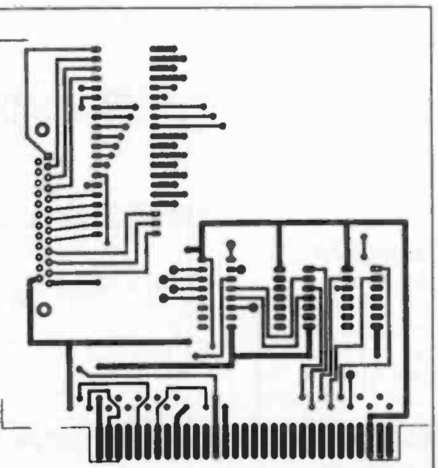


Fig. 2. Underside of the prototyping card. The complete board measures 204mm × 102mm plus "plug" section.

about £50 to £60 plus VAT. In my opinion it is well worth the cost.

Although MS/DOS 5.0 has a lot of new commands and features, the main attraction for most users is that it requires less memory than some previous versions. In particular, with an 80286 or higher processor, MS/DOS can be loaded into high memory. This means that you can actually have about 635K of free conventional memory.

In practice there will be start-up programs run by the CONFIG.SYS and AUTOEXEC.BAT files that will eat up some of this memory, but I have about 600K of free RAM once my AT has booted-up. I find that a number of programs which gave memory problems running under MS/DOS 3.3 now run perfectly happily under MS/DOS 5.0.

Shareware

In a previous *Interface* article I mentioned some PC shareware and public domain ("PD") programs of interest to electronics enthusiasts. Although the feedback from readers on this topic was totally underwhelming (i.e. no response at all!), I understand that the shareware company mentioned in the article received a fair number of enquiries.

I mentioned a printed circuit design program called PC Route (disk No. 2531), which has now been updated and renamed. The latest version is called PC Trace. The change in name is presumably to avoid people mistakenly thinking that this program is one which tells you the quickest route from where you are to somewhere else.

The new version has EGA graphics support, more printer drivers, variable pad sizes and track widths, and mouse support. The graphics still seem somewhat below the standards of commercial p.c.b. design software, and I have doubts as to whether this program can handle complex boards. However, it is still an interesting one to try if you are interested in this type of software.

I have mentioned the circuit analysis program called ACIRAN (Disk No.2609) in previous articles, and this has now been considerably updated. First and foremost, the restrictions on the trial version have now been removed. This means that circuits with up to 100 components and 500 nodes can be accommodated, and that up to 101 test frequencies can be used for each analysis.

Improvements have also been made which make it easier to get circuits into the program, and to modify them. There is actually provision for schematic capture, but you would need an expensive schematic drawing program to take advantage of it. Control of the program is via an improved menu system with optional mouse program.

ACIRAN is a powerful circuit analysis program, but unlike many programs of this type it is reasonably easy to use. It also has some powerful graphics capabilities, and will use super VGA modes if your computer supports them. It is certainly a program that anyone who has a PC and is interested in electronics should give a try.

Some of the other programs I have mentioned recently have also been updated, including LSYSTEM (Disk No.2117) the logic analyser program, and TSQUARE (Disks Nos. 2562A to D) the CAD program. There is now quite a range of electronics, radio, and other technical software available from PD and shareware sources, much of which is well worth investigating.

The programs mentioned here are available from PDSL, Winscombe House, Beacon Road, Crowborough, Sussex, TN6 1UL (☎ *0892 663298*). They may be available from other PD/shareware sources, but under different catalogue numbers. Presumably due to its specialised nature, many PD/shareware libraries do not seem to offer much software of this type.

If you are interested in printed circuit design software there are demonstration programs available from several companies. These are free or cost very little, and are mostly "crippled" versions of the real thing that enable you to thoroughly test the software.

Some of the low cost printed circuit design programs are very powerful indeed. There have been some spectacular price reductions over the last year. Printed circuit design software which would have cost many thousands of pounds not so long ago can now be yours for just one or two hundred pounds!

DOWN TO EARTH

George Hylton

Junction F.E.T.

It's only too easy for the writer of a regular feature like *Down to Earth* to forget the needs of new readers. The editor once suggested that decibels might be a suitable topic. "But I did that a couple of years ago," I objected. "Well, do it again, a different way," he said. I did, and somebody expressed appreciation.

This is my reason for coming back to familiar "topics" from time to time. If you are new to electronics and are puzzled by some bit of theory, why not write to me about it? If it's a general point, the chances are that other readers have the same problem and would welcome an article about it.

Today, I'm taking a look at field effect transistors (f.e.t.s). However, as there are too many different kinds to be covered in a short article I'm concentrating on just one of them.

Construction

The junction f.e.t. (Fig. 1) is really quite a simple device. A piece of *p*-type silicon is treated so as to create an *n*-type region called the *channel*. Electrons can flow from one end of the channel (called the *source* (s)) to the other (the *drain* (d)) when a battery is connected negative to source, positive to drain.

I say they *can* flow, because whether they do depends on what is done to a third connection, the *gate* (g). If the gate is made very negative with respect to the source, current flow is suppressed. The transistor is biassed off. As the negative bias is reduced to zero, current flows freely.

This effect is graphed in Fig. 2. Here the curve labelled $V_{GS}=0$ is for the unbiased condition and the one for $V_{GS}=-2V$ is for the case when the gate is 2V more negative than the source.

A bias of −1V would give a similar curve between these two. For −3V the curve would be somewhere beneath the −2V curve, and so on. The curves are representative of a low-power *n*-channel junction f.e.t.

Symbol

The symbol for an *n*-channel junction f.e.t. is added to Fig. 1 and Fig. 2. In my opinion it's a thoroughly bad symbol, but we are stuck with it. The gate and channel (Fig. 1) form a *pn* junction diode, and the little arrow on the symbol shows the direction in which current flows if this diode is forward biased.

The only problem is that it never is, in normal operation of the f.e.t. It would have been much more sensible to add an arrow to the source lead showing the actual direction of current flow, as in the lower symbol on Fig. 2. I use this symbol for my own private diagrams but it's non-standard.

Reverting to Fig. 1, it looks as if the source and drain connections could be reversed. This is true for many junction f.e.t.s, known as symmetrical f.e.t.s. Others, however, don't work properly if the source and drain connections are reversed.

P-Channel

It's possible to start with a block of *n*-type silicon and form a *p*-type channel. To make the f.e.t. work you then have to reverse the polarities of the applied voltages.

This gives two polarities of junction f.e.t., which correspond to their bipolar transistor equivalents. The *n*-channel f.e.t.s resemble *npn* transistors in the way the battery has to be connected, while *p*-channel corresponds to *pnp*.

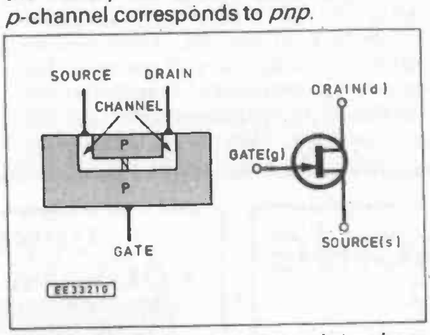


Fig. 1. Cross section through n-channel junction f.e.t.

Input Impedance

The big difference is the input impedance. Since the f.e.t. is operated in such a way that the gate-source junction is reverse biassed no current flows, apart from a very small leakage current. The resistance, looking into the gate, is very high. For most practical purposes it is infinitely high. For alternating currents it's not so high.

A f.e.t. also has an input capacitance. This may be only a few picofarads, but can be significant at high frequencies and in some circumstances even at audio frequencies.

F.E.T. Jargon

The $V_{GS}=0$ curve in Fig. 2 illustrates some important terminology. The point marked V_P, where the curve flattens out, marks a current (I_{DSS}) which is quoted on data sheets. It is the drain current I_D which flows when the gate is shorted to the source, leaving the f.e.t. unbiassed (Fig. 3a). In fact IDSS is often quoted for some higher drain-source voltage than V_P, but this makes little difference.

The value of V_P is called the pinch-off voltage. "Pinch-off" refers to something that happens inside the f.e.t. and needn't bother us.

Unfortunately, the same term, pinch-off is also used for something else. If the gate is made just sufficiently negative to suppress drain current then this value of V_{GS} is often called the gate pinch-off voltage. All very misleading. It is better to borrow an old valve term and call it the "gate cut-off bias".

The region to the right of V_P is called the "saturation region", or the pinch-off region, or the pentode region. It is the region in which the f.e.t. can operate as a fairly linear amplifier.

The region to the left is where the f.e.t. can act as a voltage-controlled resistance. This region is sometimes called the triode region.

One essential for amplification is to set the drain current to a suitable value by applying a negative bias to the gate. There are lots of ways of achieving this but the simplest is to insert resistance (R_S) into the source connection (Fig. 3b).

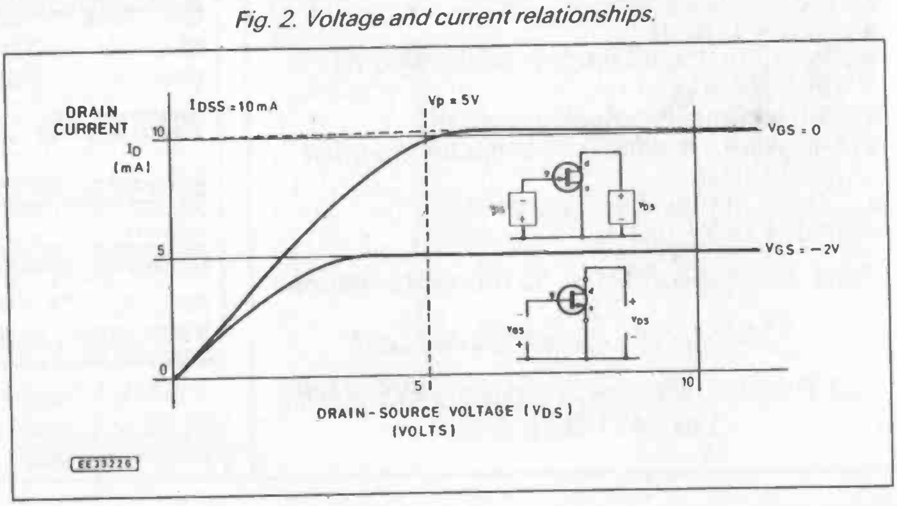
Flow of current sets up a voltage with the polarity shown. The source end is positive, and the common or "earth" end negative. Since the gate is returned to "common" it is made negative with respect to source.

This is still true when resistance is inserted into the gate lead, see Fig. 3c. Since no d.c. flows in R_G the bias voltage is unchanged. Applying an a.c. signal (V_{IN}) to the gate causes the bias to wobble and this produces corresponding wobbles in the drain current I_D. A load resistance R_D in the drain lead drops a d.c. voltage.

As I_D is wobbled by the signal this voltage varies in sympathy. These a.c. variations can be extracted via a d.c. blocking capacitor C2.

If R_D is large enough this a.c. output is greater than the input signal. The f.e.t. is amplifying the signal voltage.

Fig. 2. Voltage and current relationships.



The gain is usually lower than for a bipolar transistor. However, the higher input impedance of the f.e.t. often enables a greater input voltage to be applied.

The bias resistance R_S is normally bypassed to a.c. by capacitor C3. Leaving out C3 reduces gain.

Alternative Connections

This way of using a f.e.t. is known as *common-source* operation. The source, being a.c. connected by capacitor C3 to the zero voltage or "earth" line is used in common with the input signal, one terminal of which is also earthed. Since there are three terminals to a f.e.t., any one of which can be "earthed" to signal voltages it follows that there are two other possible connections, *common-gate* and *common-drain*.

The common-gate amplifier (Fig. 4) has about the same voltage gain as the common-source circuit, but a much lower input impedance. It is used for radio frequency amplification, where it is more stable than the common-source circuit.

