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ETI TOP PROJECTS

Nº5

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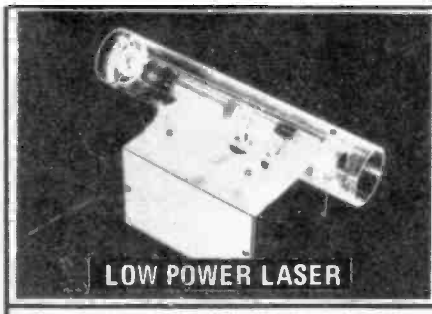
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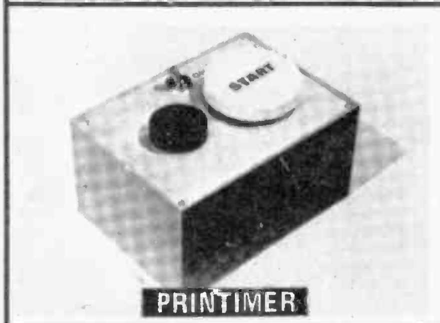

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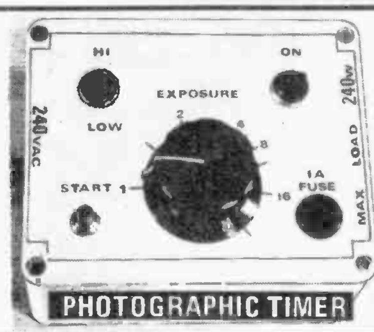

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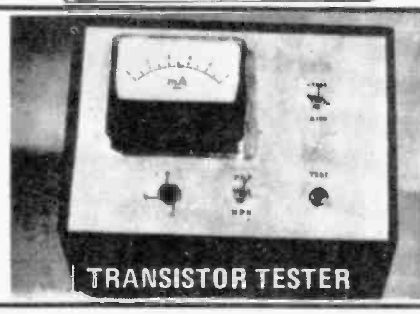
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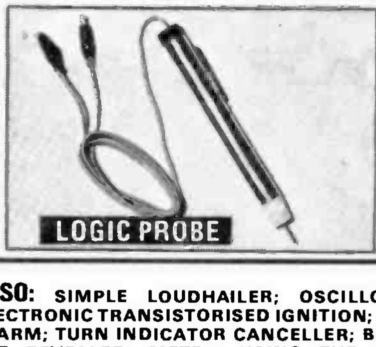
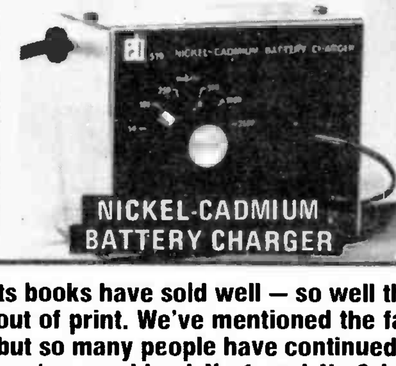

LOGIC PROBE


SIMPLE AMP



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ALL ETI Top Projects books have sold well — so well that No.1 and No.2 are out of print. We've mentioned the fact many, many times but so many people have continued to request them that we've combined No.1 and No.2 in a massive 180 page reprint containing all the original projects. This is ONLY available at present direct from: ETI Specials, 25-27 Oxford Street, London W1R 1RF. Price is £2.50 + 20p postage, sterling only please

ETI TOP PROJECTS: No 5

THE FIFTH IN A SERIES OF SPECIAL ISSUES CONTAINING REPRINTS OF POPULAR ETI CONSTRUCTIONAL PROJECTS

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25-27 Oxford Street
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Telephone 01-434 1781/2
Telex 8811896

HALVOR W. MOORSHEAD
Editor

RON HARRIS B.Sc
Assistant Editor

JIM PERRY
Specials Editor

TONY ALSTON
Project Development

JULIAN ZINOVIEFF
Production

MAREE BREEN
Technical Drawing

SANDRA ZAMMIT-MARMARA
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Administration

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Reader Services

For Advertising Enquiries ring
MARK STRATHERN
on 434 1781/2

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Publisher
Steve Braidwood
Assistant Editor

HOLLAND: Anton Kriegsman
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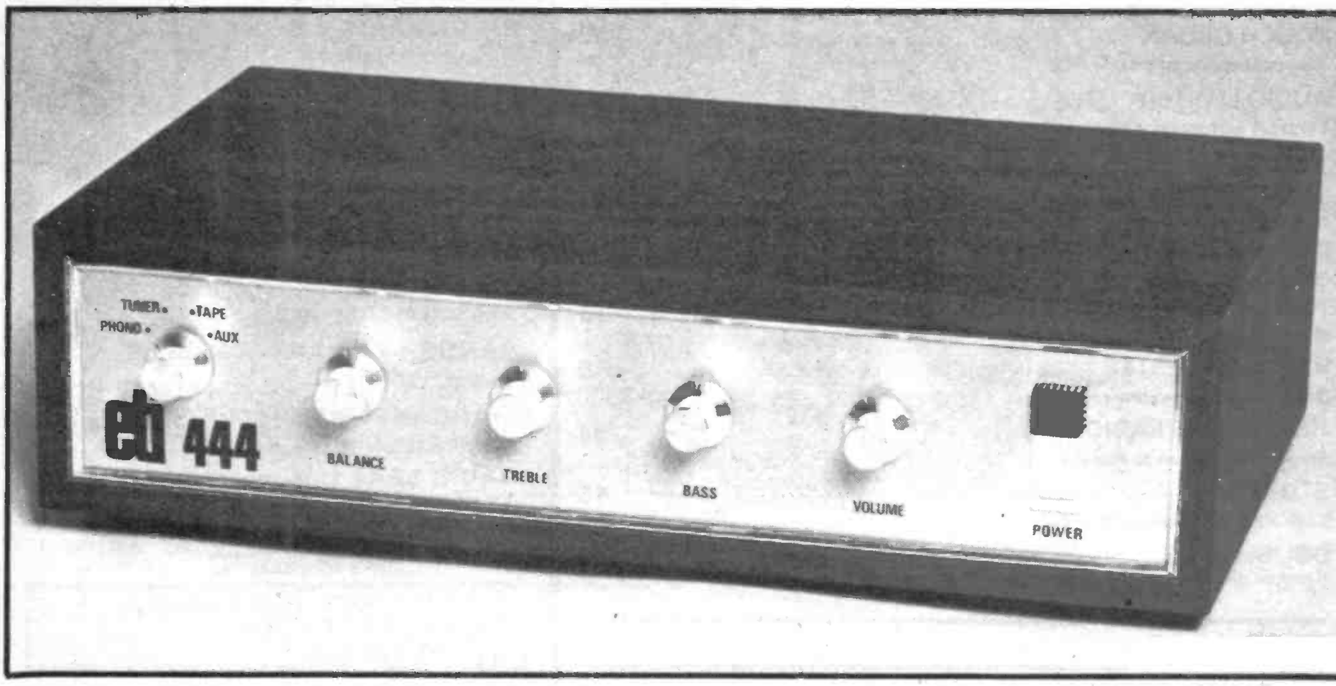
ETI project 444

FIVE WATT STEREO

This simply-constructed amplifier gives high quality reproduction for surprisingly low cost. The five watts per channel output is sufficient for the average listening room even when inefficient loudspeakers are used.



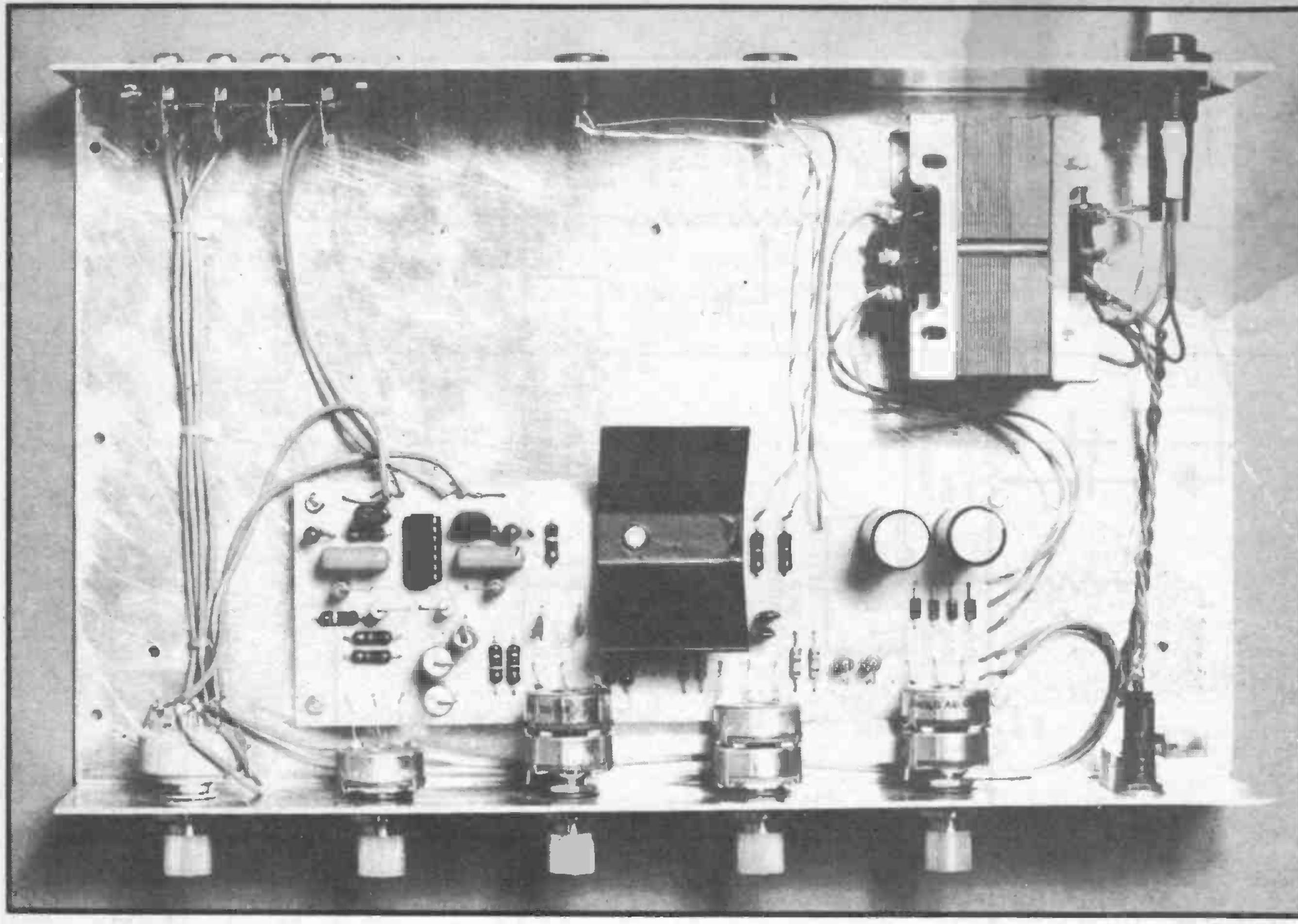
THIS PROJECT UTILISES A NEW advance by IC manufacturers. A few years ago no one would have believed a complete stereo hi-fi amplifier could be made from just two ICs plus a few passive components. Today more and more components are contained within the IC so a power amplifier is as easy to use as an op-amp.

Easy to build — Readers who were previously apprehensive about building audio power amplifiers should have no trouble with this design — there is little to go wrong.

Adequate Power — The output is unlikely to be found lacking unless the loudspeakers are very inefficient. Speakers of this type usually belong to the hifi enthusiast who spends lots of money on his system; the inefficiency of the speakers is compensated for in the amplifier. In an average set-up it is unlikely that you would, under normal listening conditions, be able to tell the difference between the ETI444 and a twenty watt amplifier.

MEASURED PERFORMANCE OF PROTOTYPE ETI 444

POWER OUTPUT	
Into 8 ohms	5 watts per channel
DISTORTION	
At 3 watts out	0.15%
At 4 watts out	0.5%
At 5 watts out	3.0%
FREQUENCY RESPONSE	
High-level input	+10 dB, −3 dB 4 Hz to 200 kHz
SENSITIVITY	
Magnetic input	1.5 mV
High level input	190 mV
LOAD IMPEDANCE	8 ohms or higher
INPUT IMPEDANCE	
Magnetic input	approx. 100 k
High level input	approx. 10 k
SIGNAL TO NOISE RATIO	
High level input	67 dB
Phono input (ref 10 mV in)	64 dB unweighted



FIVE WATT HI-FI AMPLIFIER

LM379 — National Semiconductor recently supplied ETI with samples of their new dual five-watt audio amplifier IC — the LM379. The circuitry around the IC is very simple in comparison to most of those previously available. The gain is set in a similar way to that for an operational amplifier: by the ratio of two resistors in the feedback network. In addition the IC features internal stabilization, current limiting and thermal protection.

Preamp — We decided to try the IC in conjunction with the dual low-noise preamplifier IC also from National Semiconductor — the LM382. The combination results in a simple stereo amplifier which works very well indeed.

Whilst tone control could be achieved very simply it was decided that the performance of the amplifier deserved good treatment. So we use more effective tone controls.

The result is a five-watt stereo amplifier, ETI444, simple and inexpensive to build, and with a surprisingly high performance.

CONSTRUCTION

As with most straightforward projects the use of a printed circuit board is not only desirable from an ease of construction point of view, but it also helps to ensure identical results to those of our prototype.

The components may be assembled to the board in any order but we find it preferable to assemble the low-height components first, ie, resistors, diodes. Before installing IC2 make sure that a hole of about 6 mm diameter is drilled in the board at the end where the heatsink is to

How it works

THE OUTPUT OF a magnetic cartridge is normally of the order of 5mV at 1kHz. However, in the recording process the high frequencies are recorded at a higher amplitude than the low frequencies (in order to reduce noise). The curve of amplitude-versus-frequency that is used is known as the RIAA curve. When the record is replayed the reverse characteristic of gain-versus-frequency must be applied to restore a flat frequency response. This process in the amplifier is known as equalization.

The first stage of the ETI 444 amplifier uses an LM382 dual low-noise preamplifier IC. This stage is designed to amplify and to equalise the output of a magnetic cartridge. Note that many of the resistors needed to bias the IC (and to provide equalization) are provided within the chip and very few external resistors are reqired to make it function as an RIAA compensated amplifier.

The second IC is an LM379 – a dual stereo power amplifier which provides six watts RMS per channel with supply rails of ±13 volts. The IC is unusual amongst power amplifiers in that it can be used in a similar fashion to conventional op-amps (except that it is capable of driving a low impedance load of 8 ohms).

The gain-versus-frequency response of the power amplifier is set by the bass and treble controls. The overall gain is set by the ratio of 1 + R15 / (R17 + RV4). The part of RV4 corresponding to a particular amplifier is that between the wiper and the outside tag connected to the amplifier. Thus the gain of the two amplifiers may be varied differentially by varying RV4 (which acts as a balance control). The level of the input to the power amplifier is set by RV1 (which acts as a volume control). Switch SW1 selects the input to the power amplifier from either the RIAA power amplifier or from tuner tape or auxiliary inputs as required

The power supply is simply a bridge rectifier and centre-tapped transformer arrangement which provides ±12Vdc. With both channels driven this is adequate to provide an output of 5W per channel before clipping.

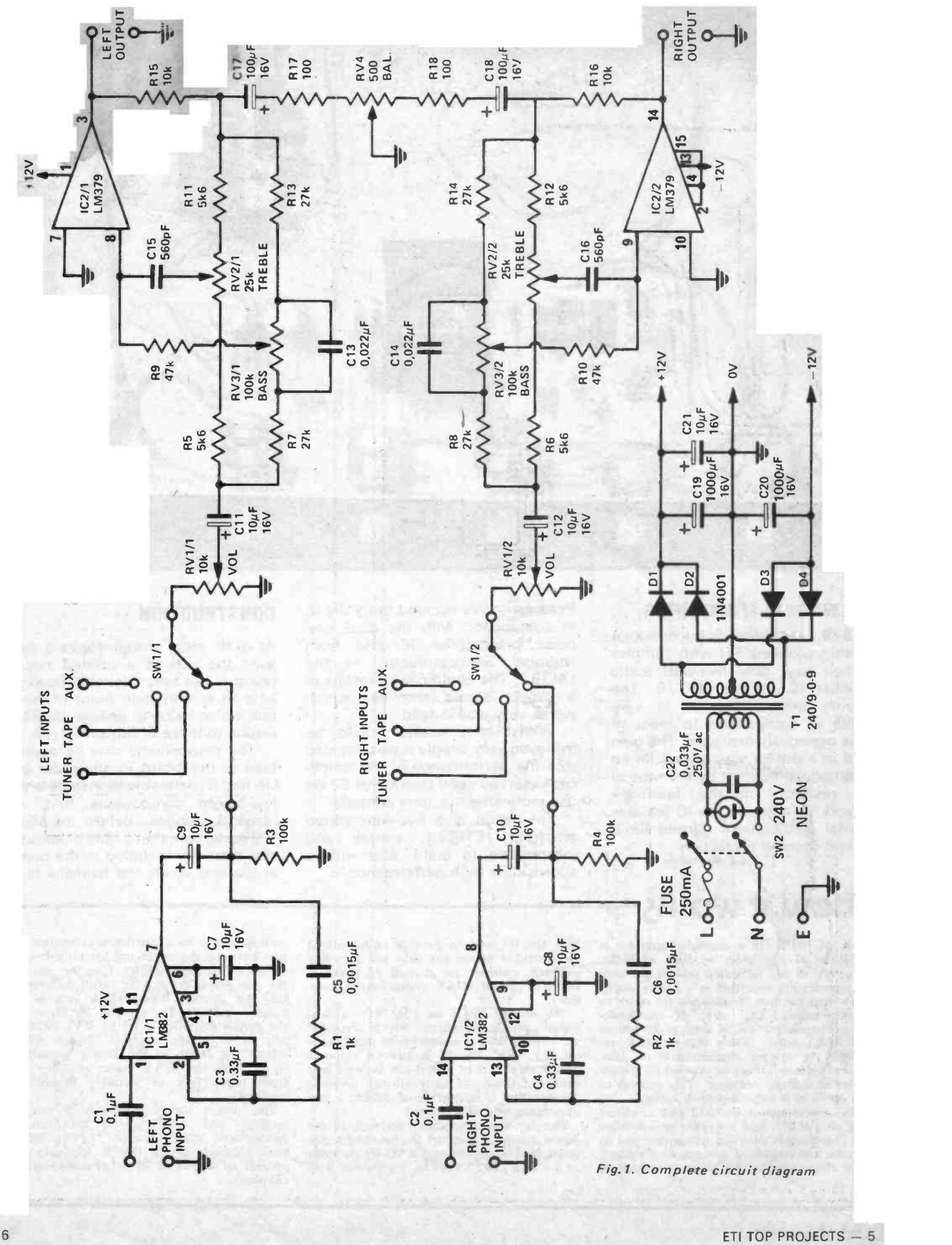


Fig.1. Complete circuit diagram

be mounted (after the IC is installed). Take care that all polarized components, such as diodes, ICs, electrolytic capacitors and integrated circuits, are mounted with the correct orientation.

Solder 25 to 50 mm lengths of tinned copper to each of the lugs on the potentiometers and then mount the potentiometers in the appropriate position by threading the tinned copper wires through the holes provided in the printed-circuit board. Pull the wires down so that the lugs are almost flush with the board and the potentiometers are all in line. Then solder the wires.

The heatsink may now be mounted onto IC2 using a single nut and bolt. Care must be taken to ensure that the heatsink does not touch any of the potentiometers as it is at a potential of −12 volts.

The unit may now be mechanically assembled by securing it to the front panel by means of the potentiometer shafts and nuts, and by fitting two 6.4 mm spacers between the rear of the board and the chassis.

Finally wire the unit as shown in the component overlay diagram. ●

continued overleaf

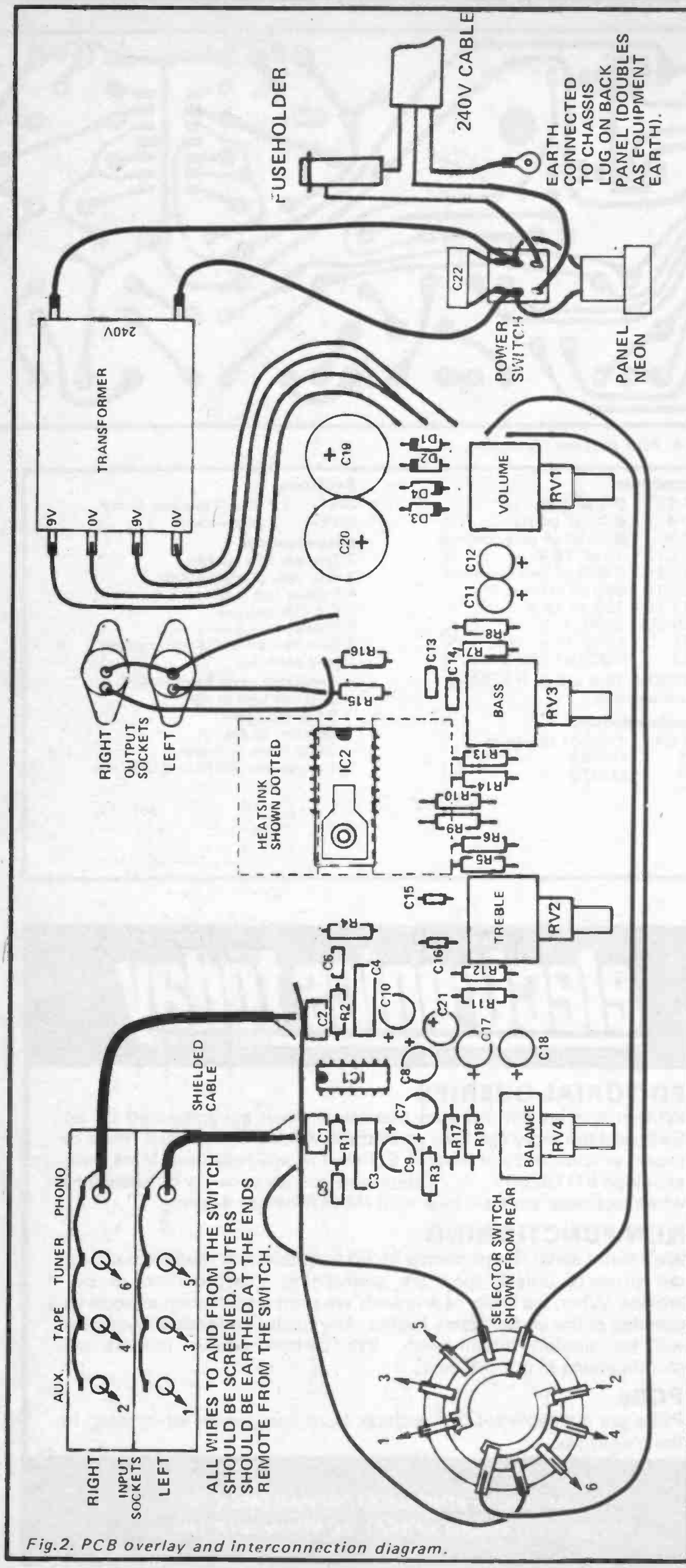


Fig.2. PCB overlay and interconnection diagram.

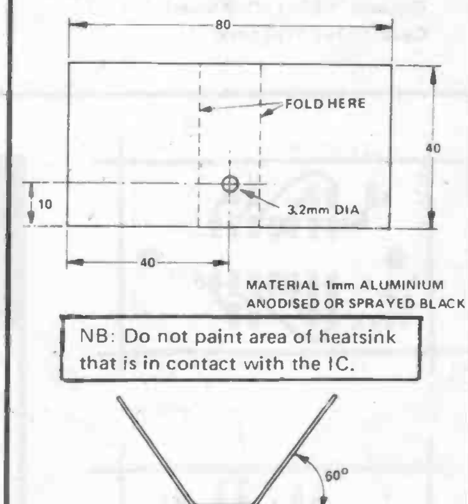


Fig.3. The heatsink for the LM379. The heatsink described will get quite hot when the amplifier is run at full output. If it has been blackened by painting it may smell a little at first but this will soon pass away. For normal domestic listening this size heatsink will be found to be entirely adequate but if the amplifier is to be run continously at full sinewave output it would be advisable to increase the size of the heatsink. No damage can be caused by using the smaller heatsink however as the IC is thermally protected and will simply shut down if it gets too hot.

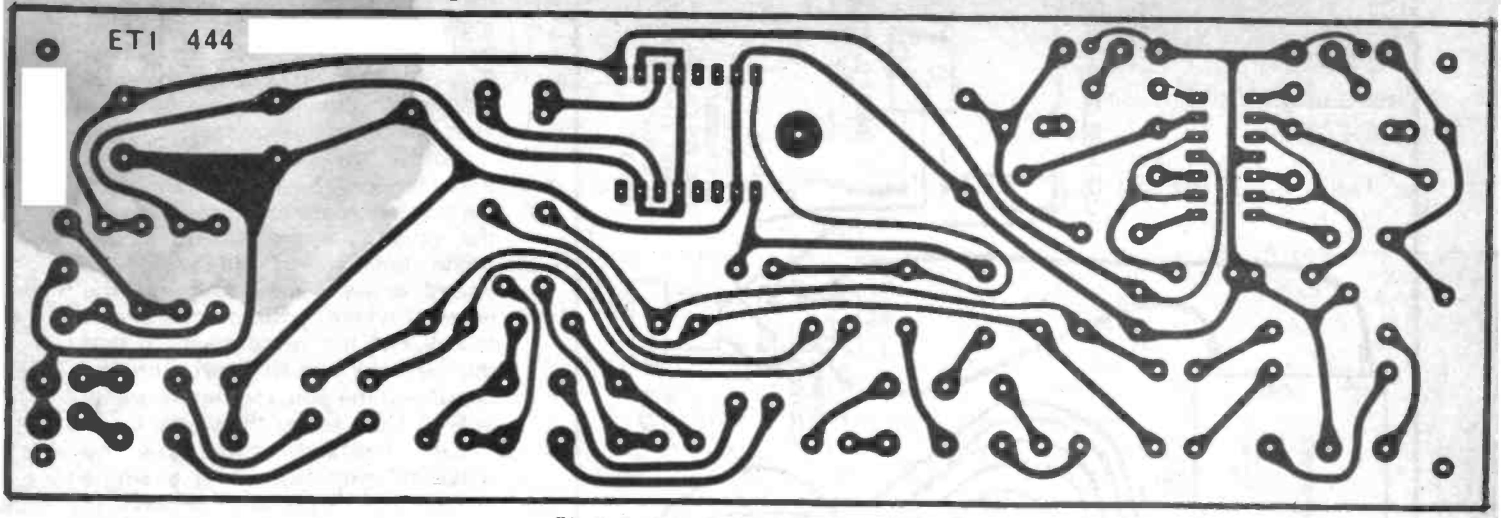


Fig.4. PCB Pattern (full size).

Parts List

Resistors

R1,2	1 k	¼W	5%
R3,4	100 k	"	"
R5,6	5k6	"	"
R7,8	27 k	"	"
R9,10	47 k	"	"
R11,12	5k6	"	"
R13,14	27 k	"	"
R15,16	10 k	"	"
R17,18	100	"	"

Potentiometers

RV1 10 k log rotary dual
RV2 25 k lin rotary dual
RV3 100 k lin rotary dual
RV4 500 ohm lin rotary wirewound

PC board ETI 444 Ramar, Crofton, Tamtronik,
Chassis 3 19x190x60mm
Case 341x201x85mm

Capacitors

C1,2	0.1 µF poly
C3,4	0.33 µF poly-
C5,6	0.0015 µF poly/ceramic
C7-C12	10 µF 16 V
C13,14	0.002 µF poly/ceramic
C15,16	560 pF ceramic
C17,18	100 µF 16 V
C19,20	2200 µF V*
C21	10 µF 16 V
C22	0.033 µF 250 V ac

* 1000µF 16 V will do if 2200 µF is not available.