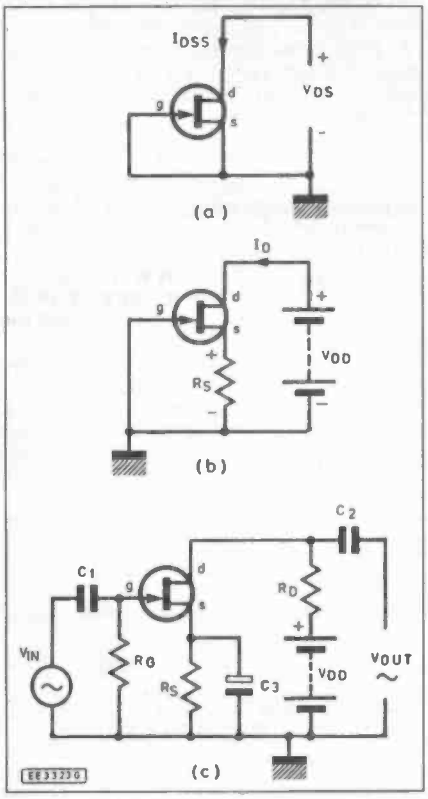


Fig. 3. Biasing arrangements.

The common-drain circuit (Fig. 5) is usually called a "source follower". It has a very high input impedance but the gain is less than one. That is, there is no actual voltage gain. The drain is a.c. connected to "earth" via the battery, which has low impedance.

Despite the loss of voltage gain the source follower is very useful. It can handle signals from a very high-impedance source such as a capacitor microphone.

In this case, to avoid excessive bass cut, the value of R_G must be at least equal to the reactance of the microphone. If the microphone has a capacitance of 100pF then to work down to 16Hz R_G must be 100 megohms.

The f.e.t., source follower amplifier, is usually built into the microphone. The output impedance of such a source follower is low (say 1k) so it can drive signals into a screened cable with an appreciable capacitance.

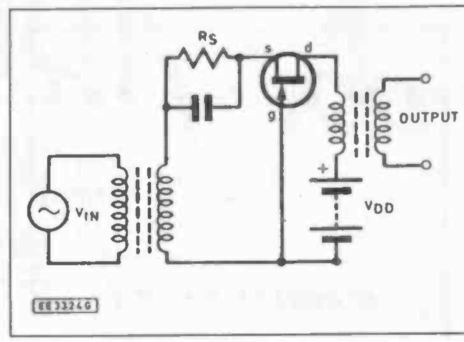


Fig. 4. Common-gate circuit.

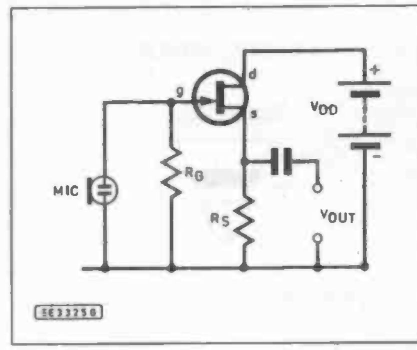


Fig. 5. Common-drain or source follower.

F.E.T. Parameters

As we have seen, applying an a.c. signal to the gate of a common-source amplifier causes variations in drain current. The drain currents of some f.e.t.s respond more to a.c. signals than others.

To describe how effectively I_D current is controlled by V_{GS} voltage, data sheets give a figure called the *forward transconductance*, or *mutual conductance*, often labelled gfs. This transconductance is measured in units called milli-siemens (mS).

A figure of 1mS means that a change in V_{GS} of one volt produces a change in I_D of 1mA. The f.e.t. of Fig. 2 has a transconductance of about 2.5mS, since a change in V_{GS} of 2V causes a change in I_D of 5mA.

For small amplifier type f.e.t.s, gfs commonly has values in the range 0.5-20mS. However, gfs is large when I_D is large, so for a power f.e.t. whose drain current runs to several amperes gfs can be hundreds of times larger.

For any f.e.t., gfs increases with I_D. It can be calculated from I_{DSS} and the cut-off value of V_{GS}. The voltage gain of a common source stage is gfs × R_D where gfs is in mS and R_D in kilohms.

The value of gfs quoted on data sheets is usually for the unbiassed condition (V_{GS} = 0). This is not usually a practical working point. However, the value of gfs at other bias voltages can be calculated from the zero bias value.

Other Types of F.E.T.

The junction f.e.t. belongs to a class of f.e.t.s called depletion-mode f.e.ts. For practical purposes this means that they need a reverse bias on the gate-source diode in normal amplifier service.

There is another class, called enhancement-mode f.e.t.s, which do not pass drain current until the gate is given a forward bias. The f.e.t.s used in CMOS integrated circuits are enhancement f.e.t.s. So are many high power f.e.t.s. That, however, is another story.

ROBOT ROUNDUP

Nigel Clark

It has been another year of change in the educational and small robot market with some new arms on the market and others disappearing. The following is a round-up of what is now on offer, as usual every effort is made to ensure that the information is accurate. The prices quoted (ex-VAT) are approximate and should only be taken as a guide. Most companies offer discounts to educational users so it is best to check with the suppliers for exact prices.

ARMS

A150 *(Orme Systems Automation)* 5 axes plus gripper, options of electric, pneumatic, magnetic and vacuum, lift 2kg, reach 660mm. Servo-driven with optical encoders. On-board processor, with instructions entered by teach pendant or lead by hand using the LIMP mode. £11,000.

A250 *(Orme Systems Automation)* Same as A150 but faster and more accurate. £13,000.

A460 *(Orme Systems Automation)* Same as A150 but 6-axis plus gripper. Lift 3kg and reach 840mm. £20,000.

Alpha II *(UMI)* 5-axis plus a variety of grippers, stepper motor drive with steel cable transmission. Lift 1.36kg, reach 467mm. Control by on-board processor using teach pendant or computer through RS232 port. Basic MHS £8,800, upgraded RDS. Work cell available and can be networked with other UMI machines. £10,250.

Atlas II *(LJ Technical Systems)* 5-axes plus gripper, stepper-driven with toothed belts. Lift 1kg. On-board micro and teach pendant for stand-alone system. Wide range of operating software. Controllable from BBC and IMB-compatible machines. Work cell available. Arm costs £3,250, IBM interface £325.

Beasty Plus *(Commotion)* 3-axes plus gripper, servo-driven lift 75gms. Supplied in kit with instructions for building four different configurations and comprehensive user guide. Kit costs £120. Interface £35 extra.

Bidriod *(Hasfield Systems)* 5-axes plus gripper, bi-polar stepper motor drive with reinforced steel belt transmission. Lift 1kg, reach 480mm. Control by BBCs, Commodores, IMB and Nimbus. £1,500.

EMU *(LJ Technical Systems)* 4-axes plus gripper, servo-driven with direct mechanical linkages, lift 100gms, software for BBC, IBM and LJ's Emma. £375. Work cell extra.

Gamma *(Hasfield Systems)* 5-axes plus gripper, stepper motor drive with toothed belt transmission. Lift 1kg, reach 560mm. Pneumatic gripper optional. £6,000 to £8,000 depending on specification.

Gryphon *(Cybernetic Applications)* 5-axes plus gripper two fingered or vacuum options, lift 1kg, reach 640mm, stepper motor driven with potentiometer feedback. On-board controller with instructions entered by teach pendant, lead by the nose, simulator or off-line on an IBM. Can be networked with up to 7 Cybernetic robots and work cell. £4,500.

Labman 450 *(UMI)* 3-axes plus gripper, electrical, pneumatic, magnetic and vacuum options. Lift 1kg, reach 450mm. Designed for laboratories it can be linked to other Labman equipment such as decappers and vibrofeeders. On-board processor with instructions by teach pendant also has software for IBM allowing routines to be written off-line. Work cell available and can be networked with other UMI machines. £11,000.

MA 2000 *(TQ International)* 6-axes plus gripper, servo-driven with toothed belt transmission, pneumatic gripper. Lift 1kg. Software for BBC, IBM and Open University's Hektor. Was developed for Open University courses. Gripper is fitted to take pneumatic tools and wired for sensors. Can be linked with MA 3000. Sells at £5,500 for export including basic software, discounts available for UK.

MA 3000 *(TQ International)* 5-axes arm plus gripper. Larger but simpler version of MA 2000. Can be linked with MA 2000 as part of system. £11.400.

Mentor *(Cybernetic Applications)* 5-axes plus gripper. Servo-driven can lift 1kg. Reach 420mm. Can be controlled by model simulator. Software for BBC, IBM and Apple, can be networked with up to seven other Cybernetic machines and work cells. £1,200.

Naiad *(Cybernetic Applications)* 5-axes plus gripper, lift 50gms, reach 500mm, powered by water hydraulics. All axes driven by different kinds of hydraulic piston all cylinders being made of see-through plastic. Gripper can be powered by hydraulic or pneumatic piston for which compressed air supply provided at extra cost. As with mentor it can be controlled by simulator and networked with up to seven other Cybernetic machines and work cells. Software for BBC, IBM and Apple. £2,000.

Neptune I *(Cybernetic Applications)* 5-axes plus gripper. Electro-hydraulically powered (water). Lifts 2.5kgs, reach 1,120mm. Software for BBC, IBM and Apple and has on-board processor. As with Mentor control by simulator and networking with seven other Cybernetic machines and work cell available. £4,500.

Neptune II *(Cybernetic Applications)* 6-axes plus gripper. Rest of specifications same as for Neptune I with the extra facility that it can be controlled by the touch sensors which are on all axes plus accelerating and decelerating. £6,200.

Rob3 *(JMA)* 5-axes plus gripper, electrical, pneumatic and vacuum options, lift 250gms. Servo-driven with optical encoders. On-board processor with instructions entered by teach pendant and software for IBM. Can be networked with Rob3i. £3,000.

Rob3i *(JMA)* Bigger version of Rob3. Lift 500gms. £6,000.

Scorbot ER III *(Boxford)* 5-axes plus gripper, lift 1kg, reach 610mm. Powered by servo motors with optical encoders. Software for IBM and on-board processor. £3,750.

Scorbot ER V *(Boxford)* Same as ERIII but faster with more complex software. £6,000.

Scorbot ER VII *(Boxford)* 5-axes plus gripper. DC servos, lift 2kg, reach 850mm, on-board processor. £9,000.

Teachmover *(UMI)* 5-axes plus gripper, stepper motor drive with steel cable transmission. Lift 454gms, reach 444mm. On-board processor with teach pendant. £1,990.

SCARA ARMS

Labman 350 *(UMI)* 3-axes plus gripper with electrical, pneumatic, magnetic or vacuum options. Lift 200kg with a working area of 350 × 600mm. Can work with Labman peripherals. Work cell available and can be networked with other UMI machines. £3,000.

Labman 900 *(UMI)* Same as 350 except lift 2kg and work area 900mm × 400mm £7,000.

Labman 1200 *(UMI)* Same as 350 except lift 2kg and working area 1200 × 600mm. £16,000.

RTX *(UMI)* 6-axes plus gripper, servo-driven, lift 4kgs. Software for IBM. Work cell available and can be networked with other UMI machines. £5,800.

RT 100 *(UMI)* More robust version of RTX intended for light industry. Work cell available and can be networked with other UMI machines. £6,500.

RT 100+ Faster and more accurate version of RT 100. £7,000.

Serpent I *(Cybernetic Applications)* 4-axis plus gripper, servo-driven with pneumatic power for vertical movement of gripper, height of arm set manually, software for BBC, IBM and Apple. Lift 1.5kg, reach 550mm. Can be networked with up to seven other Cybernetic machines and work cell. £3,300.

Serpent II *(Cybernetic Applications)* Same as Serpent I except that it has longer reach at 800mm. £3,350.

OTHERS

ICT1 Industrial Control Trainer *(Flight Electronics)* Shows simple industrial processes with sensors, conveyor and assembly system. £2,000.

Kestrel *(Cybernetic Applications)* Gantry supported arm with 3-axes plus gripper, stepper driven, works in X, Y and Z co-ordinates, lift 2kgs with frame of 833 × 626mm, vacuum or two-fingered gripper. Software for IBM can be networked with up to seven other Cybernetic machines and work cell.

MPSR1 Sorter Unit *(Flight Electronics)* Helps teach industrial control. Using gravity, coloured beads are channelled past two sensors for sorting. Can be interfaced with IBM. £450.

Petra *(LJ Technical Systems)* Standing for pneumatic/electronic training system. Collection of conveyors, pick and place arm with pneumatic gripper, component dispenser and sensor. Intended as an introduction to hybrid electronic/pneumatic devices. £2,250.

MOBILES

Jessop Turtle *(Jessop-Ralph)* Also known as Edinburgh Turtle, it looks like an upturned mixing bowl. One of the earliest turtles controlled by a version of LOGO.