Semiconductors

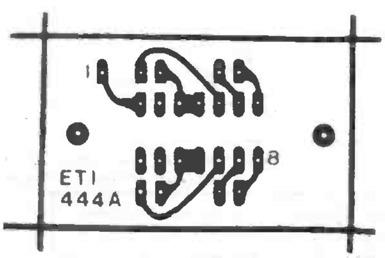
D1-D4 1N4001 or similar
IC1 LM382
IC2 LM379

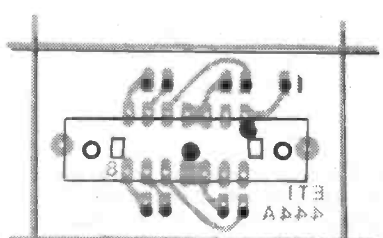
Switches

SW1 2 pole 4 position rotary
SW2 2 pole rocker

Miscellaneous

2 Two pin DIN sockets
2 Four way phono sockets
4 Rubber feet
2 6.4 mm spacers
5 Knobs
3 Core flex, plug, clamp, grommet and earth lug
Panel mounting fuseholder & 250 mA fuse to suit.
Screened cable
Heatsink to Fig. 3.
240V Neon indicator
Transformer 240V to 9-0-9V 1A





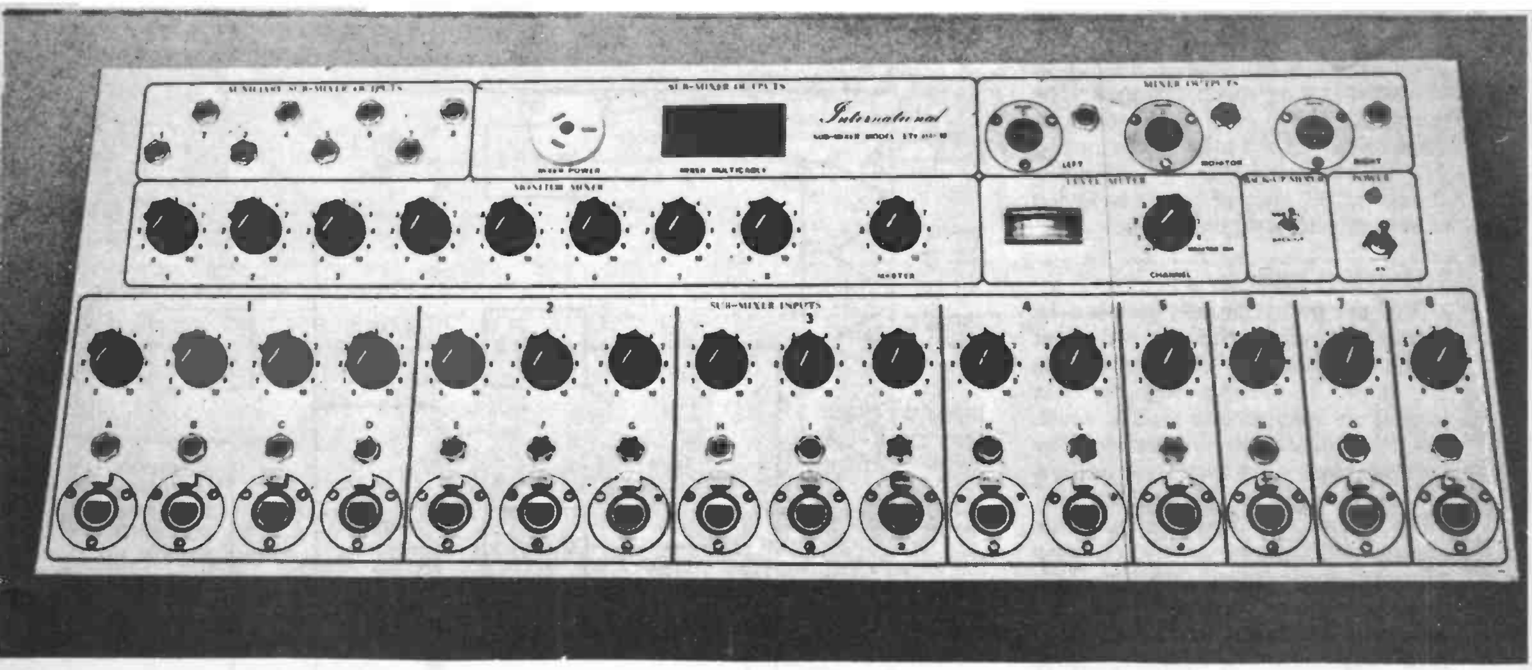
Since this article was published, National Semiconductors have stopped making the LM 379 in the package we used. Some suppliers still have stocks of the 'old' style. However if you get a 'new' 14 pin version the daughter board shown must be used.

eti project

STAGE MIXER

PROJECT 414

Sixteen amplifiers sub-mixed to eight channels — plus monitor



SEVERAL hundred of our Master Mixers (described April, May, June and July of 1973, and reprinted in Top Projects 1 & 2) have been built and are in use by groups and recording studios throughought Britain. Whilst this mixer has been enormously successful, there are several areas in which improvements can be made which will still further improve the flexibility and usefulness of this instrument especially for on-stage performances.

LONG-LINE WORKING

For most live performances the master mixer is best located in the listening area so that the mix can be continuously monitored, and controlled, for best effect. Whilst such operation is possible with the ETI Master Mixer, the inputs are not designed for long line work, especially with low-output, or unbalanced high impedance microphones. This deficiency may be overcome by using a line amplifier for each input.

THE NEED FOR SUB MIXERS

The next obvious deficiency in stage applications is that several microphones are often needed to mike the drums, or the several speakers of an organ etc. This requires the use of separate mixers, in front of the main

SPECIFICATION

NO OF INPUTS	**16**
NO OF OUTPUTS	**8 normal + 1 monitor**
NOMINAL INPUT	
maximum gain	**10 mV**
NOMINAL OUTPUT	
maximum	**8 volts**
nominal	**3 volts**
INPUT IMPEDANCE	
selectable	**< 68 k**
SIGNAL TO NOISE	
re 10 mV single channel input	**74 dB**
MAXIMUM INPUT	
on maximum gain	**30 mV**
on minimum gain	**1 V**
GAIN	
maximum	**50 dB**
variation possible	**36 dB**

Any number of inputs can be connected to any submixer. However no input may be connected to more than one sub-mixer. The VU metering is switchable to any one output channel.

STAGE MIXER

mixer, to avoid wasting the 8-channel master mixer's capability. To overcome both these disadvantages we have incorporated 16 line amplifiers and eight sub-mixers into a common unit such that the 16 channels may be grouped in any desired combination to the eight master mixer channels. The grouping shown for our prototype stage mixer (in the block diagram Fig. 1) is 4,3,3,2 plus 4 individual channels. This may of course be varied to suit individual requirements.

THE STAGE MIXER

Thus the unit described here is a 16 channel to eight channel sub-mixer which is specifically designed for use on stage. It accepts high or low impedance microphone inputs, which may be balanced or unbalanced. The unit provides eight high-level outputs for transmission to the master mixer.

The inputs may be made by either Cannon connectors or by standard tip-and-sleeve jacks. We strongly recommend that Cannon connectors be used for on-stage work because of their ruggedness. The input impedance of each channel may be tailored to suit the individual microphone (or other source) by selecting one resistor.

The gain of each line amplifier is adjustable from unity to 63 (36 dB) and the sub-mixer adds a further (14 dB), that is, a total of 50 dB gain is available.

The output level of each channel (even from a low output microphone) will be of the order of 1 volt and may be as high as 22 volts peak-to-peak without overload distortion occuring. Thus an extremely wide dynamic range may be accommodated by this mixer and the same dynamic range will also be accommodated by the Master Mixer. The Master Mixer, when used with the stage mixer may be used switched to the low sensitivity input position and such operation greatly improves the signal-to-noise ratio.

MONITOR FACILITIES

The original Master Mixer does not incorporate any monitor facilities. It is possible to use the echo-mix channel for monitoring but the level controls for each channel will also affect the monitor output. This is undesirable as if a louder level is required in the auditorium the monitor will also become louder — introducing a danger of acoustic feedback occuring.

Within the stage mixer we have incorporated a special monitor mixer which has its own level control

TABLE 1
Selection value of R11 (or 21, 31 etc)

Input Impedance	R11
200Ω	220Ω
600Ω	680Ω
47 k	150 k

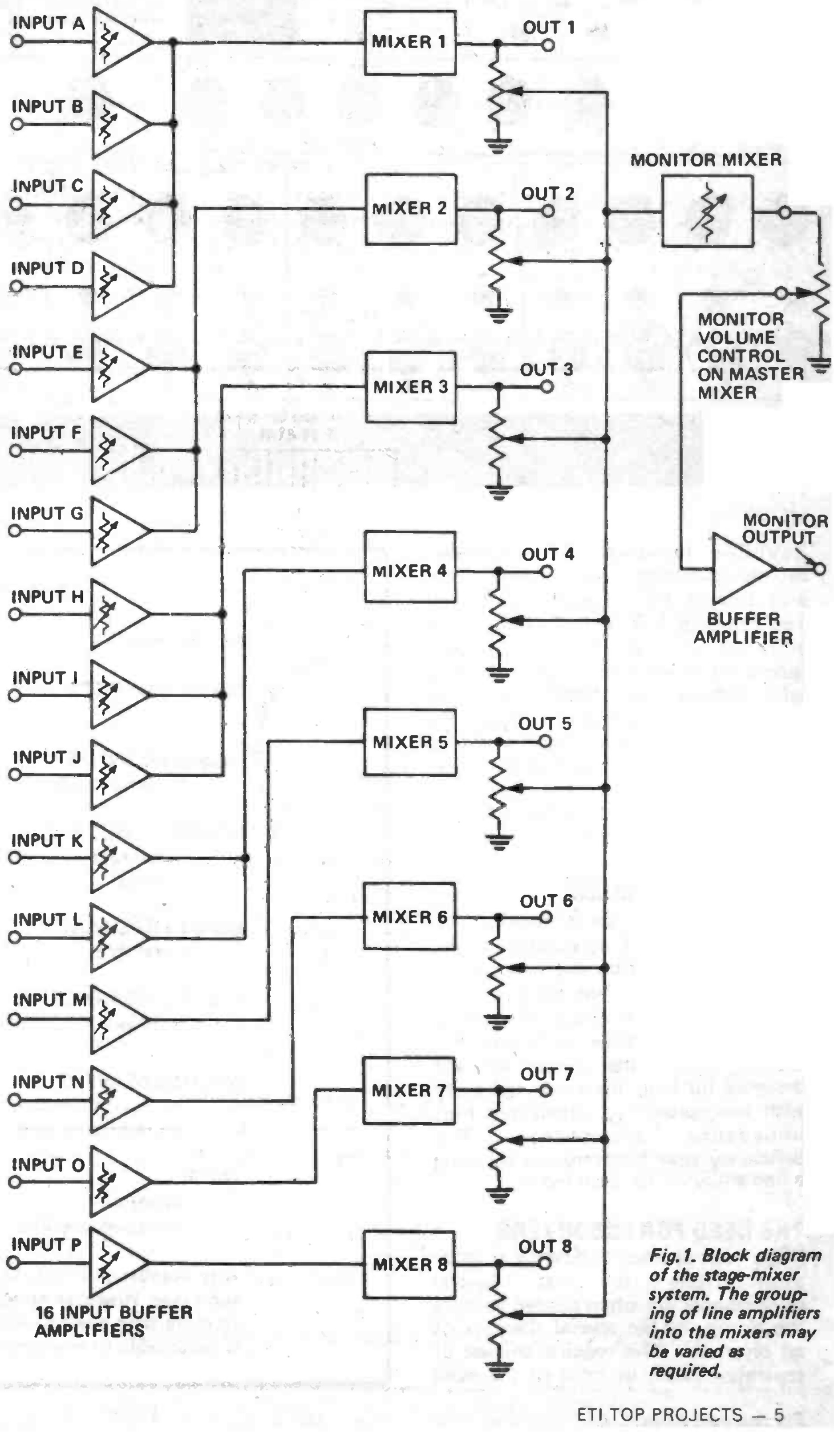


Fig. 1. Block diagram of the stage-mixer system. The grouping of line amplifiers into the mixers may be varied as required.

followed by a buffer amplifier. A second 'Master' monitor volume control is physically located on the main mixer so that it can be adjusted should acoustic feedback occur.

BACK UP MONITOR

Facilities are provided such that should the Master Mixer fail, or the cables between the two mixers be damaged etc, the stage mixer may be switched to provide an output direct to the PA system.

In this mode a 'Back up' switch takes the output from the monitor mixer and transmits it direct to both channels of the PA system. The monitor signal is still transmitted to the monitor amplifier when the mixer is in this mode. In normal use the 'back up' switch must be at 'normal'.

When the stage mixer is in 'back up' mode the master monitor level control, located on the Master Mixer, is by-passed (full volume) regardless of whether the Master Mixer is connected or not.

FINAL OUTPUTS

The Master Mixer outputs (i.e. left and right stereo plus monitor mix) are returned to the stage as part of the multicore cable and terminated on the 'stage mixer' with both 'Cannon' and standard 'Jack' type connectors.

METERING

A VU meter is provided on the stage mixer which can be used to monitor the output of any of the eight (sub) mixers or the stage monitor output. This meter will be useful for initial level settings on each sub-mixer.

POWER OUTLET

A switched, 240 volt power outlet is provided on the stage mixer. This is intended to provide power for the Master Mixer via an extension cable. Thus the power cable and the multicore cable are the only ones required between the two mixers.

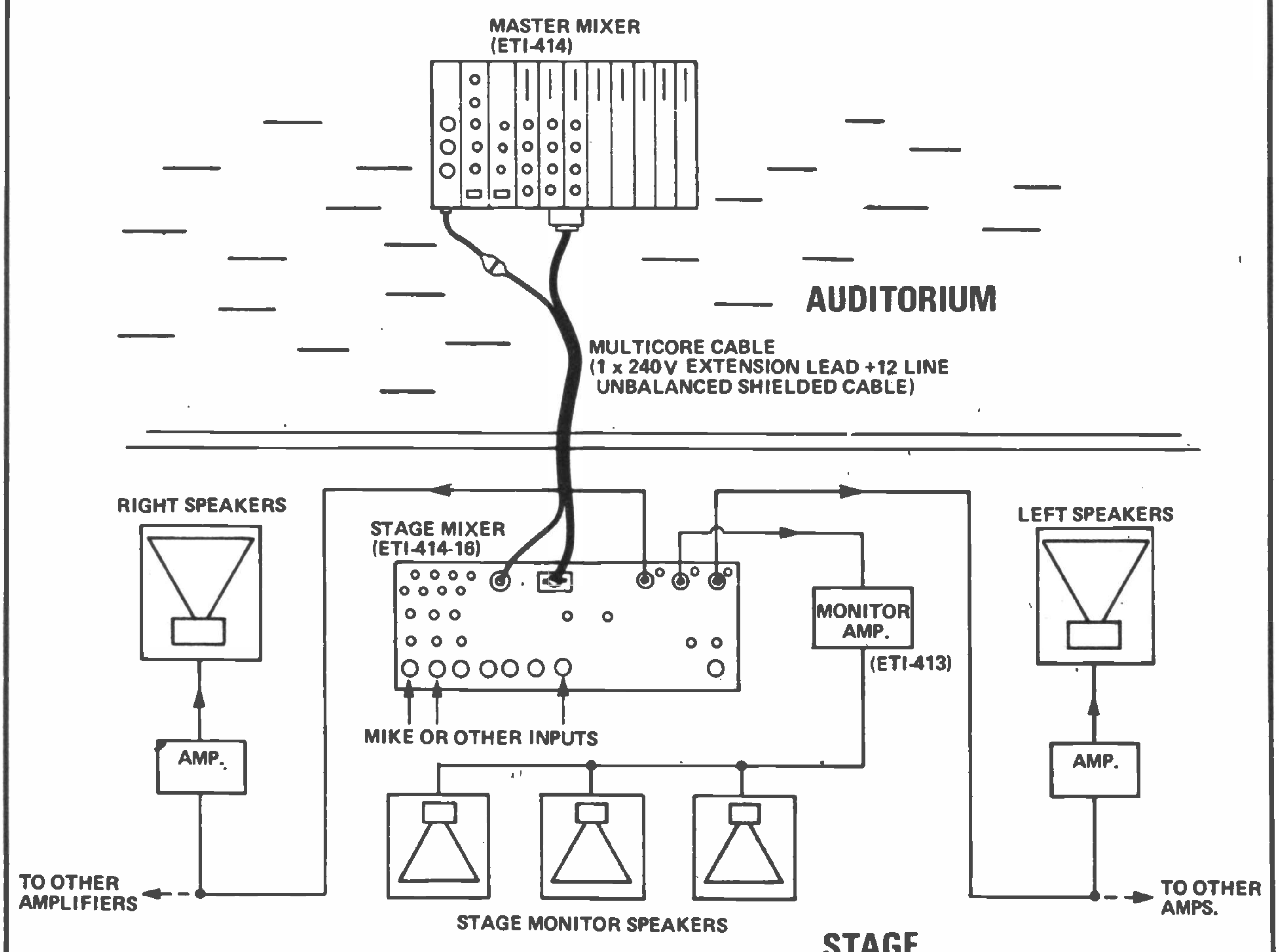
CONSTRUCTION

The mixer board (ETI 414E) should be assembled with the aid of the circuit diagram, Fig. 5, and the component overlay, Fig. 7.