Powered by servos with optical encoders, includes pen. Linked to host computer by umbilical cord. Can be used with associated Turtle Trails. Software for BBC, Apple, Nimbus and IBM. £215 plus £23 for Trails.

Lego Buggy *(Lego and Resource)* Two-wheeled servo-driven, built from Lego kit with Resource control board attached. Maze following, detecting obstacles, speed control and bar code reading can be done. Software in Buggy Basic, Control and Control IT. Kit and board £78.50, board alone £51.

PIP *(Swallow Systems)* Battery-powered stand-alone mobile uses LOGO-like language. Two-wheeled driven by stepper motors. Can store 39 program steps which can be extended by repeat function, plays simple music. BBC and Nimbus leads for downloading programs. Can be "dressed up", pencil holder included. £195 or on rental at £8 per week.

Roamer *(Valiant Technology)* Two-wheeled servo-driven stand-alone mobile uses LOGO-like language with instructions entered by keypad on top of the Smartie-shaped machines. Pen holders. Can be customised with kits and control box which are supplied extra. £150.

Trekker *(Clwyd Technics)* Two-wheeled servo-driven with pen. Designed by children of North Wales secondary school. Software for BBC and Commodores. £150.

Valiant Turtle *(Valiant Technology)* Two-wheeled servo-driven with pen remote-controlled via infra-red link designed to resemble a turtle. Uses version of LOGO and software for BBC, Apple and IBM. Microworlds available at extra cost. £260.

CONTROLLERS

SEQ *(ProCom)* Battery-powered with power supply alternative. LOGO-like instructions entered by a keypad, up to 40 instructions can be stored. All outputs and inputs have indicators. £90 power supply extra.

Ezi-Dun *(Commotion)* One input and four outputs which can control up to three motors with simple on-off and reverse switches. L.E.D.S on all channels. No memory. £35.

Valiant Controller *(Valiant Technology)* Eight inputs and eight outputs, uses LOGO-like language, sound and capacity for 650 instructions. £150.

CONTROL PERIPHERALS

There are a growing number of packages enabling models to be controlled electronically or to react to their environments, most are collections of sensors as with the *Philip Harris Education* sensor range or Commotion's sensor package. Others are tied in with an interface as with Commotion's **Control Box**.

As collections can vary depending on the items included it is best to contact the distributor or manufacturer for full details.

Philip Harris produces a selection of **Blue Box** sensors backed up by its **EMU Easy Memory Unit** for storing information. For younger children there is the **First Senses** range, the **Universal Interface** can be used with Nimbus, BBCs and IBMs.

Commotion's collection includes a link for the BBC machines. It can also be interfaced with its Control Box which is BBC and Nimbus compatible. The Control Box package includes motors and lights as well as the sensors.

A similar package is being produced by *NES Arnold*. Called the **Microtec Pack**, it is based around the Microtech BBC interface. It is intended for younger pupils and its software has different levels of complexity.

System Omega, distributed by *Economatics*, contains a power supply, three boards, sensors and outputs such as sounds and a counter. It is intended as a simple introduction to electronics.

KITS

There are many types of modelling materials from which robotic devices can be build, for example **Meccano** and **Plawcotech** and even old cardboard boxes, but most need the addition of electronic parts to allow them to be controlled. The manufacturers mentioned here all supply kits with their own controllers designed for robotic projects.

The most well known are *Lego* with its **Lego Technic** series and **Fischertechnik**. Lego provides a variety of kits covering a range of complexity. Control can be provided by a simple hand-held controller with no memory as well as computer control from a BBC.

Lego have also developed kits for all levels of schooling complete with teacher packs and worksheets. The models include arms, an X-Y plotter and a buggy.

Fischertechnik was one of the first to develop kits for computer-controlled models, including collections developed on behalf of *Economatics*, its main UK distributors, it offers a large range with some special kits to be used for teaching the Craft and Design Technology section of the National Curriculum.

There is also Nimbus and BBC software for the designing of control systems on screen. The kits include d.c. motors, potentiometers and switches to make a number of devices such as arms, a buggy and an ingenious simulation of a spot welder.

Testbed Technology provides a similar array of components and a BBC interface in its **Polymek** range. Course materials have been developed with pupil texts and teacher guides. The models can be controlled using Testbed's own Micro Control Language, available on ROM chip for the BBC.

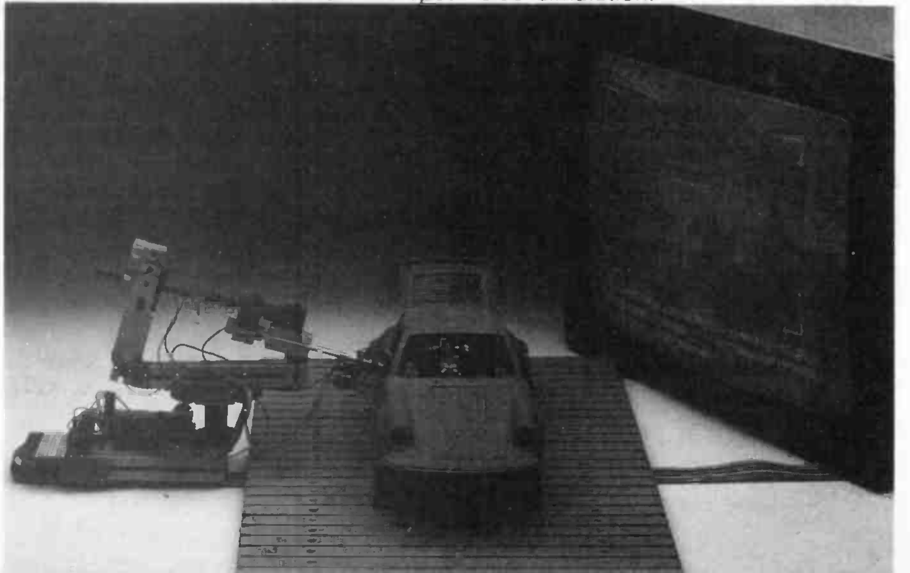
Stevenage Adventure Workpacks offer collections of motors, gears and switches with plans for building devices and a circuit diagram for a simple BBC interface. The kits are intended as introductions to control technology.

Ezi-Dun, distributed by *Commotion*, has a basic kit of electronic and mechanical components and a special board which allows components to be connected without soldering. The kit works with the Ezi-Dun controller.

ADDRESSES

Boxford, Wheatley, Halifax, West Yorkshire HX3 5AF.
Clwyd Technics, Antelope Industrial Estate, Rhydynwyn near Mold, Clwyd.
Commotion, Redburn House, Stockingswater Lane, Enfield EN3 7TD.
Cybernetic Applications, West Portway Industrial Estate, Andover, Hampshire S10 3LF.
Economatics, Epic House, Darnall Road, Attercliffe, Sheffield S9 5AA.
Flight Electronics, Flight House, Ascupart Street, Southampton SO1 1LU.
Hasfield Systems, The Old Rectory Stables, Hasfield, Gloucester GL19 4LG.
Jessop-Ralph, PO Box 925, London SE20 7EH.
JMA, Unit 15/16, Highfield Industrial Estate, Bradley Road, off Warren Road, Folkstone LT19 6DD.
LJ Technical Systems, Francis Way, Bowthorpe Industrial Estate, Norwich.
NES Arnold, Ludlow Hill Road, West Bridgford, Nottingham NG2 6ND.
Orme Systems Automation, PO Box 3, Stakehill Industrial Park, Middleton, Manchester M24 2RH.
Philip Harris Education, Lynn Lane, Shenstone, Lichfield WS14 0EE.
ProCom, 2 Churchill Road, Tavistock, Devon PL19 9BU.
Resource, Exeter Road, off Coventry Grove, Doncaster DN2 4PY.
Stevenage Adventure Workshops, 29 Lytton Fields, Knebworth, Herts SG3 6BA.
Swallow Systems, 32 High Street, High Wycombe HP11 2AQ.
Testbed Technology, The Science Park, Hutton Street, Blackburn BB1 3BY.
TQ International, Bonsall Street, Long Eaton, Nottingham NG10 2AN.
UMI, UMI House, 9-16 St James Road, Surbiton, Surrey KT6 4QN.
Valiant Technology, Gulf House, 370 Old York Road, Wandsworth, London SW18 1SP.

Fischertechnik spot welder simulation.



REPORTING AMATEUR RADIO

Tony Smith G4FAI

RSGB VIDEO

I recently viewed the RSGB's new recruitment video *Amateur Radio for Beginners*, sponsored and produced by Yorkshire Television in support of the Society's Project YEAR (Youth into Electronics via Amateur Radio). Presented by Jim Bacon, G3YLA, a well-known weather forecaster on Anglia TV, this two part production is intended for public viewing arranged by local radio clubs affiliated to the RSGB.

Part 1, "Amateur Radio – The Hobby of the Space Age", starts off with shots of the RSGB's station, GB3RS, in contact by voice and TV with Dr Tony England, W0ORE, on board the shuttle *Challenger*, back in 1985 when manned amateur radio first went into space.

Viewers are then taken to Surrey University's Spacecraft Engineering Research Unit, a project largely staffed by radio amateurs under Prof. M. N. Sweeting, G3YJO, which designs, builds, launches and operates small microsats.

The *UOSAT* control room follows and controls the progress of the satellites, and the unit provides unique learning opportunities for students from around the world, linking its projects with the professional and amateur communities, and with the thousand or so schools which actively track amateur satellites from their club stations.

We visit the White Rose Amateur Radio Society in Leeds and observe their varied activities, including visits by club speakers to local schools to explain what amateur radio is all about, putting pupils "on-the-air" to give them a taste of radio operating.

Practical demonstrations illustrate various amateur radio modes, speech, Morse, data, TV, facsimile, and so on, via conventional radio paths and via amateur satellites.

BASIC INFORMATION

All the basic background to the hobby is brought to life. QSL cards and their uses; awards for operating skills and achievements; home construction and how to approach it; amateur radio rallies and flea markets and what can be found at them. Operating from home and in the car. The value of the hobby to the disabled and housebound; amateur radio and scouting; RAYNET, the Radio Amateur Emergency Network, providing communications in emergencies as well as assisting at large scale sporting events or other public occasions, when widespread communications and control is required.

And so it goes on. "Fox hunting" (radio direction finding) in China; contacts with foreign stations; "field days", memorable events with radio stations under canvas providing part of the competitive element of the hobby plus fun and a social side. Contacts with friends locally. Worldwide contacts. Worldwide friendships.

The video stresses that while some of the radio equipment seen in this presentation is obviously expensive, beginners need not be deterred. Low cost simple sets and modest wire antennas will get the newcomer on-the-air, with contacts across the UK and with many other countries.

The message from this first part is that while amateur radio can be a hobby for life for those of any age, it also offers a useful addition to school curriculum science, while its practical engineering aspects can be very helpful in the early stages of a career in electronics, providing a useful background when studying for professional qualifications.

NO PREVIOUS KNOWLEDGE

Part 2 – "How to become a Radio Amateur", points out that most newcomers have no previous electronic knowledge at all. Many books and courses are available, while one of the best ways to find out about amateur radio is to listen to existing amateurs on-the-air.

Short wave listening is an important part of the hobby, and many beginners make a simple receiver to start with, using just a handful of components. They go on to make simple low power transmitters and receivers suitable for amateur operation, using inexpensive wire antennas.

This sort of activity is the basis of the new amateur Novice licence which allows limited low power operation on the amateur bands. A full licence can be obtained later, enabling the holder to take part in any of the numerous activities available within the hobby.

The course for the Novice licence is described, with its emphasis on the practical approach. The reason for a licence is explained and demonstrated. Users of radio transmitters capable of causing interference to others, especially to the emergency services, must be licensed to ensure that potential causes of interference are controlled.

BEGINNERS' PACK

The video urges newcomers to amateur radio to contact their local radio club who will be pleased to offer guidance and help. They are also advised to write to the Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar EN6 3JE, for the Beginners Pack. This contains information on magazines, books, manuals, etc, details of the Novice licence, and how to contact local clubs.

Presenter Jim Bacon's last words put it all in perspective. "Keep it simple. Keep it cheap. And above all, make it fun." I strongly urge any readers with the slightest interest in radio communications to try to see one of the showings of this video arranged by local clubs. And let me know what you think of it!