When assembling boards take particular care with orientation of ICs, transistors diodes and electrolytic capacitors. It is advisable to use terminal posts or pins for the eight input lines, the O V line and the +19.6 volt line. This makes later interconnection considerably easier.

Our prototype was constructed in a simple pan shaped chassis and cover. We suggest that the sides of the front panel be bent up (rather than the ends as shown in the photographs). This will strengthen the front panel and allow the transformer to be mounted on it rather than in the case as shown in our prototype unit.

Mount the spacers for the printed circuit boards, the multi-cable socket, VU meter and power outlet socket to the front panel with countersunk



This is the way that the ETI Stage Mixer would be used for a live performance.

STAGE MIXER

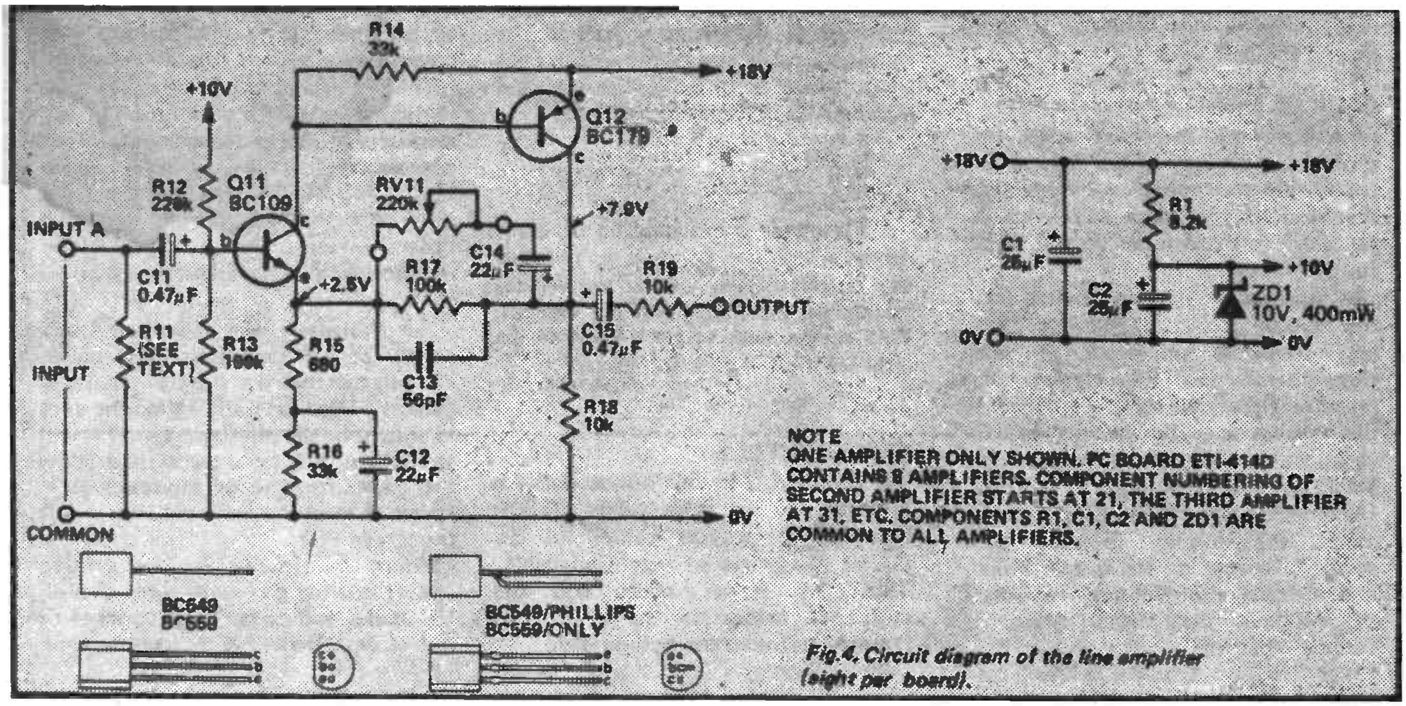


Fig.4. Circuit diagram of the line amplifier (eight per board).

HOW IT WORKS – ETI 414

LINE AMPLIFIER

The input impedance of the amplifier (referring to Fig. 2) is determined by the combined value of R11, R12 and R13 – all in parallel. The parallel impedance of R12 and R13 is 68 k and this is therefore the upper limit of input impedance (R = ∝).

For impedances less than 5 k the values of R12 and R13 may be ignored and R11 is set to the same value as the desired input impedance. Hence the circuit as shown matches microphones having 200 ohm output impedance.

The output of Q12 is fed back to the emitter of Q11. This path via R17 in parallel with RV11 and C14 provides negative feedback as well as supplying a dc bias which sets the overall gain of the stage.

The gain of the amplifier may be calculated using the following formula (assuming ideal transistors).

$$\text{Gain} = \frac{(R17//RV11) + R15}{R15}$$

When the gain control is at maximum the gain is 102 or 40 dB (in practice 36 dB), and when the gain control is at minimum R17//RV11 is zero and the gain is therefore unity.

MIXER/POWER SUPPLY

The signals from any number of line amplifiers may be summed by one of the sub mixers (eight per board IC1-IC8) the output from each mixer is taken directly to output socket to the Master Mixer, and via a 22k level. control to the monitor mixer, IC9.

The output of the monitor mixer is taken to the master-monitor, level control on the Master Mixer and then returned to a buffer amplifier in the stage mixer, IC10.

In an emergency (main mixer faulty) SW2 disconnects the outputs from the Master Mixer and connects the output of the monitor amplifier to the PA channels.

Power for the Stage mixer is provided by a conventional supply which provides plus and minus 15 volts for the mixer amplifiers and plus 19.6 volts for the line amplifiers.

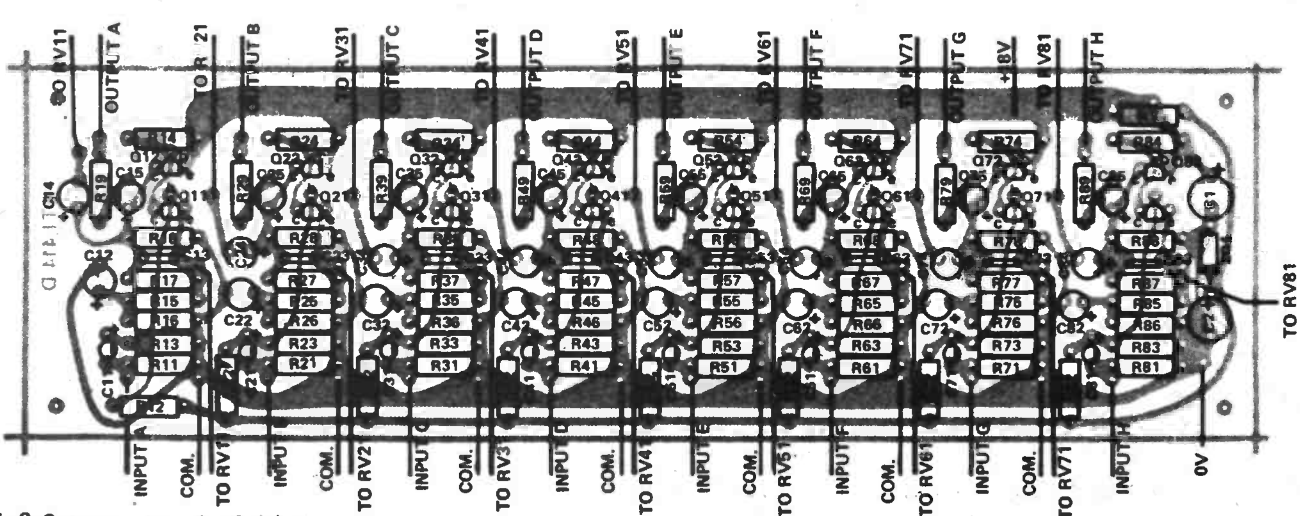


Fig.2. Component overlay for the preamplifier board.

PARTS LIST

INPUT AMPLIFIERS

16 off are required for all components below

R11 resistor see text
R15 resistor 680Ω ¼w 5%
R18, 19 resistor 10k ¼w 5%
R14,16 resistor 33k ¼w 5%
R13 resistor 100k ¼w 5%
R12 resistor 220k ¼w 5%

RV11 potentiometer 220 k rotary log.

C13 capacitor 56pF ceramic
C11, 15 capacitor 0.47µF TAG Tantalum
C12 capacitor 22µF 16V electrolytic

Q11 transistor BC549 or similar
Q12 transistor BC559 or similar

2 off are required for all components below —

R1 resistor 8k2 ¼w 5%
C1, 2 capacitor 25µF 25V electrolytic

ZD1 Zener diode 10V,400mW
PC Board ETI-414D

SUB-MIXERS,POWER SUPPLY

R2,5,8,11 resistor	100Ω	¼w	5%
R14,17,20	"	100Ω	¼w	5%
R23,25,28	"	100Ω	"	"
R29,30,31	"	390Ω	½w	"
R1,4,7,10	"	47 k	¼w	"
R13,16,19,22	"	47 k	"	"
R3,6,9,12	"	100 k	"	"
R15,18,21	"	100 k	"	"
R24,26,27	"	100 k	"	"

RV1,2,3,4 potentiometer 22k rotary log
RV5,6,7,8 potentiometer 22k rotary log
RV9 potentiometer 470k rotary log

C4,5,6 capacitor 0.1µF polyester
C1,2,3 capacitor 470µF 25V electrolytic

IC1-IC10 integrated circuit µA741C Mini dip or TO5

D1-D4 diode 1N4001 or similar
ZD1,2 Zener diode 15V,400mW

T1 transformer 240V/15-0-15V
PC Board ETI-414E
SW1 switch DPDT toggle 240V rated
SW2 switch 4PDT toggle

PARTS LIST GENERAL

Chassis
Box
Escutcheon
16 Cannon sockets
3 Cannon plugs
27 Phone jacks — mono— 6.4mm
1 LED and panel holder
1 11 position 1-pole rotary switch
1 VU meter
1 240V power outlet similar
1 21 pin socket
26 Knobs
12 1" spacers
nuts, bolts, 3 core flex & plug etc.

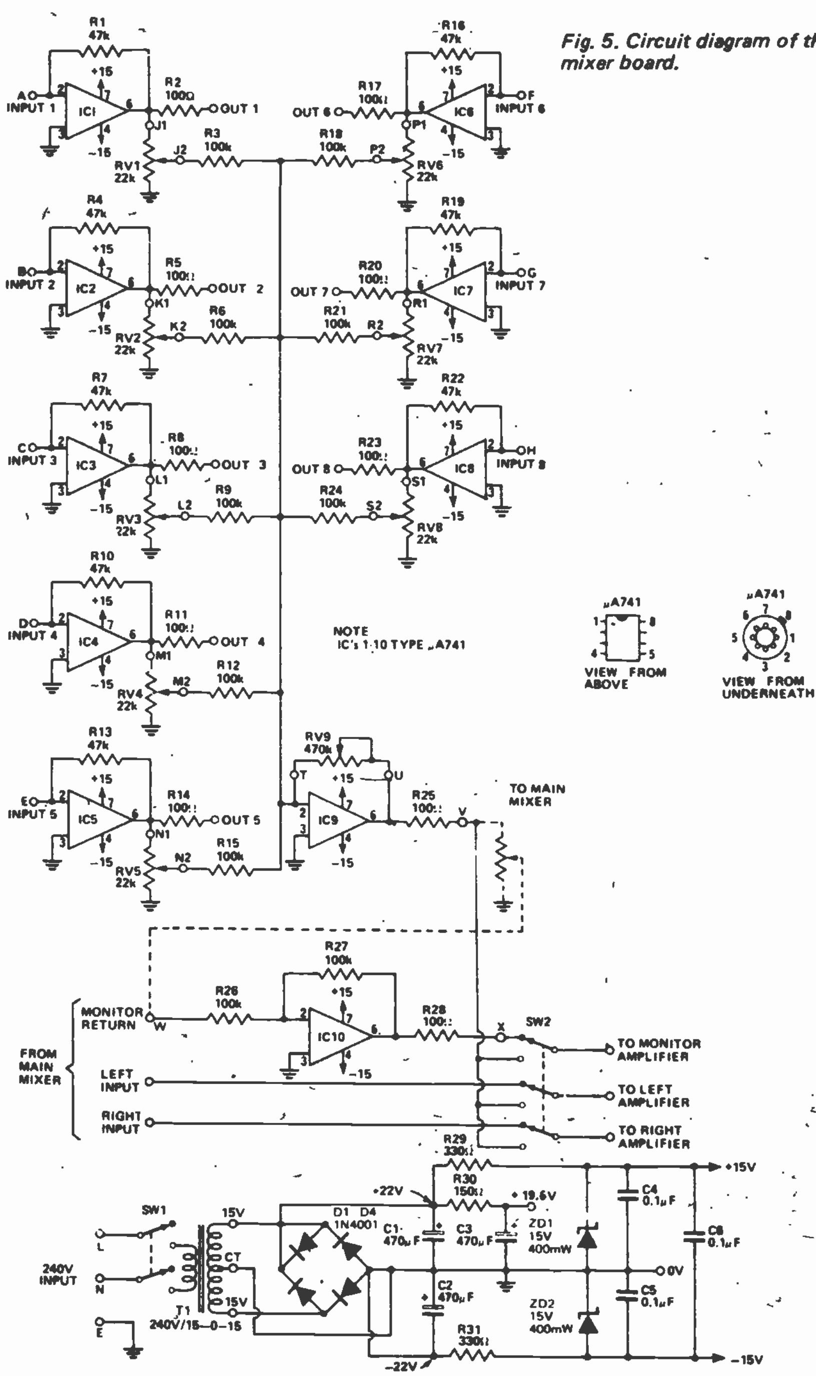


Fig. 5. Circuit diagram of the mixer board.

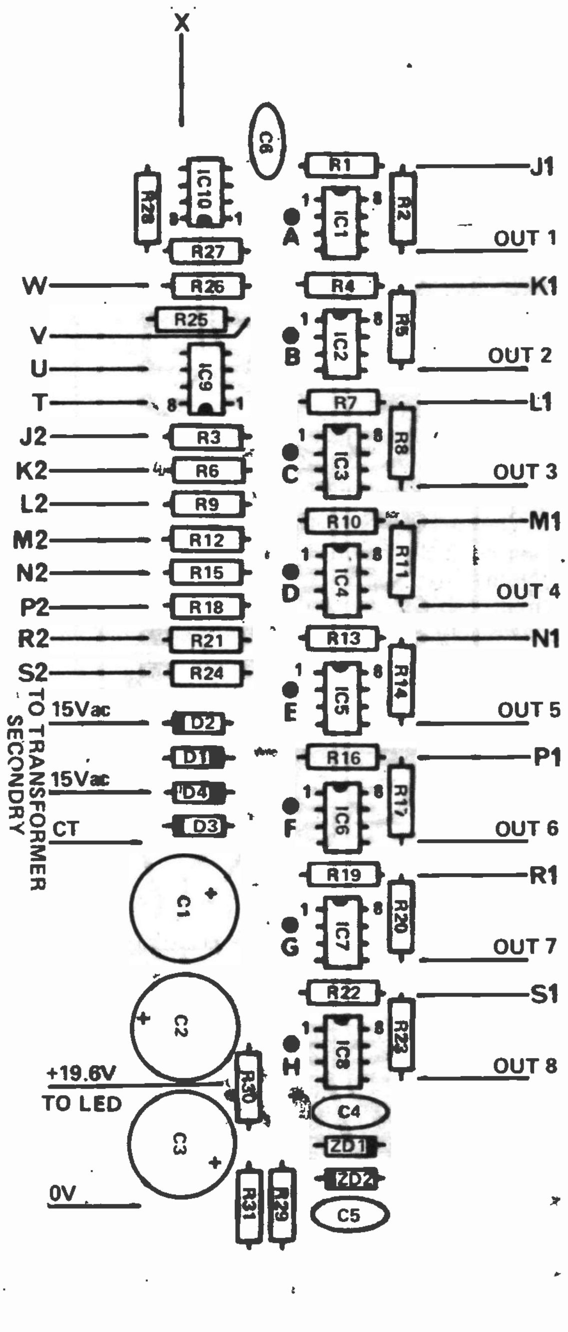


Fig. 7. Component overlay for the mixer/power-supply board.

screws. It is suggested that the wires to the three-pin socket be attached before mounting – it is difficult later. All other front-panel components can now be mounted along with the escutcheon.

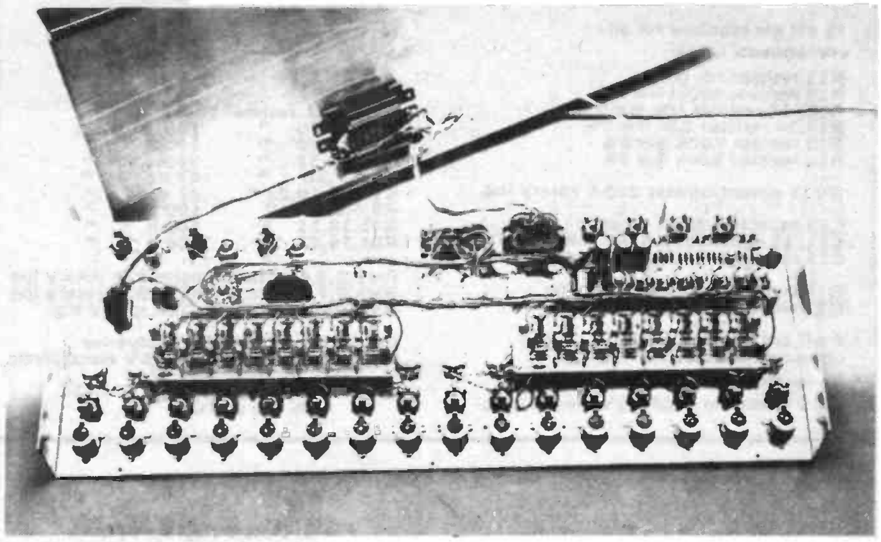
Since the mixer may be subject to rough handling it is recommended that all screws be sealed in position with LOCTITE or similar compound.

Commence interconnection wiring by connecting the input sockets and potentiometers as shown in Fig. 8. This diagram shows connections to channel 1 of the preamplifiers – all other channels being similar. For neatness, we terminated these wires by soldering to the appropriate places on the underside of the board. Attach wires to the preamplifier outputs, on both boards, long enough to reach the appropriate mixer inputs. Similarly attach wires for the 0 volt and +18 volt supply lines.

The +18 volt supply comes from the negative side of the LED, the positive side being fed from the 19.6 volts of the power supply (1.6 volts drop across LED). When all these leads are attached, both boards may be mounted in position on the chassis.

The mixer/power-supply board may now be interconnected with the aid of Fig. 9. Figure 10 shows the wiring to output sockets and VU meter.

The selector switch and VU meter wiring is as shown in Fig.10 and 11. Note that pins 1 to 9 of the multi-cable socket will have 2 sets of leads, one set from the mixer outputs and one set from the VU meter selector switch. ●



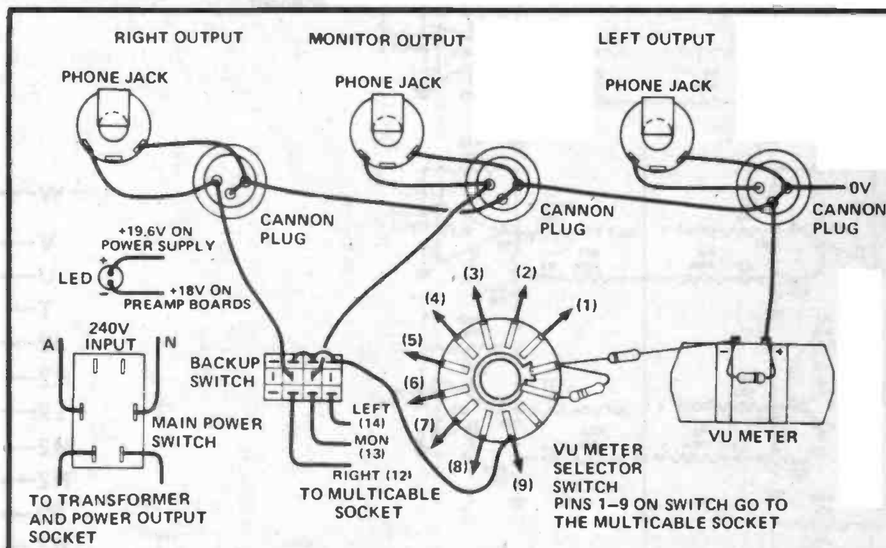


Fig. 10. Interconnection of output sockets VU meter and switch and backup switch.

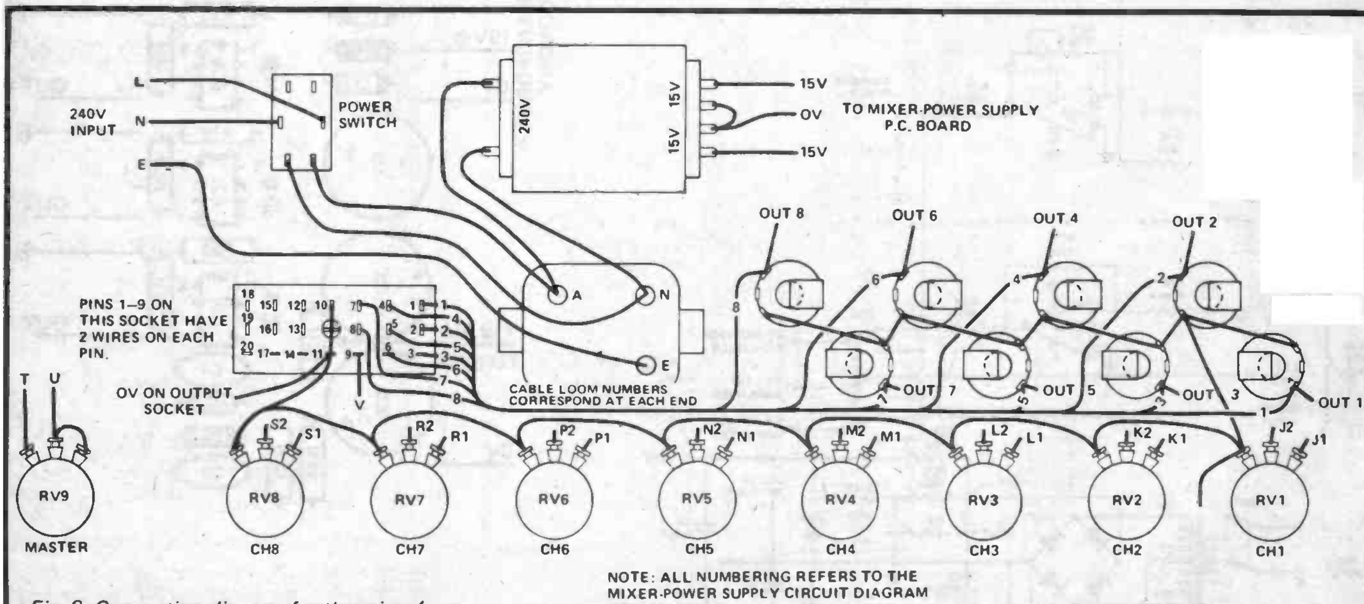


Fig. 9. Connection diagram for the mixer/power-supply board.

This project was designed to be used with our 'Master Mixer' full details of which are in Top Projects 1 + 2. This is a special reprint of 180 pages and costs £2.50 plus 20p postage. Obtainable from: ETI Specials, 25-27 Oxford Street, London W1R1RF. Please mark the reverse of your cheque with name, address and TP 1 + 2. Payment in sterling only please.

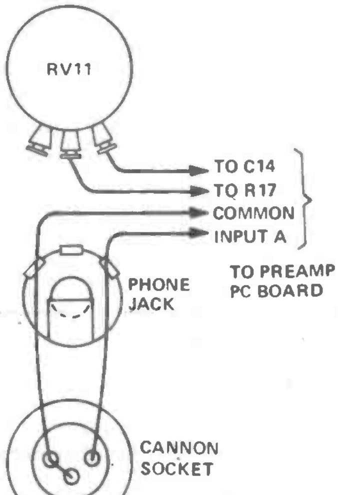


Fig. 8. Wiring to input sockets.

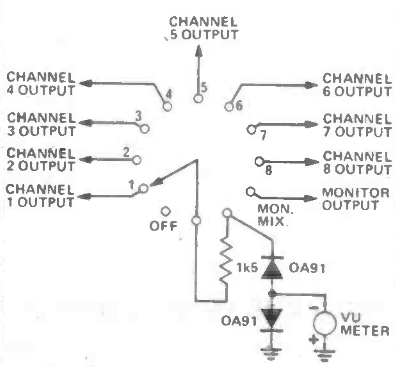


Fig. 11. Circuit diagram of the VU meter.

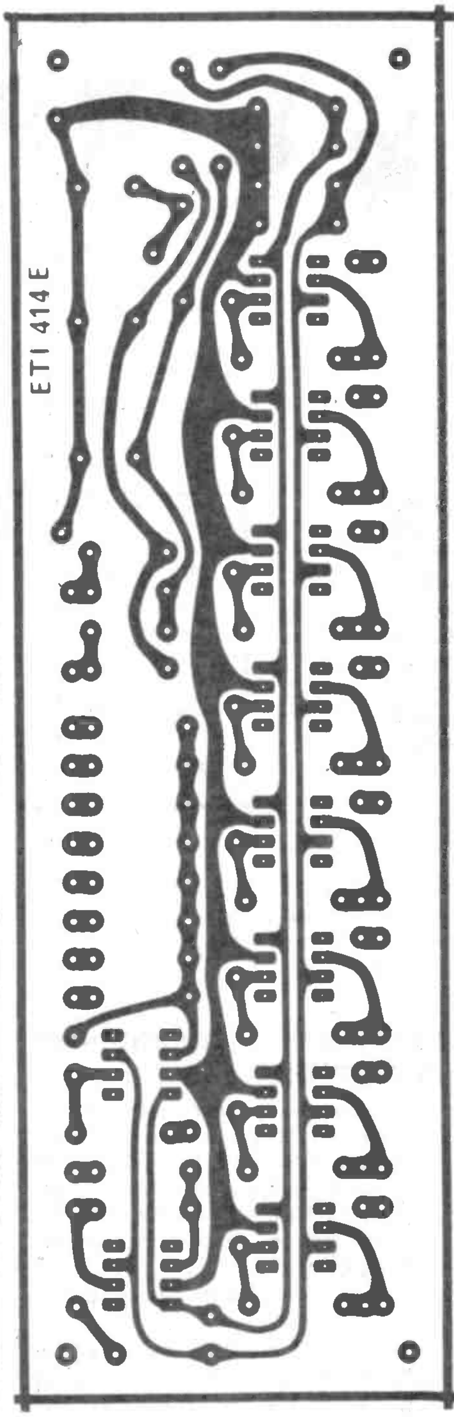


Fig. 6. Printed circuit layout for the mixer/power-supply board. Full size 182 x 57 mm.