FIRST NOVICE LICENCES

Of the 185 candidates who took the first Novice Radio amateur's examination in June 153 (82.7 per cent) were successful. A number of these also passed the 5 w.p.m. Morse test, qualifying for the new Novice "A" licence (with both v.h.f. and h.f. facilities), while the remainder qualified for the Novice "B" (v.h.f. only) licence. Seven of the successful candidates, aged between 11 and 16, received their licences from Telecommunications Minister John Redwood at a special presentation on 25 July.

Unfortunately some candidates had difficulty in finding examination centres prepared to offer the Novice examination, presumably because of the lower than usual age limit. It is understood that the City & Guilds Institute is now urgently seeking to increase the number of centres willing to accept entries from young persons.

HAPPY MEMORIES

Hearing the Science Museum's demonstration station on the air recently, celebrating the Morse bicentennial with the special call GB200SM, reminded me of a visit I once made to the museum. Many people have first encountered amateur radio at this station, usual call GB2SM. It has an impressive array of antennas on the museum roof 120ft above street level, and is comprehensively equipped to demonstrate most amateur modes and frequencies.

Some visitors are inspired by what they see and hear and go on to take up the hobby themselves. I was myself when I went there with my young son some 20 years ago. The operator was talking to a station in Singapore while we looked on. I called out, "I was in Singapore in the RAF", and the next moment I was swapping memories of that city with the Singaporean via the Science museum operator.

I came away determined that as soon as possible I would be able to talk to Singapore, or anywhere else come to that, through my own licensed radio station. My son and I enrolled in a local class, took the exams, and we went on the air for the first time, with consecutive class B callsigns, on 2 October 1973.

With v.h.f. only licences at that time we couldn't reach Singapore of course but we certainly worked GB2SM a few times and told our story over the air for the benefit of visitors. We still go to the museum occasionally and always try to visit the station. It normally operates on Tuesdays, Wednesdays, Thursdays and Sundays, but owing to staff shortages it is not always possible to maintain this schedule.

Constructional Project

MODULAR DISCO LIGHTING SYSTEM

Part Six: VU MODULE

CHRIS BOWES

Light up your party or disco road show with these easy-build effects modules.

THIS month's module is the first of the effects modules which is designed to be operated by the sound output from the Disco. As a result it is the first module which can be used to provide pulses in time with the music and which can be used to provide the external pulses which are fed to the "EXT" pulse inputs to which mode all of the modules, other than the Simple Chasers, can be switched.

A number of disco systems are available commercially with "Sound-to-Light" features. These are usually based on the principle of separating the sound picture into a number of bands (often Treble, Mid and Bass) and providing an on/off output for each channel if the volume of sound available in that band exceeds a preset level threshold.

The VU Module described in this article works on a different principle by sampling the overall sound picture and controlling the outputs according to the total amount of sound produced by the disco system. This enables the lighting system to be operated in a more versatile manner, which makes better use of the sophisticated control functions available within the module and through connection to the Masterlink Module.

CIRCUIT DESCRIPTION

The full circuit diagram for the VU Module appears in Fig. 1. The power supply arrangements for this module are the same as for the rest of the effects modules in this series, with diodes D1 and D2 being included in order to allow connection of this module to any two output modules. Diode D3 is used to feed power to the Masterlink Module (if connected), l.e.d. D4 is the "Power On" indicator, a tantalum capacitor C1 is used to decouple the Logic gates in the module.

SOUND SENSING

The heart of the sound detection part of the circuit is IC1, which is a LM3915 l.e.d. Bar Driver i.c. The normal function of this type of i.c. is to provide a digital output to ten l.e.d.s, (used as the indicators in "digital" sound meters) which are sequentially switched off and on as the "volume" increases.

This integrated circuit exists in three forms, all of which provide similar functions but operating to different laws. These are: LM3914, which operates in linear steps; the LM3915, which operates in a logarithmic law with the l.e.d.s being switched at 3dB intervals and the LM3916, which operates in the VU mode with steps similar to that used in VU meters.

Any of these ICs can be used for this application, depending on which law of operation you prefer. The LM3915 version has been specified for this module, simply because of it's logarithmic law, which tends to give a more spectacular display. There is, however, no reason why constructors should not experiment with different versions depending on availability and preference.

A simplified explanation of how this i.c. operates is that the incoming signal is presented to pin 5 of the i.c. It is then buffered and presented internally to the inputs of ten internal comparators, each of which are biased to a different level by

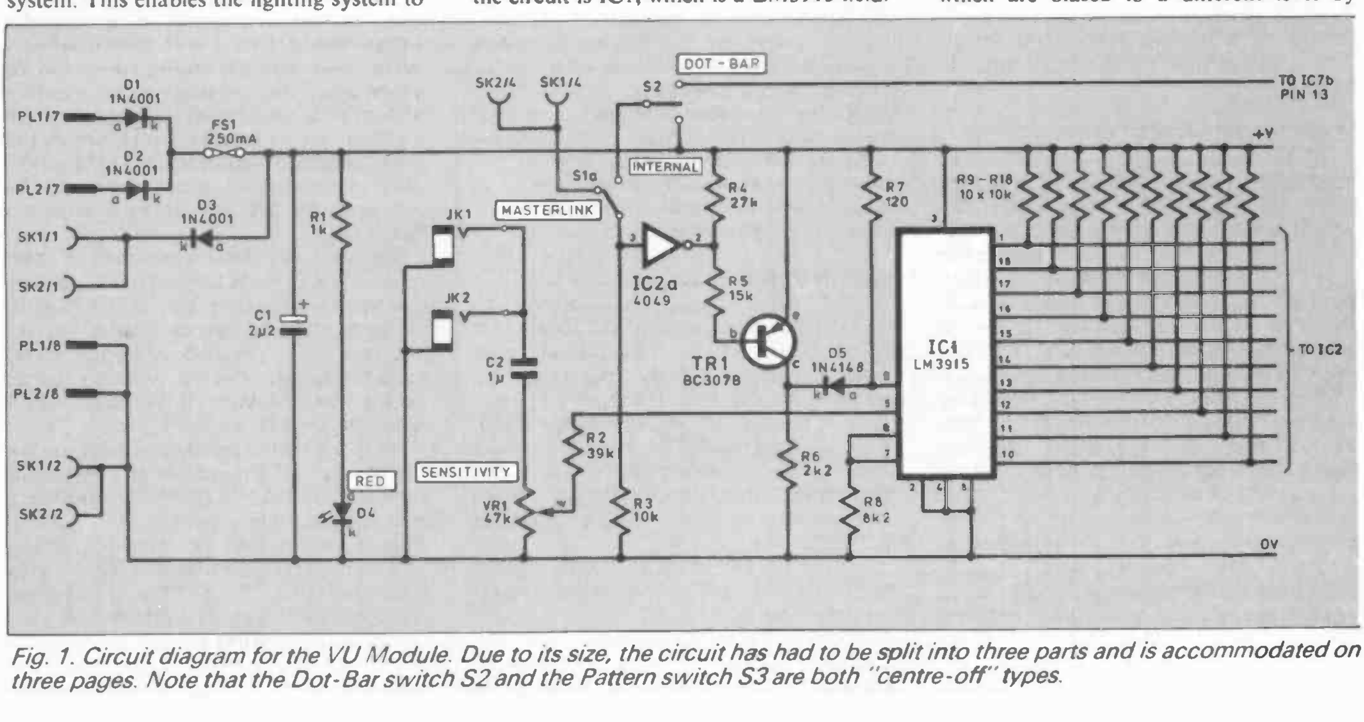


Fig. 1. Circuit diagram for the VU Module. Due to its size, the circuit has had to be split into three parts and is accommodated on three pages. Note that the Dot-Bar switch S2 and the Pattern switch S3 are both "centre-off" types.

means of an internally generated reference voltage and a chain of ten resistors. As the signal level increases each of the comparators is made to switch in turn and each acts as a current sink which would, in the normal manner of operation, draw current through the l.e.d. associated with that comparator's output.

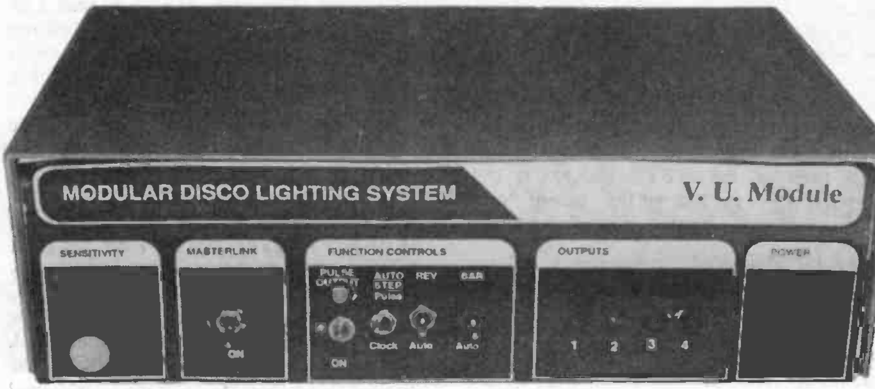
Although the thresholds of the internal comparators can, in theory, be altered by adjusting the values of resistors R7 and R8 in the circuit shown in Fig. 1, this has attendant complications so a simpler method of adjusting the sensitivity of the module has been chosen. This takes the form of attenuating the incoming sound level. This has been achieved by feeding the signal from the two parallel jack sockets (JK1 and JK2) to potentiometer VR1, which is configured in the traditional volume control arrangement.

The output from the wiper (w) of the potentiometer is connected to the signal input of IC1 (pin 5) via resistor R2, which is included so as to allow the use of any loudspeaker output (including 100 volt line sources) as the sound source for this module. Capacitor C2 is included in the circuit so as to block any d.c. bias, which might exist on the loudspeaker output feed, from interfering with the operation of the module.

Two jack sockets are provided, wired in parallel, so as to provide an input and output feed connection within the module. This will allow the loudspeaker feed to be connected from the amplifier to the module and another cable used to continue the circuit to the loudspeaker.

DOT/BAR MODE

The LM3914/5/6/ i.c.s have facilities for altering the output display mode, by means of the presence or absence of plus volts (+V) at pin 9. When pin 9 is connected to +V then the output operates in "Bar" mode. In this format each output becomes active as the signal exceeds the turn – on point of the associated comparator and remains active until the signal falls below the threshold.



When pin 9 is left "open circuit" the display operates in "Dot" mode, whereby each output is active only when the signal is within the range covered by the comparator associated with that particular output. In this mode only one output is active at any one time whereas in the "Bar" mode more outputs become active as the signal increases.

This latter function is adapted to suit the control environment of the Modular Disco Lighting System by means of the circuit consisting of IC2a, resistors R4, R5, R7, transistor TR1 and diode D5. IC2a is one sixth of a 4049 hex inverting buffer i.c., which is used in this circuit both to invert the signal from the control system of the Modular Disco Lighting System, and to provide buffering.