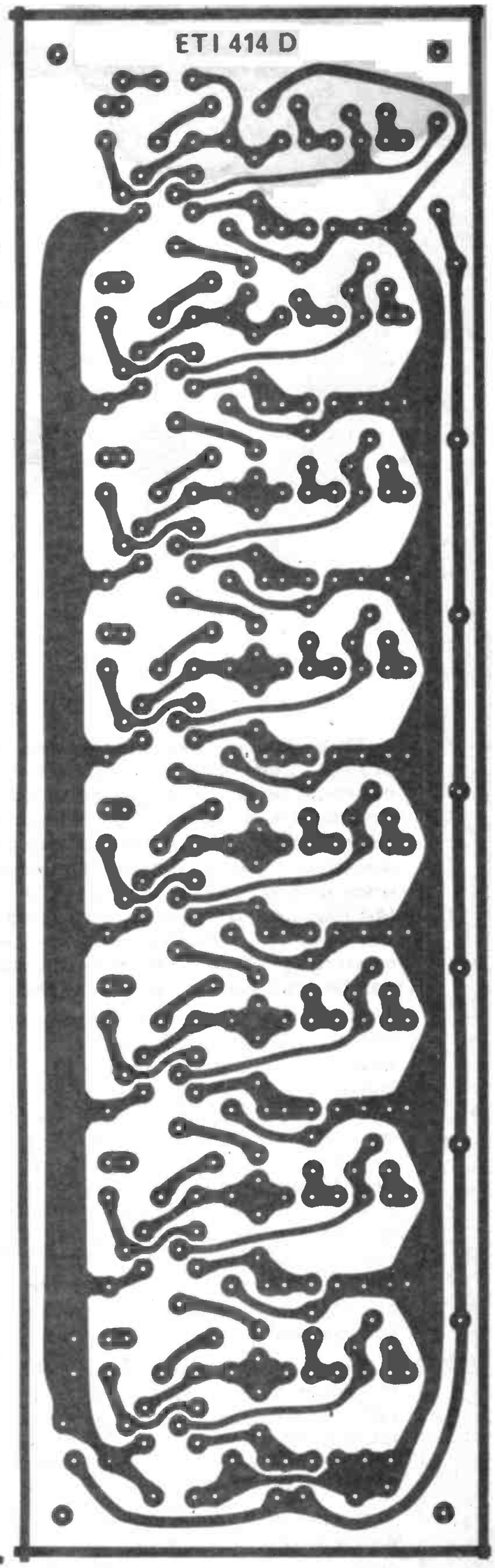
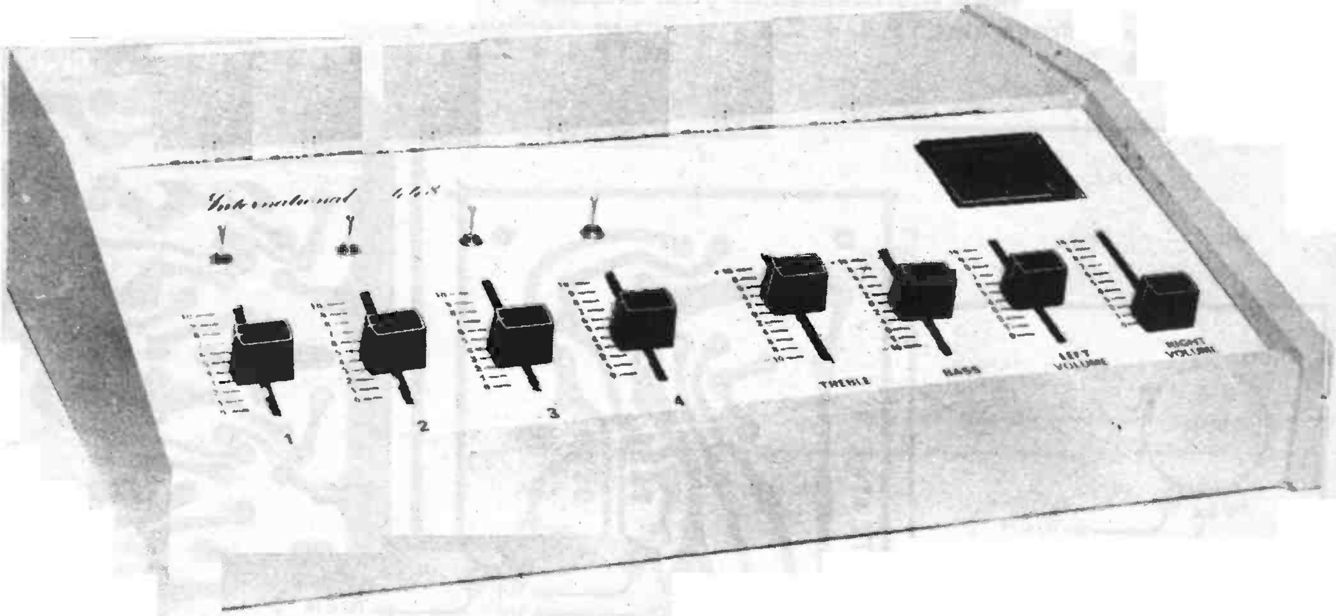


Fig.3. Printed circuit board layout for the preamplifiers (two required for 16 channels). Full size 223 x 63 mm.

DISCO MIXER



This is a general-purpose mixer project that can be tailored by the constructor, to meet specific needs. Five boards are used in the design; Disco mixer board (448); Mono headphone amplifier (448A); Balanced microphone preamplifier (449); Stereo VU circuit (449A), and General purpose preamplifier (445). Also a simple ceramic cartridge preamp is shown — so simple it can be built on the input sockets!

SPECIFICATION	ETI 448
No. of inputs	Nominally 4
No. of outputs	2 main signal outputs 1 headphone amplifier output
Tone controls	Overall bass and treble
Output noise (Mixer stage only)	1 mV (mainly hum)
Maximum output voltage	6 V

Using the boards listed above virtually any audio sources can be mixed by the operator, to provide a stereo signal suitable for driving power amplifiers directly (such as the ETI 413 100 W amps). The mixed signals can also of course be used to feed tape recorders etc. The inputs from turntables, tape recorders, microphones etc must be correctly matched to the inputs of the mixer board. To do this the correct preamplifiers must be selected and constructed.

Our prototype was constructed for use with twin stereo magnetic cartridges, balanced low impedence microphone and stereo cassette recorder. However, the permutations are virtually limitless!

Before beginning construction, decide which preamplifiers you will need (tape recorders do not need any and connect direct to the mixer). Decide what type of sockets you want to use and how many channels you want (although shown as four input the mixer can be expanded by adding extra control pots and mixer resistors).

BALANCED MICROPHONE PREAMPLIFIER

The beauty of this circuit is that it eliminates a costly line transformer! Although designed for 600 ohm input and 40dB gain other impedances and gains can be handled R1 = R4 = input impedance divided by two
R5 = R11 = voltage gain times the value of R3.

The first equation works for impedances up to about 5k. Above this value R2 + R3 must be included in the calculation.

As most people have only one mouth, the output from this circuit can be used to pan the output from stereo by using two 10k resistors or a 20k linear pot with the wiper connected to the output can be used to pan the output from left to right.

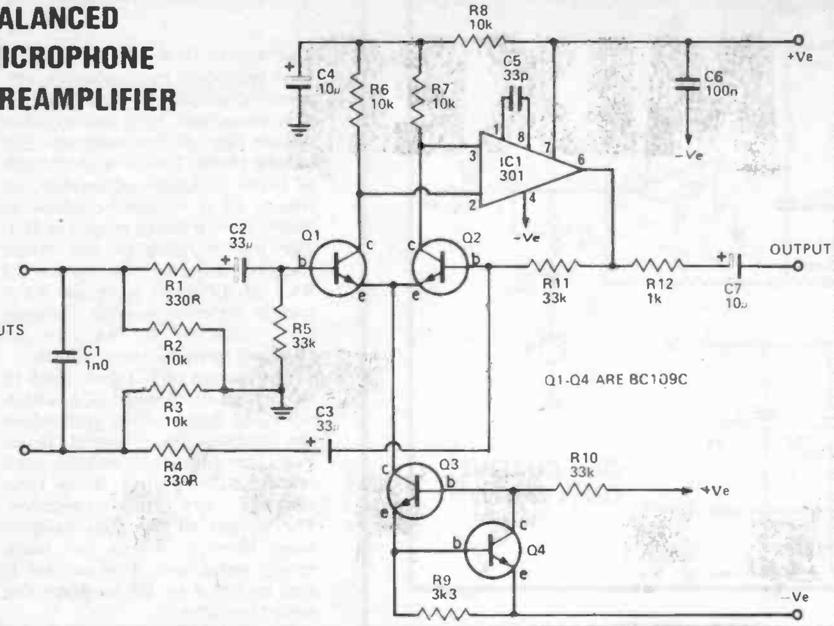
If a high impedance microphone is used ETI 446 should be used.

If 446 is used R2 values are as follows: 47K microphone R2 = 4k7 (limiting R2 47k) if used with balanced preamp as input for limiting R2 = 15k.

MIXER AND POWER SUPPLY

Because of the high ripple rejection of the integrated circuits, used in the various modules, the power supply requirements are simple. A straightforward bridge rectifier, large smoothing capacitors with a RF bypass capacitor and we have an adequate power source.

BALANCED MICROPHONE PREAMPLIFIER



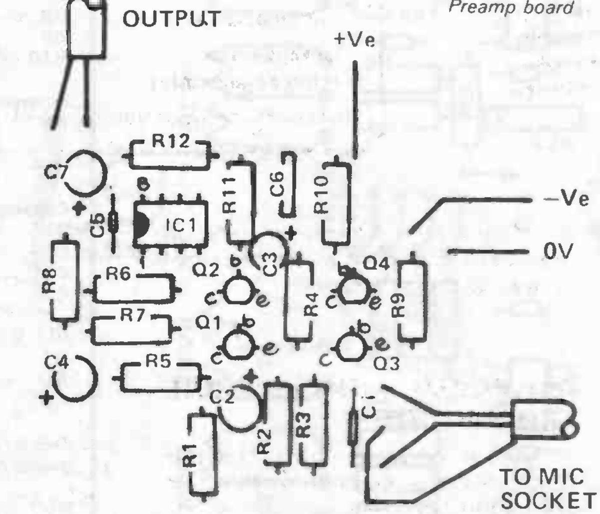
Frequency Response	**10 Hz – 20 kHz (<5 V output) $^{+0}_{-3}$ dB**
Gain	**40 dB**
Equivalent Input Noise	**–123 dB (0.5 μV)**
Distortion	**0.05% 300 mV – 5 V output 100 Hz – 10 kHz**
Max Input Voltage	**100 mV**
Common Mode Rejection Ratio	**60 dB**
Maximum Common Mode Signal	**3 V**

Connection of Cannon plug for microphones

Pin 1	EARTH
Pin 2	BLACK INPUT connect to R1
Pin 3	RED INPUT connect to R4

FOR UNBALANCED INPUT CONNECT PIN 1 AND 2 TOGETHER ON MICROPHONE PLUG.

Overlay of Balanced Preamp board



PARTS LIST ETI 449

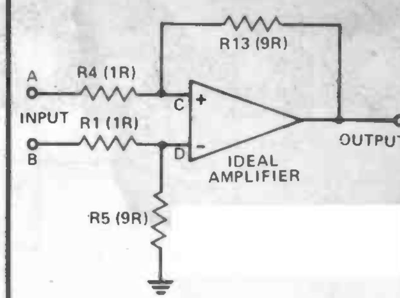
Resistors all 1 W 5%

R1	330R
R2,3	10k
R4	330R
R5	33k
R6,7,8	10k
R9	3k3
R10,11	33k
R12	1k

Capacitors

C1	1n0 polyester
C2,3	33μ 10v
C4	10μ 16v
C5	33p ceramic
C6	100n polyester
C7	10μ 16v
Q1 Q4	Transistors BC 109C
IC1	LM301A
PC Board	ETI 449

HOW IT WORKS ETI 449



A "balanced" amplifier or differential amplifier has two separate inputs and only the difference between these inputs is amplified. To explain how this works refer to figure, which is a simplified version of the circuit. To make the maths easier we will reduce the gain to nine by making R1 = R4 = 1 and R5 = R11 = 9. The actual units are not important, only the ratio.

We will start the explanation by looking at the case where point B is at 0V and A is at +100mV. An ideal amplifier does two things — it does not take any current into the input terminals and it adjusts the output to maintain no voltage difference between the input terminals. We therefore must have 100mV across R4 and consequently a voltage of 900mV across R11 (it has 9 times the resistance and the same current as R4). This gives a gain of nine. The output is therefore —900mV.

In the case when point A is at 0V and point B is at +100mV, point D will be at

$$(VB \times \frac{R5}{R1 + R9}) = 90mV$$

Therefore point C will also be at +90mV. The voltage across R4 will be 90mV and voltage across R1 will be 810mV (9 x 90mV).

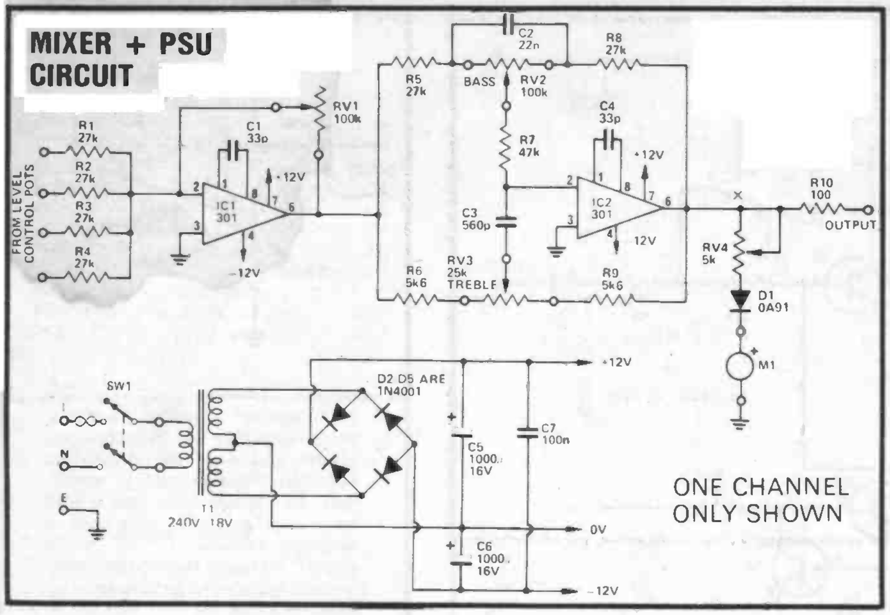
This means the output voltage must be +900mV. This is also a gain of nine. Notice, however, that the polarity (or phase) is different.

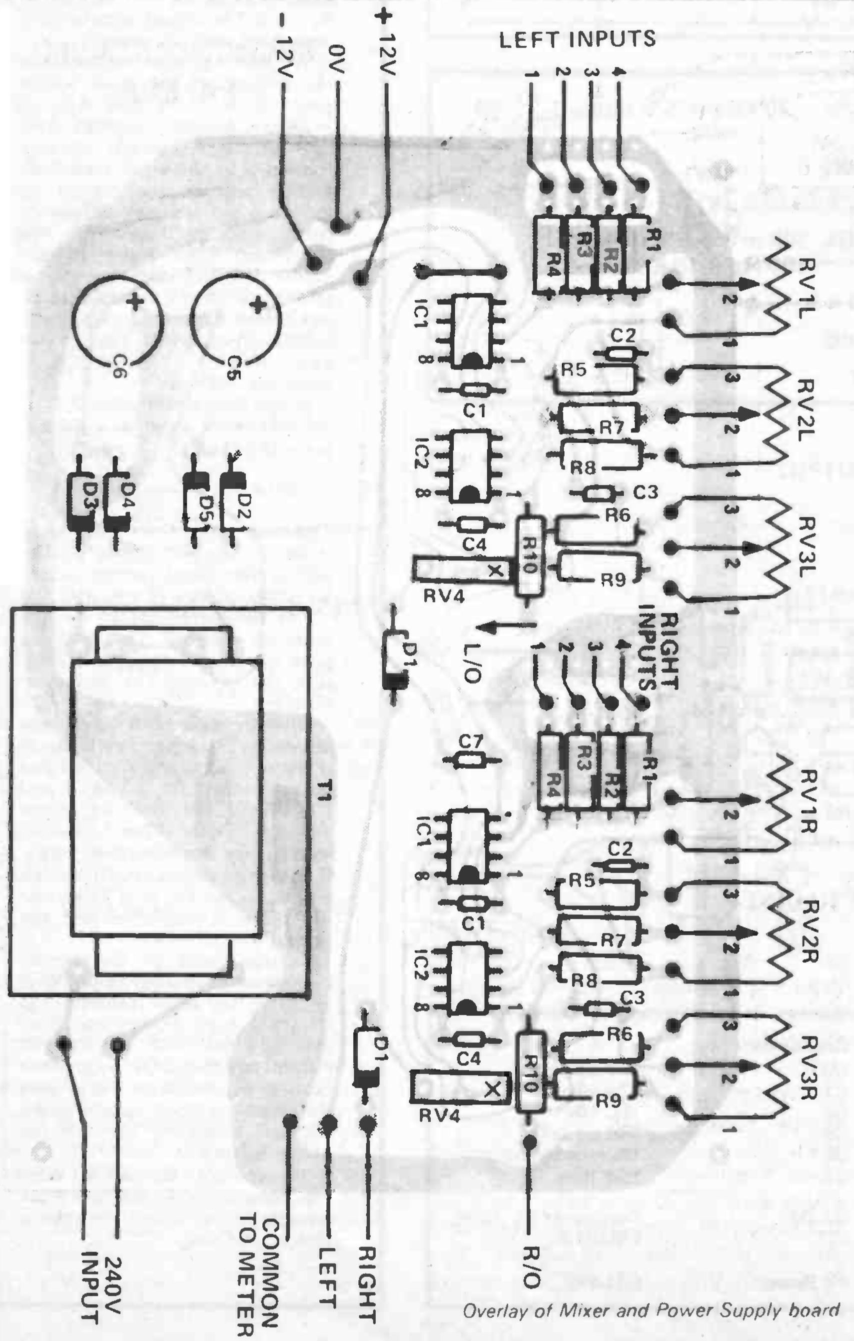
Now suppose both inputs are at, say, +1V, point D will be at +900mV and so will point C. The voltage across R4 is 100mV and R11 900mV. This gives an output voltage of 0V. The common signal is not amplified in any way. If, however, one input (B) is at 1V and the other (A) is at 1.01V the difference is amplified and the output will be —1V.

Getting back to the actual circuit, we have used an LM301A with two low-noise transistors in the front stage. These transistors are supplied with a constant current by Q3 and Q4. A constant current is needed as this allows the inputs to move up and down without changing the voltage across R6 or R7.

The resistors R2 and R3 refer the inputs to 0V but are high enough not to affect the operation in any way.

DISCO MIXER





Overlay of Mixer and Power Supply board

HOW IT WORKS ETI 448

The inputs from the turntables, tape recorders microphones, etc, must be amplified, and if necessary equalized, by a preamplifier before any of the controls can handle them. The output of each of these preamps adjustable, by means of a volume control or fader, before being mixed in IC1. The overall gain of the mixer stage is adjusted by means of RV1. If different preamps have widely differing output voltages the value of R1-R4 can be changed to make them match.

The output of IC1 goes then to the tone control stage, IC2, which normally has a unity gain when the controls are centered. However, this gain is adjustable, with respect to frequency, if the tone controls are not centered. The output of the tone control stage directly drives the main power amplifiers. This output is also rectified by D1 to drive the meter circuitry.

The mixer gives stereo outputs — this is achieved by duplicating the circuitry for the second channel. The exception is the tone controls which are dual gang potentiometers. Note that the volume controls are individual units.

The power supply is simply a full wave rectified supply with a centre tap giving about ±12VDC.

PARTS LIST ETI 448

Resistors all ½w 5%

R1-R5	27k
R6	5k6
R7	47k
R8	27k
R9	5k6
R10	100R

Potentiometers

RV1	100k log single gang slide 45mm
RV4	5k trim

Capacitors

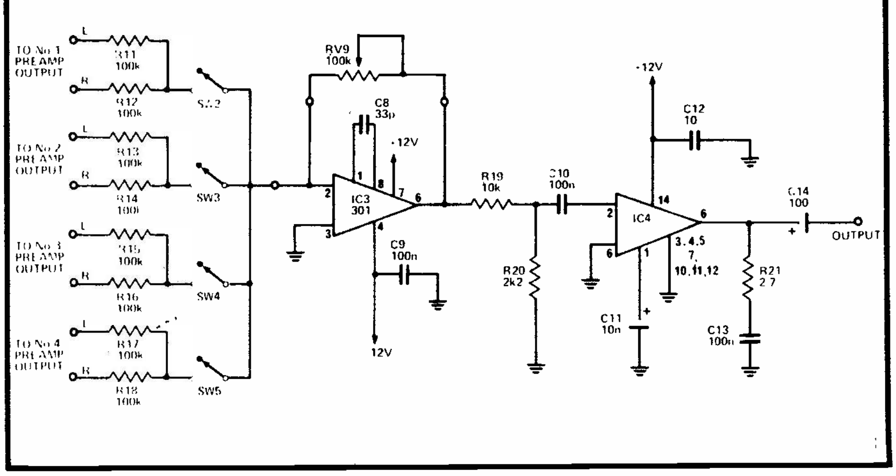
C1	33p ceramic
C2	22n polyester
C3	560p ceramic
C4	33p ceramic
IC1, 2	LM301A
D1	OA91
M1	VU Meter

Two of all the above components are required for stereo operation.

RV2	100k lin dual slide
RV3	25k lin dual slide
RV5-RV8	10k log dual slide
C5, 6	100 16V
C7	100n polyester
D2 — D5	IN4001 or similar
Transformer	240V 9-0-9
pc board	ETI 448
Fuseholder	250mA fuse to match
Switch	2 pole 2 position 240 V toggle

See text

HEADPHONE AMPLIFIER



HOW IT WORKS ETI 448A

The resistors bridging Left and Right channel outputs are to provide a composite mono signal, without seriously degrading the main mixer stereo separation. The signal is selected by SW2-SW5 and fed to a buffer with variable gain (IC3). The output is then fed to a LM380 power amplifier which drives the monitor headphones.

As with the mixer the input resistors can be increased, to reduce high signals to the level of the other channels.

PARTS LIST – ETI 448A

Resistors all ½w 5%

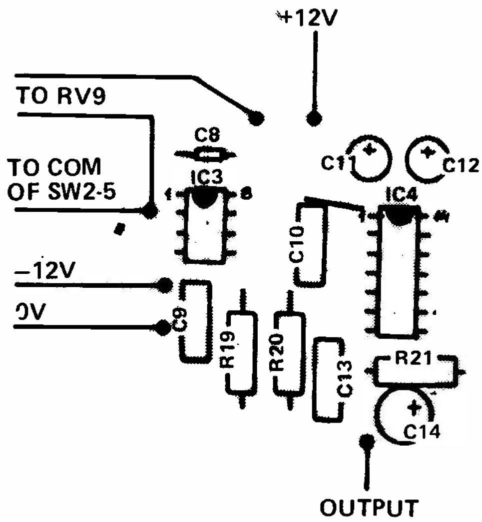
R11-R18	100k
R19	10k
R20	2k2
R21	2.7R

Potentiometer

RV9	100k log rotary

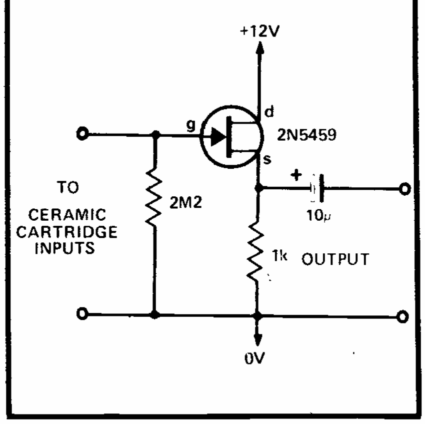
Capacitors

C8	33p ceramic
C9, 10	100n polyester
C11, 12	10µ 16 V
C13	100n polyester
C14	100µ 16 V
IC3	LM301A
IC4	LM380
SW2-SW5	single pole toggle
pc board	ETI 448A



Overlay of Headphone board

CERAMIC CARTRIDGE PREAMP



The mixer is a conventional summing amplifier with variable feedback (ie gain), followed by a Baxandall tone control network.

If input levels are not of the same magnitude, the 27k input resistors can be changed to lower the highest signals increase resister value. Don't reduce below 27k as this will reduce overall sensitivity of the mixer.

The VU circuit can be used, but we recommend the alternative VU board (see VU text).

UNIVERSAL PREAMPLIFIER

Response and gain can be selected from the chart by the components list further details were published in November 76.

HEADPHONE AMPLIFIER

The output from each preamplifier can be switched into this circuit, so that you can cue signals before mixing them into the output. It is suggested that if headphones only are to be used a 100ohm 1 watt resistor be fitted in series with the output. This is to protect your ears and reduce the power dissipation of the LM 380 — otherwise a small heatsink would be required. The volume control can be mounted on the rear of the mixer as it is not adjusted very often.

VU CIRCUIT

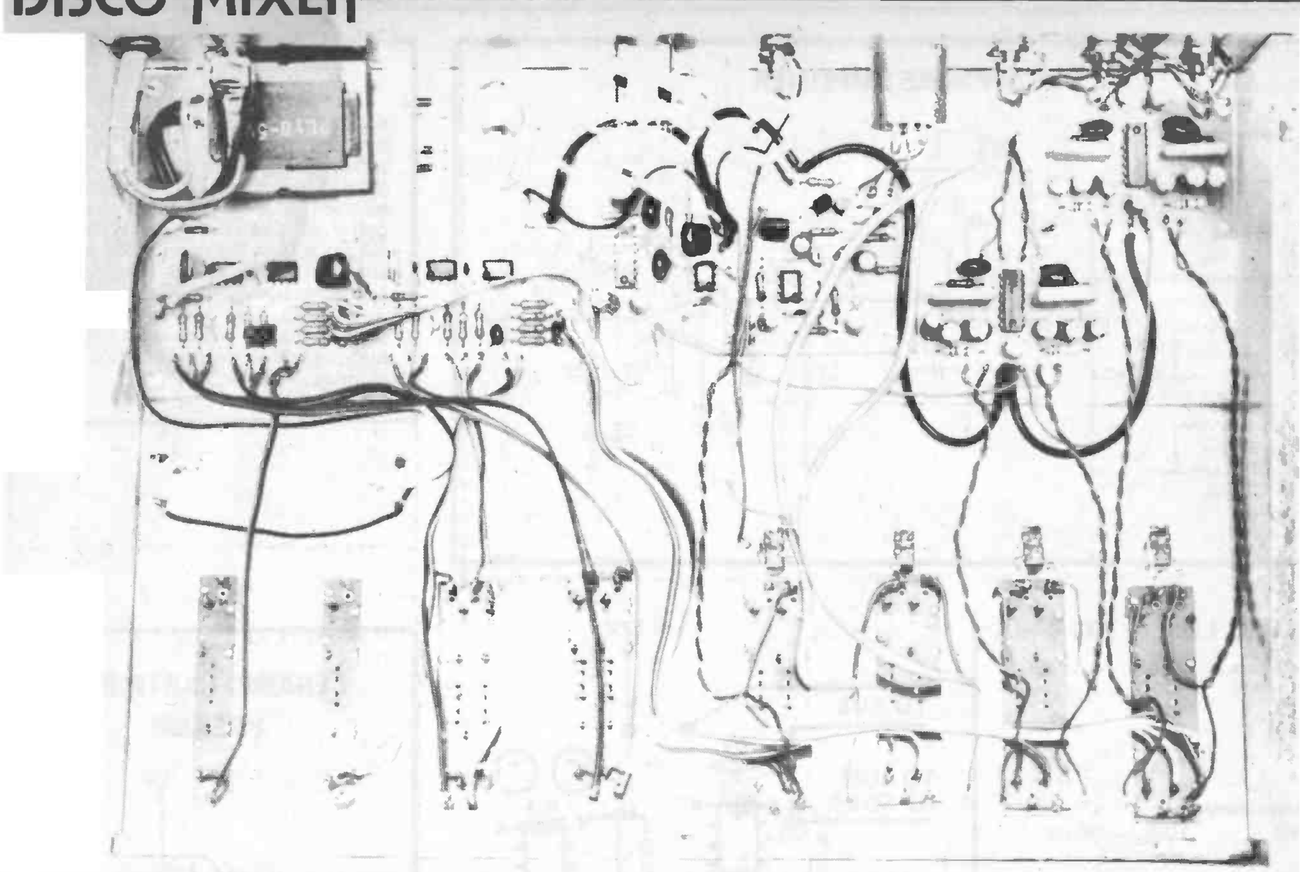
The meter circuit used in the mixer board is very basic — although suitable for some applications — distortion introduced into the output signal is as much as 2% THD.

We strongly recommend the VU board. If used omit RV4 and D1 from the mixer board and connect point X to the input of the VU board. Calibration is by the preset on the VU board, feed a signal through the mixer until the output is just distorting the amplifier, and adjust the preset to indicate +3VU.

CONSTRUCTION

Assemble the boards with the aid of the overlay drawings, for your convenience we have put all the PCB layouts together, on page 22. The photograph on page 21 shows the general layout we used, but this is very flexible, ours was built into a wooden box with metal front and base but a metal box would be more suitable in an electrically noisy environment.

Interboard connections can be worked out from the individual circuits and overlays. All connections should be as short as possible and kept away from the mains wiring. We in fact moved the power switch to the back panel to reduce hum pickup (a metal box, with an aluminium shield around the mains transformer will ensure minimum hum pickup) If this is done unscreened cable can be used internally.



GENERAL PURPOSE PREAMPLIFIER

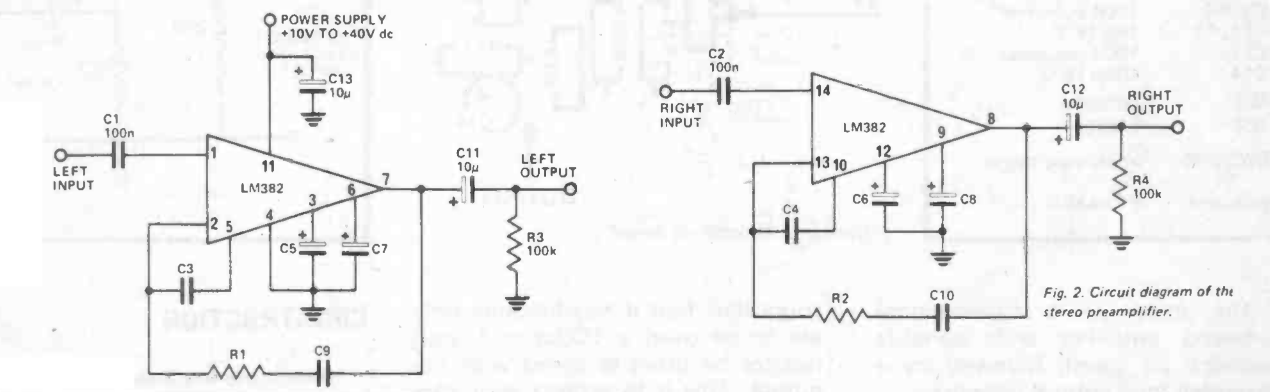


Fig. 2. Circuit diagram of the stereo preamplifier.