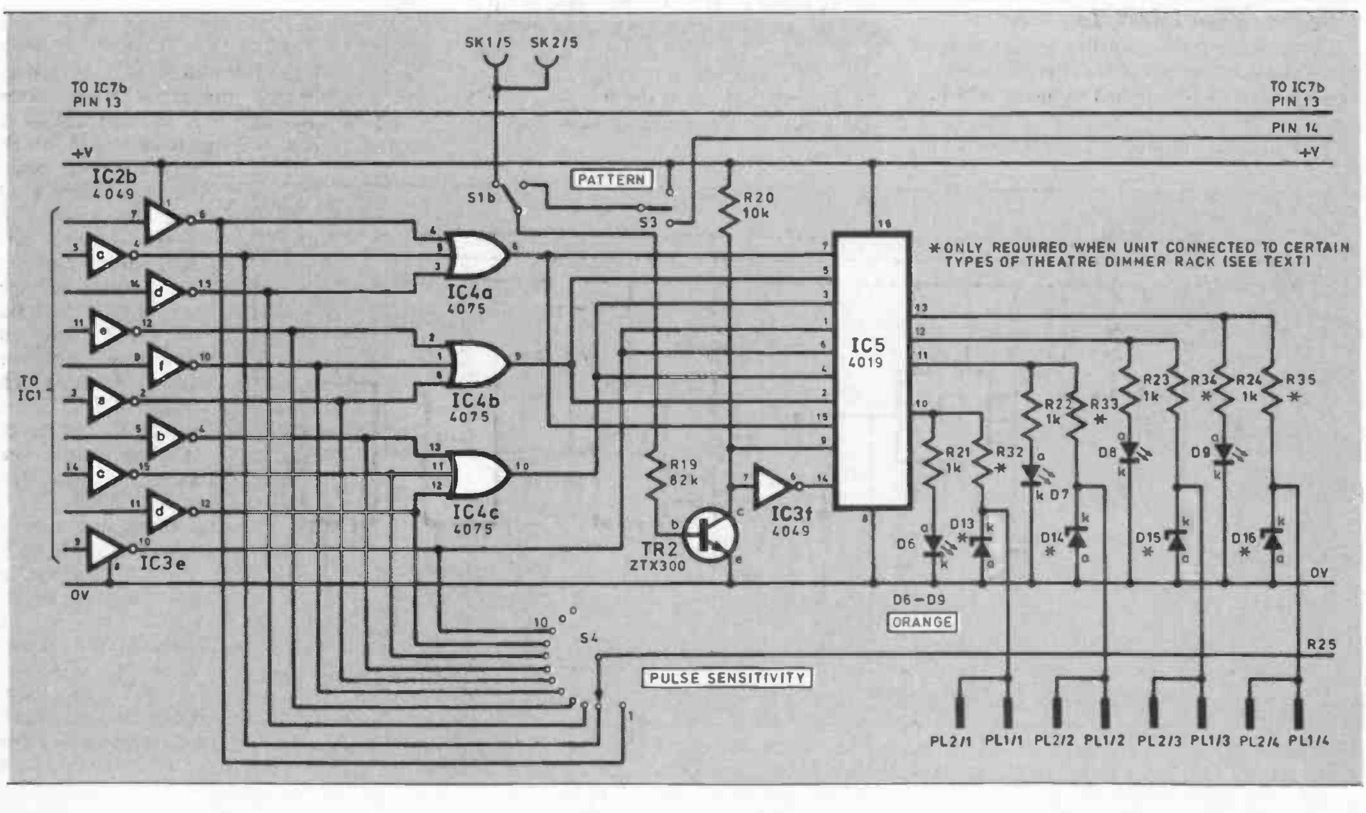
The inversion process is necessary because of the inversion provided by the action of TR1. By inverting the input via IC2a the inverting action of TR1 is negated, in so far as the control signals within the system are concerned and the action thus becomes compatible with the rest of the outputs to the system from the Masterlink Module. The use of TR1 is necessary in order to provide the remote (Logic Controlled) switching action to select the display mode of IC1 in accordance with the control regime used by the Modular Disco Lighting System.

Routing switches S1a and S2 are used to control the input signals to the inverting buffer IC2a from the control signals available within the system. Switch S1 is the Masterlink in/out selector, which is used to transfer control of the display change signals from the internal switching of the VU Module to the Masterlink module's outputs.

When switch S1 is in the "master" position the Masterlink Module takes over all control functions. When it is in the Internal position the Dot/Bar display control functions are determined by the position of S2 and/or the output from the internal Auto selector function, to be described later.

Pins 1 and 10 to 18 of IC1 are the outputs of the i.c. which are normally connected to the anodes of the output indicating l.e.d.s (LED_0 to LED_{10}), with the comparator circuits within IC1 acting as current sinks when active, thus drawing a current thorough their associated l.e.d. and causing it to light. In this application the outputs of the i.c. are not connected directly to the l.e.d.s and it is therefore necessary to provide some form of load into which the comparators can work. This function is provided by the load resistors R9 to R18, each of which are 10kilohm "pull up" resistors.

These resistors pull up the outputs from IC1, and hence the inputs of the invertors connected to them, to the Logic 1 level, except when the associated output from IC1



is active, in which case the action of the i.c. is to cause a current to flow through the associated resistor and force the output to 0 volts, which is the Logic 0 state. In the normal application of this type of i.c. resitor R8 would be used to control the brightness of the l.e.d.s in the display but, since there are no l.e.d.s connected to the outputs, R8 is used to set the current flowing through the outputs to the correct level.

OUTPUT INDICATOR

The sound level sensing circuit IC1 provides ten individually switched outputs but the system is tailored to have only four output circuits. In order to utilise the ten outputs of IC1 to drive the standard four outputs of the system it is necessary to amalgamate several outputs from IC1 into a common channel. This is done in two stages by the next stage of the circuit.

As the outputs from IC1 are in the "wrong sense" (i.e. normally at Logic 1) it is first necessary to invert each of the signals. This is accomplished by the use of the inverting buffers (IC2b to IC3e). In each case the buffer inverts the Logic state, producing a Logic 1 output if the input is at Logic 0 and vice-versa.

The output signals obtained from the inverters connected to the first nine outputs of IC1 are further processed by combining them, in groups of three, so that each group produces a single signal by the use of the triple, three-input OR gates contained in the 4075 i.c. (IC4a, IC4b and IC4c). Thus O_1 to O_3 of IC1 are combined into one signal by IC4a. This results in the output of IC4a being at Logic 1 if the sound source is of a sufficient magnitude to cause any of the outputs O_1 to O_3 of IC1 to be active.

The same process is applied to the other outputs by combing O_4 to O_6 and O_7 to O_9 into two further control signals. The final output of IC1 (O_{10}) is left uncombined and fed directly to the next stage of the signal processing circuitry.

PATTERN REVERSING

In addition to the Dot/Bar pattern selection provided within IC1 a further pattern control circuit is included by using IC5 to reverse the order of the display outputs. Normally the outputs of O_1 to O_3 of IC1 are connected so as to drive Channel 1 of the module, with the other outputs following in sequence until Output O_{10} is used to drive Channel 4 of the module. IC5 is a 4019 quad two-input multiplexer.

The outputs from IC4a, IC4b and IC4c together with output O_{10} of IC1 are connected, in sequence, to the "B" inputs (B_0 to B_3) and in reverse order to the "A" inputs (A_3 to A_0) of IC5. The selection of whether the outputs are fed from the A or B inputs of the multiplexer is controlled by the Logic States of the S_A (pin 9) and S_B (pin 14) inputs. When S_A is at Logic 1 the outputs are the same as their respective A inputs and when the S_B input is in the Logic 1 state then the outputs correspond to their respective B input states.

Complications could arise in the event of the S_A and S_B inputs either being both at Logic 0 or both at Logic 1. In order to prevent this occuring an inventor (IC3f) is connected between pins 9 and 14 so as to ensure that this cannot occur.

The operation of the input is determined by the presence or absence of a voltage at the base of the transistor TR2. The base of TR2 is connected to the control voltages required by means of switches S1b and S3, which operate in the same manner as described for the Dot/Bar arrangement. R20 is a pull up resistor which is used to control the Logic state of the input to IC3f and the S_A input of IC5.

When no voltage is present across the base/emitter junction of TR2, as happens when S3 is in the mid or "Normal" position, the transistor is not biassed so no current is allowed to flow through the emitter/collector circuit and hence no current flows through R20. This causes the Logic state at the input of IC3f and the S_A input of IC5 to be in the Logic 1 state. The outputs of IC5 thus follow the Logic states of their respective A inputs.

When a voltage is present at the base of TR2 it causes the transistor to be biased and thus conduct, causing a current to be drawn through the emitter/collector junction of TR2 and hence through resistor R20, forcing the input to IC3f and hence the S_A input of IC5, to the Logic 0 state. This causes a Logic 1 state to exist at the S_B input of IC5. The output states of the channels of the module are therefore made to correspond to those of the B inputs to IC5 and hence to the normal, ascending, sequence.

This explanation would indicate that the operation of the outputs is the reverse of what would be expected and occurs because the inputs to IC5 are reversed in order to facilitate the design of the p.c.b. This minor problem is, however, overcome by reversing the order of connection of the outputs so that Channel 1 of the module is driven by output O_3 of IC5 etc.

The output circuits and indicators of the VU Module are the same as that used for previous modules, with the l.e.d.s D6 to D9 indicating which outputs are live. As with previous modules the resistor and Zener diode networks formed by D13 to D16 and R32 to R35 are only required if the module is to be connected directly to certain types of commercial dimmer rack.

PULSE OUTPUT

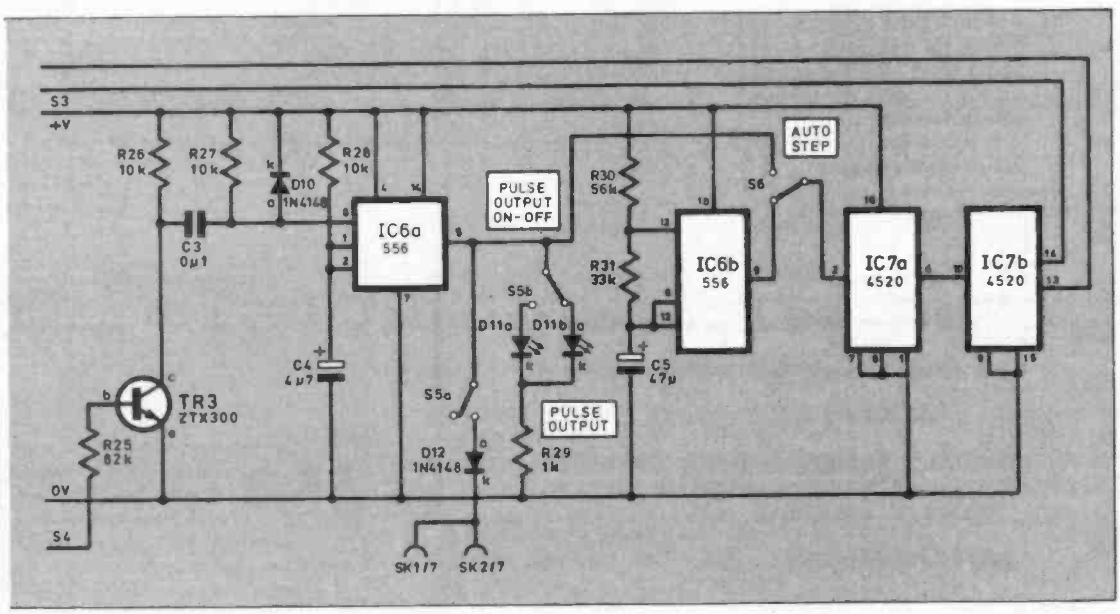
A major feature, designed into all of the modules except for the Simple Chaser and Simple Sweeper Modules, is the ability for sound driven modules, such as that featured in this month's module, to provide an output pulse, in response to the fluctuations in the sound signal from the Disco Deck, which can be used to drive the modules, including the Masterlink Module. In the VU Module the signal used to trigger this "External Pulse" signal is derived from the inverted outputs of IC1.

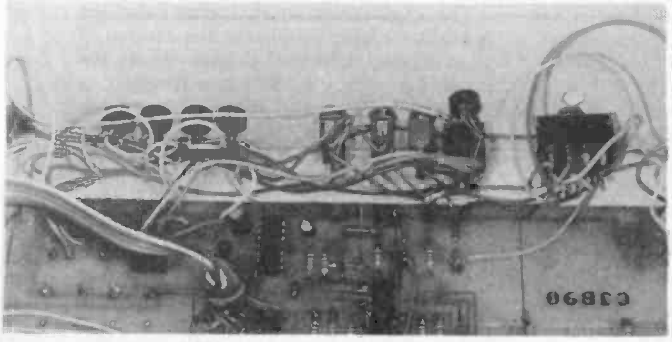
Each of the outputs from the inverter/buffer circuits connected to IC1 is fed to a contact on S4, which is a one-pole, ten-way rotary switch. The wiper or pole of the switch is connected to the base of TR3 via a base current limiting resistor, R25. The function of R25 is the same as for the other base current limiting resistors (R5 and R19) in that the presence of the resistor stops the base/emmiter voltage (V_{BE}) of the transistor from exceeding the maximum permitted value of approximately 0.7 volts.

If the base resistor were not present then the transistor would attempt to bring the input voltage (in this case V+ or 16 volts) down to the required 0.7 volts by dissipating the excess energy as heat. This would cause considerable damage to the transistor and possibly to the source of the voltage.

When the inverted output from the sound level sensing circuit which has been selected by the position of S4 goes active, current then flows through R25 and causes TR3 to conduct. This in turn causes a current to flow through resistor R26, which together with resistor R27, diode D10 and capacitor C3 forms a trigger circuit which converts the positive voltage fed into the base of TR3 into a very short, negative going, pulse which triggers IC6a. This is a CMOS 555 timer (packaged into the same i.c. as it's partner IC6b).

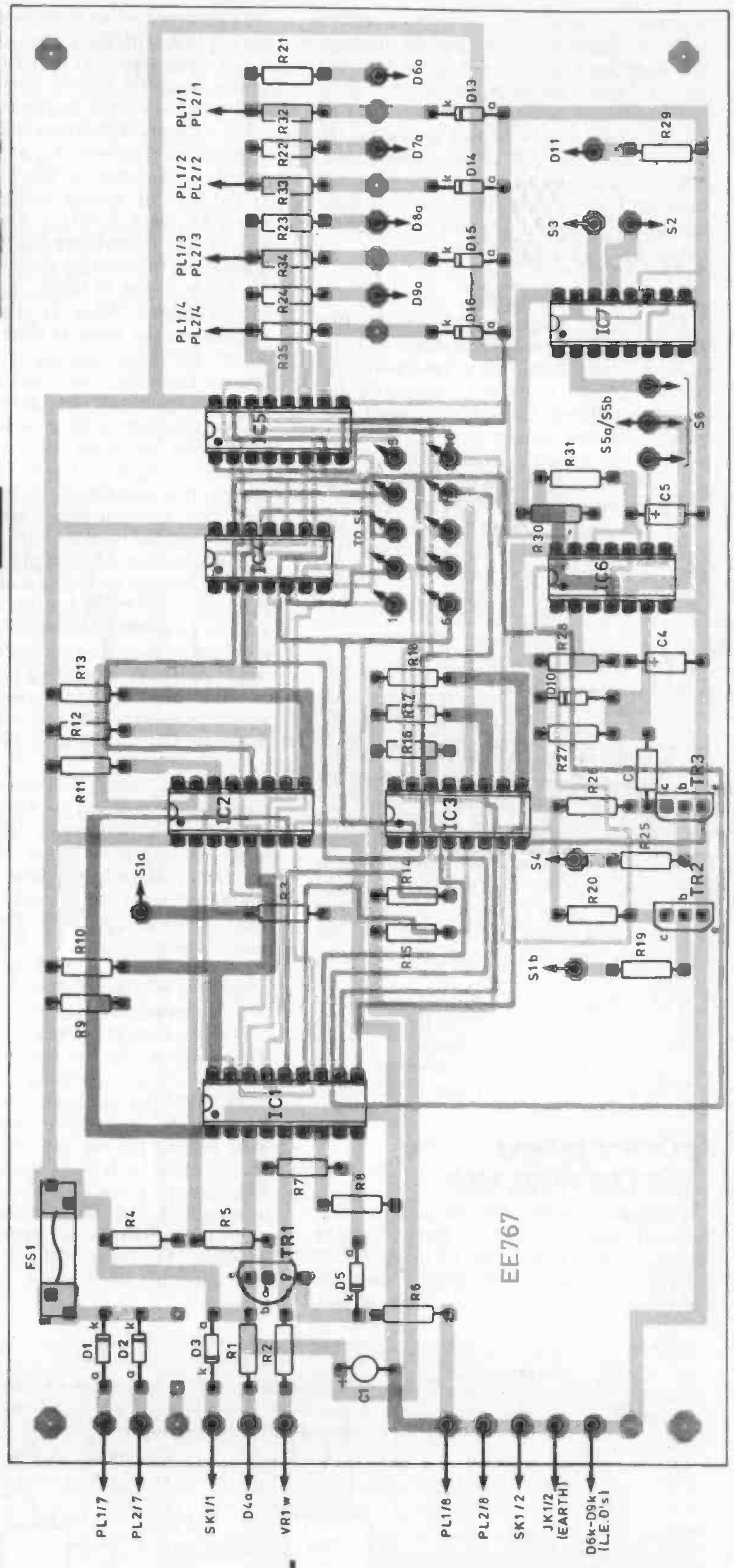
Configured as a Monostable, IC6a is set to produce a positive going pulse, which lasts for a time period determined by the values of R28 and C4, every time it's input is triggered. This pulse is monitored





(above) Wiring to front panel l.e.d.s and switches.

Fig. 2 (right). Printed circuit board (double-sided) component layout. Zener diodes (D13-D16) and limit resistors (R32-R35) are optional components only required for certain theatrical dimmer racks.



COMPONENTS

Resistors

R1, R21-R24, R29	1k (6 off)
R2	39k
R3, R9-R18, R20, R26-R28	10k (15 off)
R4	27k
R5	15k
R6	2k2
R7	120
R8	8k2
R19, R25	82k (2 off)
R30	56k
R31	33k
R32-R35	(See text)

All 0.25W high stability types, unless otherwise stated.

See SHOP TALK Page

Potentiometer

VR1	47k rotary carbon, log.

Capacitors

C1	2μ2 tantalum, 25V
C2	1μ polyester or similar, 250V
C3	0μ1 polyester
C4	4μ7 p.c.b. elect., 25V
C5	47μ p.c.b. elect. 25V

Semiconductors

D1-D3	1N4001 1A 50V rec. diode
D4	Standard red l.e.d.
D5, D10, D12	1N4148 signal diode (3 off)
D6-D9	Standard orange l.e.d. (4 off)
D11	Tricolour l.e.d. (common cathode type)
D13-D16	Zener diode (see text)
TR1	BC307B *pnp* transistor
TR2, TR3	ZTX300 *npn* silicon transistor (2 off)
IC1	LM3915 logarithmic bar l.e.d. driver
IC2, IC3	4049 Hex inverting buffer (2 off)
IC4	4075 triple, three-input OR gate
IC5	4019 quad, two-input multiplexer
IC6	556 CMOS dual timer
IC7	4520 dual binary counter

Switches

S1, S5	Miniature d.p.c.o. toggle (2 off)
S2, S3	Miniature s.p.c.o. centre-off toggle (2 off)
S4	Single-pole 10-way rotary
S6	Miniature s.p.c.o. toggle

Miscellaneous

JK1, JK2	Standard jack socket, with matching plug (2 off)
PL1, PL2	Chassis mounting 10-way circular video plug, with matching cable socket (2 off)
SK1, SK2	Chassis mounting 7-way DIN socket, with matching plugs (2 off)

Aluminium case (Maplin "Blue Case 233"), size 250mm x 150mm x 75mm; 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket (3 off); 18-pin d.i.l. socket; plastic knobs for S4 and VR1 (2 off); l.e.d. clips (5 off); 250mA 20mm anti-surge fuse and p.c.b. fuse clips; self-adhesive pillars (4 off); solder pins; nuts & bolts; connecting wire; solder etc.

Printed circuit board available from the EE PCB Service, code EE767.

Approx cost guidance only **£51** *excl case*

Diode D12 wired directly to pin 7.

by the tricolour l.e.d. D11 and can be switched to be fed to the other modules, via SK1 pin 7 of the Masterlink DIN sockets by switch S5. This switch is included so that more than one sound activated module can be included in the lighting rig and the required output switched in and out of the system so that the external pulse, which is used to operate the other modules when they are switched to the external pulse mode, may be selected.

Diode D12 is a blocking diode which is included to prevent any other output pulse from another module, which might also be selected, from interfering with the operation of the rest of the circuit. D11 is a tricolour l.e.d. which flashes on whenever an output pulse is produced by IC6a, IC6b. This l.e.d. contains two separate l.e.d.s (one red and the other green) within the same package. S5b is included so as to change the colour of the l.e.d. in order to show that not only is a pulse being generated but to indicate whether it is driving into the Masterlink connections or not.

AUTO PATTERN CHANGE CIRCUIT

In addition to the Dot/Bar and reverse functions being selected by the appropriate switches and selected for control by the outputs from the Masterlink module, they can also be controlled automatically from within the module so that they change in a regular sequence. This is achieved by means of a counter circuit which is made up of both halves of a 4520 dual Binary counter, IC7. The two counters are cascaded so that the output O_4 of IC7a is used to feed pulses to the input of the other counter.

The auto pattern outputs are taken from the two highest outputs O_2 and O_3 which give a pattern, which changes after every 128 input pulses and every 256 input pulses respectively. The source of the pulses which drive the auto change circuit are selectable by means of switch S6 so that the pulses for this circuit can be obtained either from the output of the sound pulse circuit or from the other half of IC6, an astable circuit which produces pulses at a frequency governed by the values of R30, R31 and C5.

With the values shown the frequency produced by this circuit is approximately 0.2Hz. This is further divided by IC7 to give a pattern change approximately every 10 seconds and a pattern reversal approximately once every 20 seconds. The given values are not critical and may be altered either for convenience of if a different frequency is required.

CONSTRUCTION

Construction of this project is very similar to that of the other modules in this series. The components (with the exception of the switches, JK1, JK2, VR1 and diode D12) are all mounted on a double-sided printed circuit board (p.c.b.) as shown in Figs. 2, 3 and 4. A ready drilled and tinned p.c.b. can be purchased from the *EE PCB Service*, code EE767.

Although the operation of the circuit is not dependant on the order in which the components are assembled onto the p.c.b. it will probably be more convenient to install the components in ascending order of size. The integrated circuits should be installed in sockets wherever possible, since this will reduce the risk of damage occuring and make it possible for them to be installed as a final stage in the completion of the p.c.b.

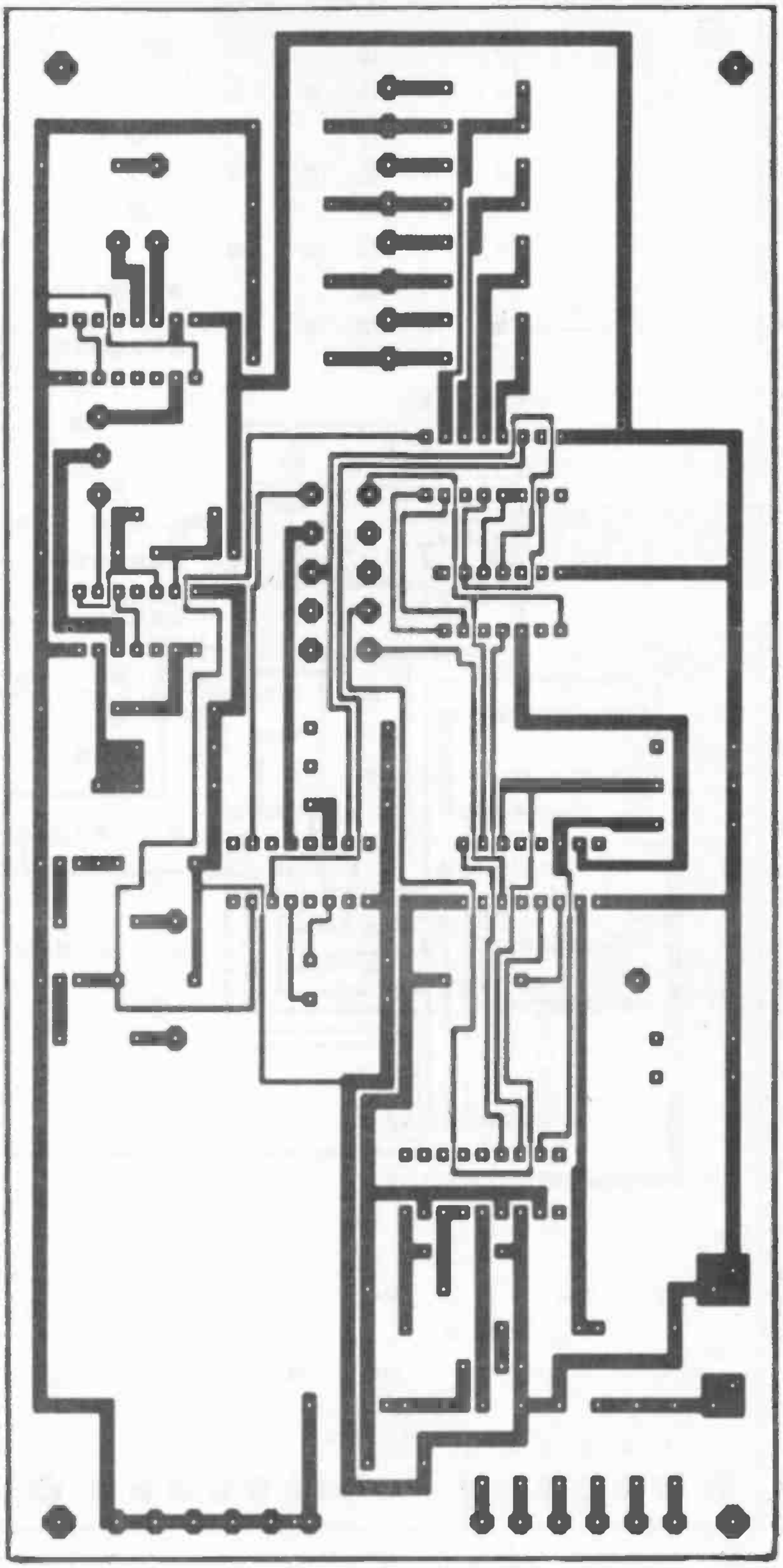


Fig. 3. Full size copper track master pattern for underside of board.

This is easy where the i.c. pins make connections only to the underside of the p.c.b. Where connections are required to both sides of the p.c.b. the i.c.s can either be soldered directly onto both sides of the p.c.b. or a wire-wrap socket can be utilised and soldered both to the top and bottom tracks of the board by lifting the socket sufficiently clear of the p.c.b. to allow access for soldering the socket into place.

When fitting the i.c.s, or the sockets into which the i.c.s will fit, care should be taken to ensure that the "bump" on the i.c. or socket corresponds to the notch in the i.c., as shown in Fig. 2. This will aid installation of the i.c. with the correct polarity at the later stage of construction.

Care must also be taken to ensure that all the polarised components, such as the transistors, diodes and polarised capacitors are inserted into the board with the correct orientation. Considerable damage will occur should this precaution not be observed.

Scrutiny of Fig. 2 will show that there are a small number of occasions when spaces are left on the board layout with empty holes not connected to components. This is intentional, since space and connections have been left for possible future developments of this module to accommodate the possibility of an additional display, utilising part of the circuitry of this module.

Installation of the board in the case will be greatly eased if the connecting points where wires are attached to the p.c.b. are fitted with terminal pins during the course of installing the other components. Once the board has been completed any i.c.s which require fitting into their sockets should be installed and a careful visual check should be carried out to ensure that there are not broken or shorted tracks, that all of the components are installed in the correct places and that, where polarised components are used that they are installed the correct way round.

CASE

The case design for the system described in this series is important, in so far that all

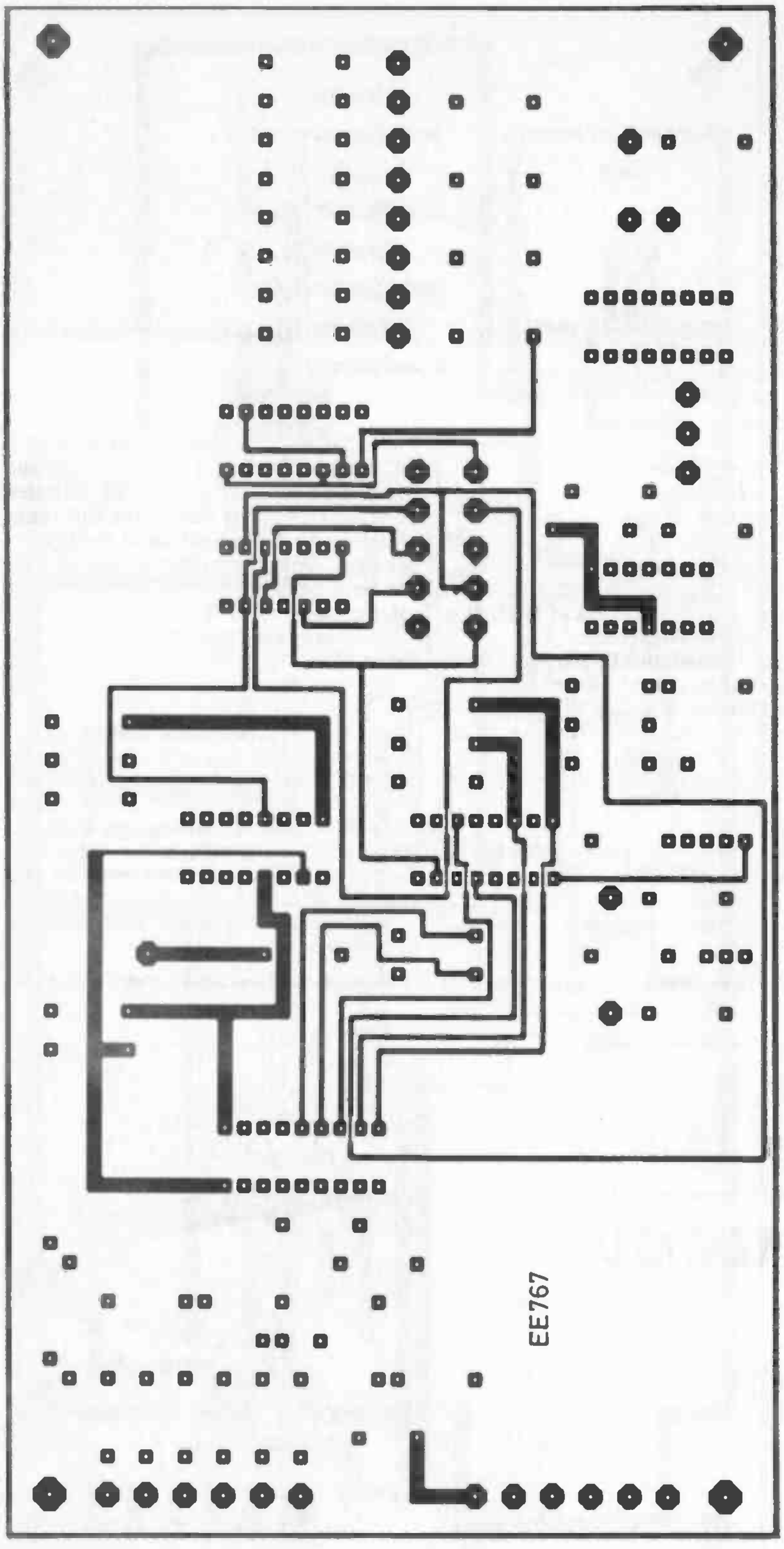


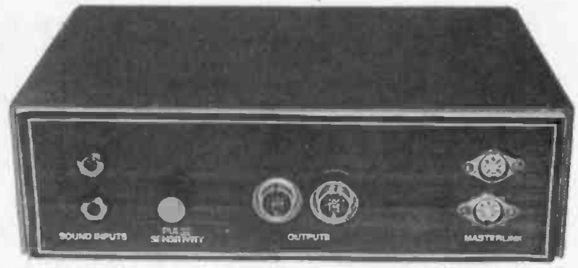
Fig. 4. Full size copper foil track master pattern for top, component side of the p.c.b.

of the modules are designed with a common appearance and to utilise the case specified in the components list. Prior to installing the p.c.b. and panel mounted components in the case it should be drilled and the panel markings completed.

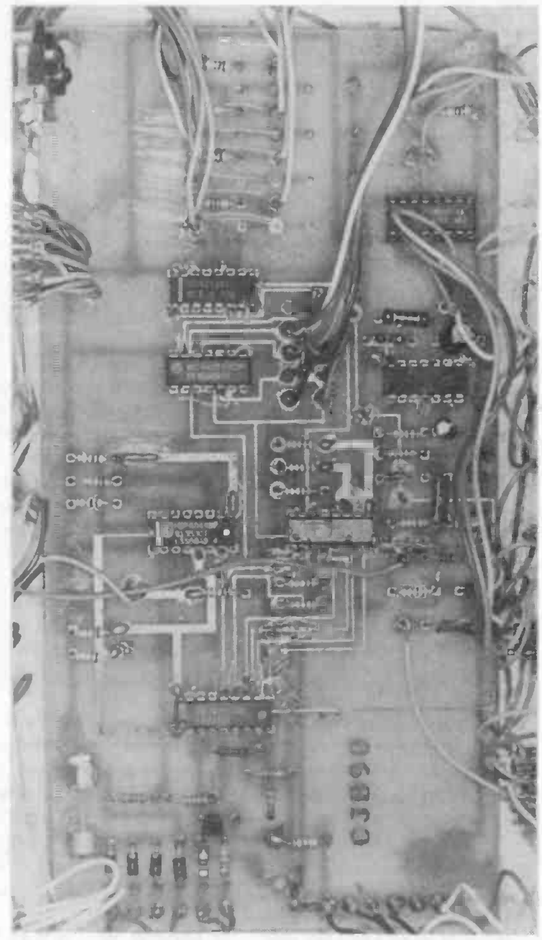
Once this has been done, the case mounted components, such as the sockets and switches can be wired up to flying leads and then fixed into place. There are a great number of wired connections to be made in the module and use of as many different colours of wire as are available will make indentification easier.

The l.e.d.s (D1, D6 to D9 and D11) should be fitted into the case by means of l.e.d. clips and then wired to flying leads which are then soldered to the connection pins of the board. The cathodes (k) of all of the l.e.d.s are best commoned together with bare wire and then a single insulated wire used to connect them to one of the 0 volt connection points on the p.c.b.

Self adhesive standoffs should be inserted in the 4mm clear holes at the board corners and the coverings protecting the adhesive removed, so that the board can then be carefully offered into position in the case and the standoffs pressed onto the case interior to secure them into place. Once the p.c.b. has been secured in position the flying leads from the case mounted com-



Rear panel showing socket/plug layout.



The completed prototype board showing component layout and topside copper tracks.

ponents can then be attached to the correct places on the board.

It should be remembered that it may be necessary to remove the board from the case for faulting finding and servicing. Care should therefore be taken when installing the leads to the case mounted components to ensure that sufficient wire is available to remove the board from the case should it be necessary so to do.

TESTING

Once the p.c.b. has been connected up to the case mounted components a final check should be carried out to look for incorrect connections, incorrectly polarised components, short circuits and any other faults before testing out the unit. In order to test the module it will be necessary to connect it either to any of the compatible output modules, or to supply the correct voltage (+16 volts) to the power inputs of the p.c.b.

A suitable sound source should be connected into one of the jack sockets and the controls adjusted to ensure that the module operates in accordance with the circuit description and the "In Use" instruction given below. If any faults are found it will be necessary to check through the operation of the circuit as given in the circuit description, in order to locate and clear the fault(s).

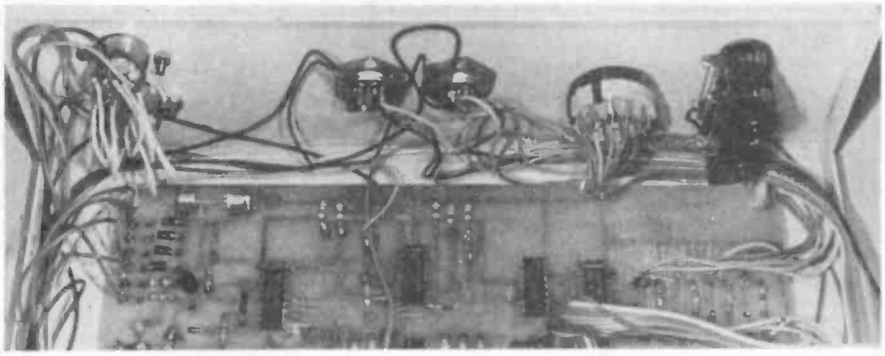
IN USE

In order to use this module it is necessary to connect it to a suitable sound source. The unit has been designed to accommodate a wide range of sound sources, but it is intended that the module should be used predominantly with loudspeaker outputs (including 100 volt line outputs) from the disco sound system.

Although it is possible to utilise any sound source which is capable of driving the LM3915 i.c. it is possible that the low power outputs from sound sources such as un-amplified record decks, tape recorders and microphones may not be powerful enough to drive the unit directly. Given that these sources are also not sufficiently powerful to give an audible output either, it will be necessary in practice to amplify them anyway, so there should be no problem in finding a suitably powerful sound source with which to drive the module.

The VU Module described in this article is designed for use with **monaural sound sources only.** Two connecting jacks are provided, wired in parallel so that a loudspeaker feed from the amplifier may be plugged into one socket and another jack lead taken from the other jack to feed the loudspeaker.

Under no circumstances should two loudspeaker outputs be commoned together, such as would occur by plugging the outputs of two separate amplifiers or the twin outputs from a stereo amplifier into the two jack sockets of the module, since this is likely to cause serious damage to the amplifiers concerned. In practice the sound levels produced in the two outputs of stereo sound systems are sufficiently similar for an acceptable effect to be obtained by plugging the module into the output of ONE of the channels of the system only.



Wiring to rear mounted components. Each pair of DIN sockets, output "plugs" and input jack sockets are wired in parallel so that only one of each need be connected to the circuit board.

The module should also be plugged into the input(s) of at least one Switched Output Module or Dimmer Interface Module and the Masterlink connections between the modules in use should also be made if the external pulse facility is to be utilised, since the connections for this facility are bussed through the Masterlink sockets. Similarly the Masterlink unit, if required, should also be plugged into the equipment stack by using the Masterlink connections.

Once the connections described above have been made a suitable sound source should be utilised to drive the module and potentiometer VR1 should be adjusted until the signal just causes the full range of output l.e.d.s to light up at the loudest passages. Once the correct setting of VR1 has been achieved then switch S4 can be rotated until a satisfactory pulsing of l.e.d. D11, in time with the music, is observed.

The control switches S1, S2, S3 and S6 can then be set to provide the control of the system you desire. If the External Pulse feature is to be utilised it is necessary not only to set switch S5 of the VU Module to the ON position, so as to send the pulses from the module through the Masterlink connection cable, but to set the "pulse" switches of the modules that you wish to drive to the "EXT" position.

Next Month: Super Chaser and Super Sweep.

ACTUALLY DOING IT!

by Robert Penfold

A MAJOR PROBLEM for anyone taking up electronic project construction as a hobby is that they are not likely to be familiar with the various types of component. Clearly it is essential to accurately identify each component if a project is to be assembled correctly.

Many of the problems experienced by beginners can be overcome by studying component catalogues, and this is certainly one of them. A few of the larger component catalogues will provide you with a lot of general data and information on a massive range of components. By spending a few hours studying the catalogues you can learn a tremendous amount, and much of what you learn will be practical information that will be invaluable when constructing projects.

For the beginner one of the most important aspects of a good components catalogue is the numerous drawings and (or) photographs of the components. This enables you to become familiar with a wide range of components before you have actually bought anything.

Also, once you have bought the components for a project, the catalogue, together with the illustrations in the article which describes the project, should enable you to identify all the components without too much difficulty. If necessary, you can place components alongside illustrations in the catalogue in order to find a match.

As it has been pointed out many times before, a few component catalogues might cost you a few pounds, but it is money well spent. Apart from the data and other information provided in most catalogues, you will be unable to obtain all the components you need without resorting to some mail order suppliers. These days a few component catalogues have to be regarded as an essential part of the hobby.

RESISTORS

Something that can be confusing for beginners, and can even cause some head scratching for those of us who have been in electronics for some time, is the vast range of components that are available. It is probably not the more specialised components that cause the difficulties, as their individualism makes it unlikely that they will be confused with anything else. It is the numerous variations on a particular type of component that causes the problems.

Look at the resistor section in a large component catalogue for instance, and you will probably find more than a dozen different types (including presets etc.) on offer. In fact, some catalogues list a dozen or more different types of fixed value resistor. In some cases there is little physical difference between two types of component, just rather subtle electrical differences. Studying the illustrations will not help to sort things out in such cases.

In components lists you will usually find that the resistors are all specified as 0.25 watt (W), 5 per cent (%), carbon film types. If you look through some component catalogues you will find that some of them do not actually list any resistors which meet this specification. However, this does not mean that suitable resistors are not available from the company concerned. Resistor specifications in component lists are a sort of minimum requirement.

The wattage rating is the power that the component can dissipate without overheating. It has been interesting to see how the physical size of resistors have reduced over the years, while their power ratings have increased. To some extent this is due the improvements in manufacturing processes, but to a large extent it seems to be due to the way power ratings are derived.

At one time the maximum power rating would produce a fairly low operating temperature, and the component could withstand an indefinite 100 per cent overload. These days it seems more normal for a resistor operating at its maximum power rating to get very hot indeed, and to be something not too far off burning up.

What this means in practice is that you should never use resistors having a *lower* power rating than that called for in the components list. On the other hand, it is quite safe to use a component which has a power rating that is *higher* than the one specified in the components list.

The only potential problem in doing this is that the higher power resistor might be too big to fit into the available space. If a 0.25W resistor is specified, then a miniature 0.33W or 0.6W type should be perfectly satisfactory, but something like an old 0.5W resistor will probably not fit into the layout.

TOLERANCE

The percentage figure quoted for resistors (and some other components) is the tolerance rating. No component has precisely its marked value, and in some cases there is a considerable discrepancy between the theoretical and actual values.

The tolerance rating is the maximum acceptable discrepancy. With a 10k 5 per cent resistor for example, its value must be no more than 5 per cent away from 10k, or between 9.5k and 10.5k in other words.

If a components list calls for 5 per cent resistors, but you can only find 1 per cent or 2 per cent types in a components catalogue, then these closer tolerance resistors are perfectly satisfactory substitutes. This would not normally be a good idea because close tolerance resistors tend to be much more expensive than ordinary 5 per cent or 10 per cent types.

However, some component suppliers have rationalised their resistor ranges, and now sell close tolerance resistors as their standard low power type. These resistors are sold at prices which are comparable to ordinary 5 per cent and 10 per cent types.

Of course, using (say) a 10 per cent resistor in place of a 2 per cent type would not be a good idea. It is unlikely that this would cause a complete malfunction of the circuit, although this is a possibility. It is more likely that the circuit would function, but with reduced performance (poor accuracy in the case of a test gear project for instance).

COMPOSITION

When dealing with resistors you will inevitably encounter terms such as "carbon", "carbon film", and "metal film". These describe the physical construction of the components, and these terms are not purely of academic importance. The values of all resistors change with ageing and with variations in temperature.

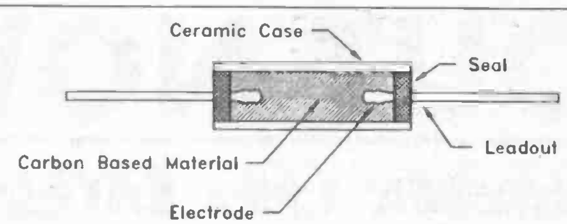


Fig. 1. The basic method of construction used for carbon resistors.

All electronic components, including passive types such as resistors and capacitors, produce electrical noise. The resistors which have a simple method of manufacture tend to have relatively poor stability with regard to their values, and also generate higher noise levels.

The most simple type of resistor is the carbon type. This is basically just a ceramic case with an electrode at each end, and a filling made from a substance that is a mixture of carbon and a ceramic material, see Fig. 1. Carbon has quite a low resistance – the ceramic material has a very high resistance. The value can be controlled by varying the percentage of ceramic material used, with higher ceramic contents giving higher values.

This type of resistor can be manufactured quite easily and cheaply, but carbon resistors are little used these days. The tolerances of these components tend to be quite high, as does their noise level. Their stability is not very good either.

Most small resistors are now of the film variety. The cheaper ones use a carbon film, while the more expensive components have a metal film. These two types of resistor are very much the same in their general make up, and Fig. 2 shows the basic arrangement used.

The basis of the component is again a ceramic tube, but in this case the carbon or metal based material is in the form of a thin film covering the *exterior* of the tube. The interior of the tube is simply left empty. A pair of metal end caps provide connections between the film and the two leadout wires.

The value of a film resistor is governed by the composition of the film material, and also by the thickness of the film. This enables the values to be accurately trimmed to the required figure during the manufacturing process by cutting a groove into the film. This enables close tolerance resistors to be produced easily. Film resistors have lower noise levels and better stability than carbon types, with metal film types performing better than carbon film components in both respects.

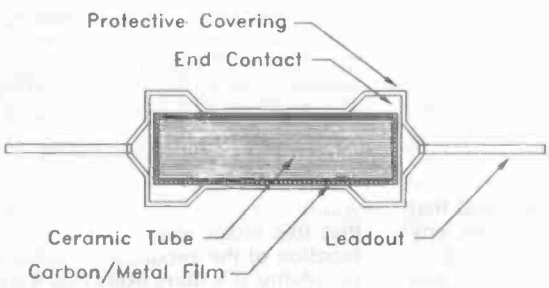


Fig. 2. Method of construction used for metal and carbon film resistors.

Carbon film resistors are adequate for most purposes, and metal film types are normally only specified for critical applications. These include such things as low noise preamplifiers and attenuators in test equipment. Using a carbon or carbon film resistor in applications of this type should not cause a complete malfunction of the circuit, but its performance will probably not live up to expectations.

WIREWOUND

There are actually a number of other resistor types, but most of these are highly specialised, and are the type of thing you will probably never use. Here we are talking in terms of special ultra-low noise and highly stable components, and very high value types where you must not touch the body of the component as this would significantly alter its value!

One further type of resistor you will find in most catalogues though is the wirewound variety. This is a very simple form of resistor which has the usual ceramic former, and a coil of resistance wire is wound onto this.

The value of the resistor is controlled by using different grades of resistance wire, and various lengths of wire in the coil. In order to avoid having a resistor that also acts as an inductor, the first half of the coil is wound in the opposite direction to the second half. The inductances of the two halves then cancel out each other, giving zero inductance.

It is easy to make high power resistors using this method of construction, and wirewound resistors generally have power ratings of about three watts or more. Carbon and metal types normally have power ratings of about 2W or less incidentally.

Wirewound types having power ratings as high as 25W are quite commonplace, and 100W components are available. These higher power types usually come fixed into an aluminium heatsink. Low power wirewound resistors do not seem to be manufactured, and there would presumably be no point in using this method of construction for low power components.

Where a high power resistor is needed there would seem to be little choice but to use a wirewound type. No other type of high power resistor seems to be available.

POTENTIOMETER

While on the subject of resistors I will take the opportunity to answer a couple of often asked questions about potentiometers. The first is simply "what is the difference between *logarithmic* ("log.") and *linear* ("lin.") potentiometers"?

With a linear potentiometer any two pieces of track of equal length will have about the same resistance. With the component at a mid-setting, there is a more or less equal resistance from the wiper (moving contact) to each track terminal.

In practice the linearity of most linear potentiometers is not very good, and adjustment towards the ends of the track usually has relatively little effect. This does not matter in most applications though.

If a linear potentiometer is used as a volume control it gives unsatisfactory results. Advancing it slightly causes a large increase in volume, while further advancing the control seems to have little effect. This is more due to the way in which the human hearing mechanism works than due to any fault in linear potentiometers.

Logarithmic potentiometers have a non-linear law which gives a more satisfactory control characteristic in volume control applications. Logarithmic potentiometers are used as volume controls, while linear types are used for practically all other applications.

The second question is "are preset resistors linear or logarithmic types"? This is a fair question, since few component catalogues specify the law for the ranges of preset resistors that are listed.

Actually both types are manufactured, but these days component retailers do not seem to stock the logarithmic type. Applications that require these are few and far between.

Unless a preset resistor is specified as being a logarithmic type, it can be assumed to be a linear component. Similarly, if a components list does not specify the law for preset resistors, it can be assumed that linear types are required.

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88 pages Temporarily out of print

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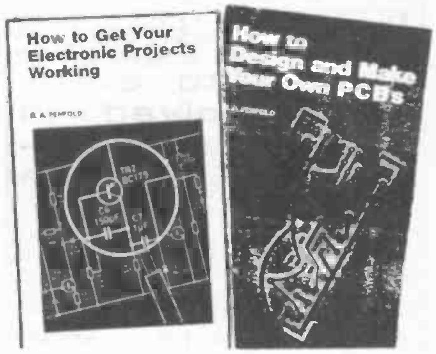

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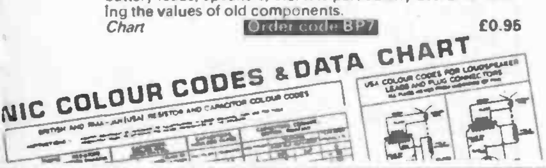

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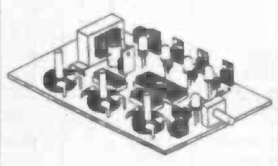

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