PARTS LIST — ETI 445

Resistors

R1, 2 see table
R3, 4 100k ½watt 5%

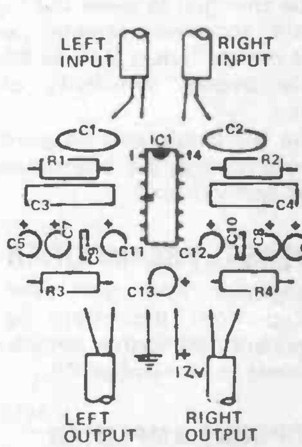
Capacitors

C1, 2 100nF polyester
C3 – C10 see table
C11-C13 10μF 25V
IC1 integrated circuit LM382
PC board ETI 445

HOW IT WORKS ETI 445

Not much can be said about how the LM382 works as most of the circuitry is contained within the IC. Most of the frequency-determining components are on the chip - only the capacitors are mounted externally.

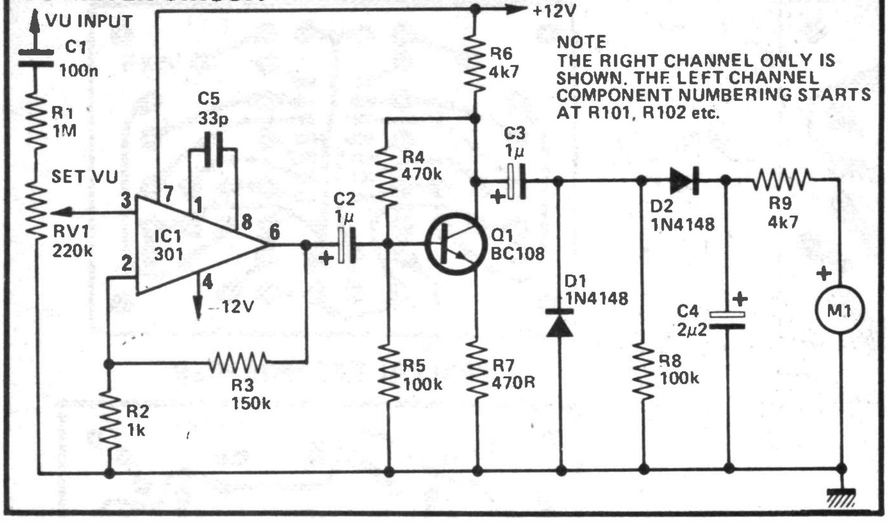
The LM382 has the convenient characteristic of rejecting ripple on the supply line by about 100 dB, thus greatly reducing the quality requirement for the power supply.



Overlay of General Preamp board

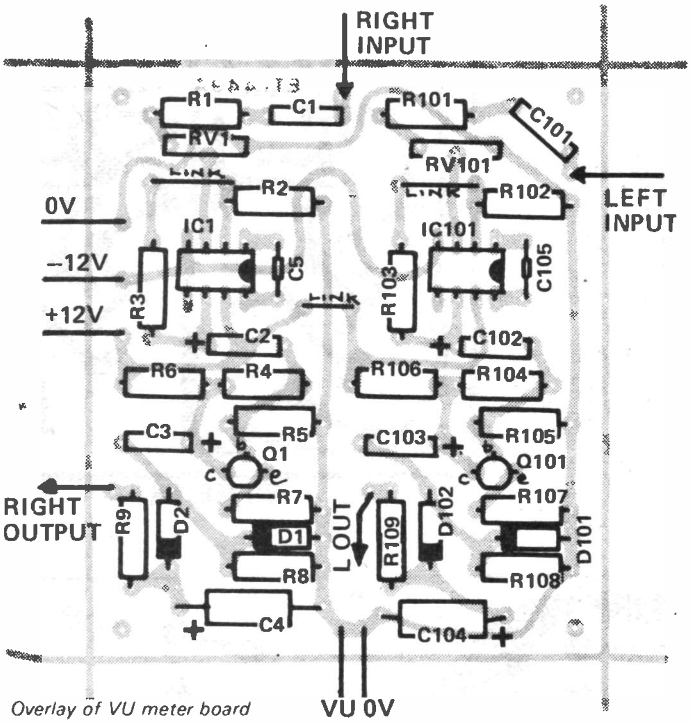
FUNCTION	C3, 4	C5, 6	C7, 8	C9, 10	R1, 2
Phono preamp (RIAA)	330n	10μF	10μF	1n5	1k
Tape preamp (NAB)	68n	10μF	10μF	–	–
Flat 40dB gain	–	–	10μF	–	–
Flat 55dB gain	–	10μF	–	–	–
Flat 80dB gain	–	10μF	10μF	–	–

VU METER CIRCUIT



HOW IT WORKS ETI 449A

This VU circuit has an input impedance in the region of 1M and therefore will not load the mixer output by any discernable amount. The IC has a gain of 43dB, the signal is then amplified again by Q1 to get enough level to drive the VU meter. Under no signal conditions the voltage at the junction of D1, D2 falls to OV because of R8. When a negative going signal appears at collector of Q1, C3 will discharge on the negative peak. Difference between negative and positive peaks is transferred through D2 to C4, and hence to the VU meter.



Overlay of VU meter board

PARTS LIST — ETI 449A

Resistors all ¼w 10%

R1	1M
R2	1k
R3	150k
R4	470k
R5,8	100k
R6,9	5k7
R7	470R

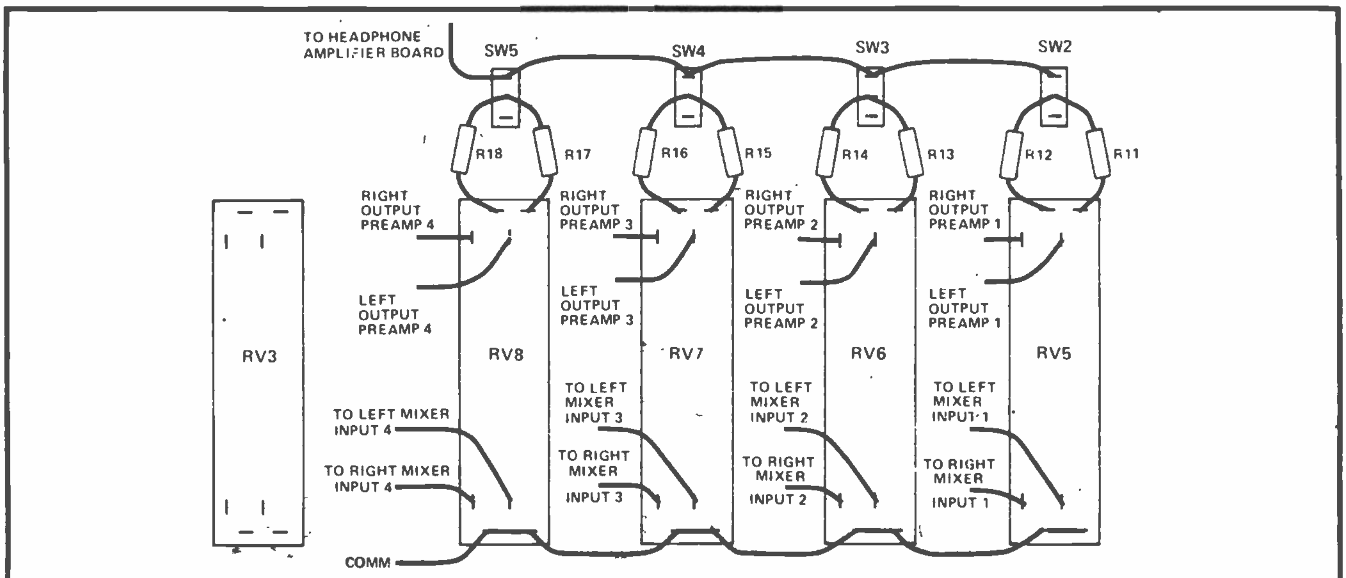
Potentiometers

RV1	220k preset

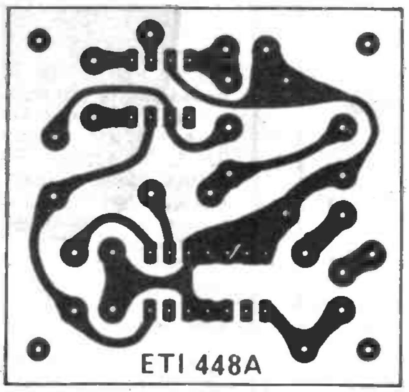
Capacitors

C1	100n polyester
C2,3	1μ 16V
C4	2μ2 16V
C5	33p ceramic
1C1	LM301
Q1	BC108
D1,2	IN4148
M1	VU meter

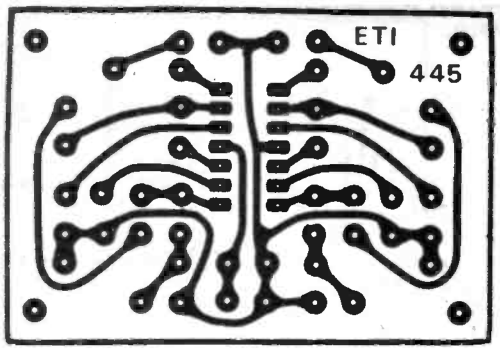
Two of each required for stereo
PC Board ETI 449A



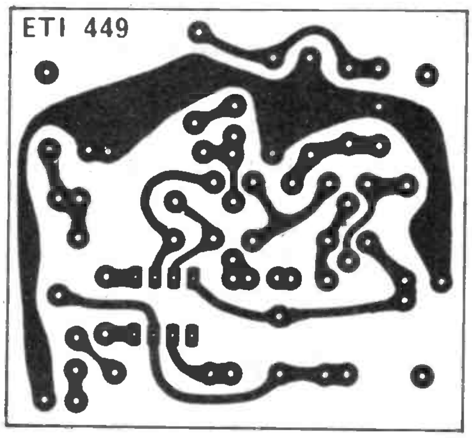
Interconnection diagram of individual volume controls and headphone amplifier selector switches.



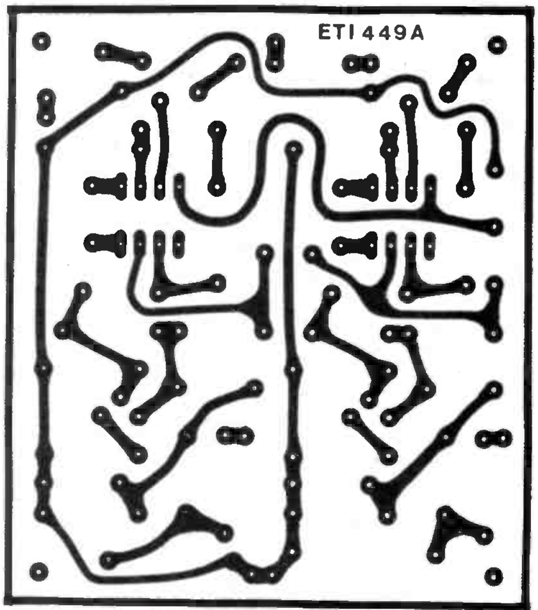
HEADPHONE AMPLIFIER



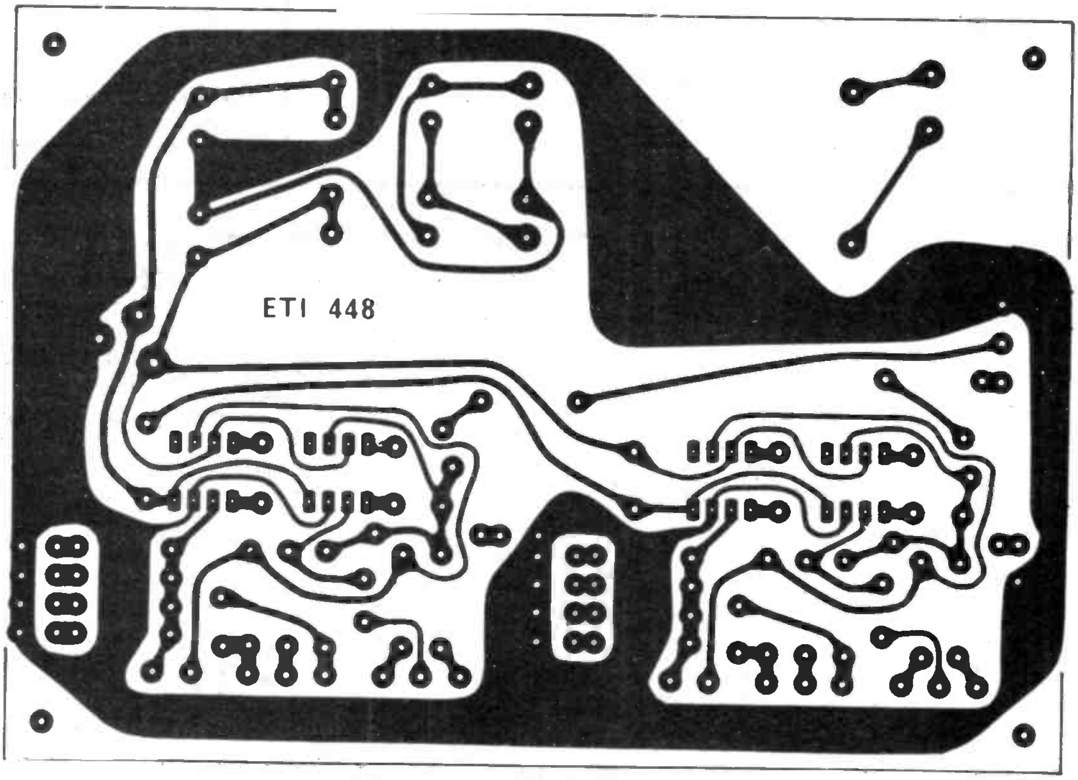
GENERAL PREAMPLIFIER



BALANCED PREAMPLIFIER



VU METER



MIXER AND POWER SUPPLY

TOUCH ORGAN

With all the electronics on one pc board this organ is easy to build yet has features like touch keyboard, variable tremolo, two voices and a full two-octave range.

AN ELECTRONIC ORGAN IS A fascinating instrument which these days seems to be rapidly assuming the position in the home once occupied by the piano. Modern organs are, however, very expensive which puts them beyond the reach of most people. Lower down the scale in cost and performance are chord organs which although still polyphonic are fairly limited reed type instruments operated by a small blower. The name chord organ comes from the fact that the bass accompaniment is by means of buttons which generate the appropriate chord.

The cheapest possible organ is the so called monophonic organ (only one note can be played at a time) which is usually little more than pocket sized and is played with a stylus.

The first obvious improvement required is to devise a better keyboard arrangement as the stylus operation can only be described as somewhat of a nuisance. However the £40 cost of a full keyboard cannot be justified. As can be seen from the photographs the new keyboard is still of the touch type but has now been designed so that the organ is played simply by touching the appropriate key, as in a full scale instrument. Tremolo is also provided and this too is switched on and off by means of touch switches and a control is provided to adjust tremolo depth.

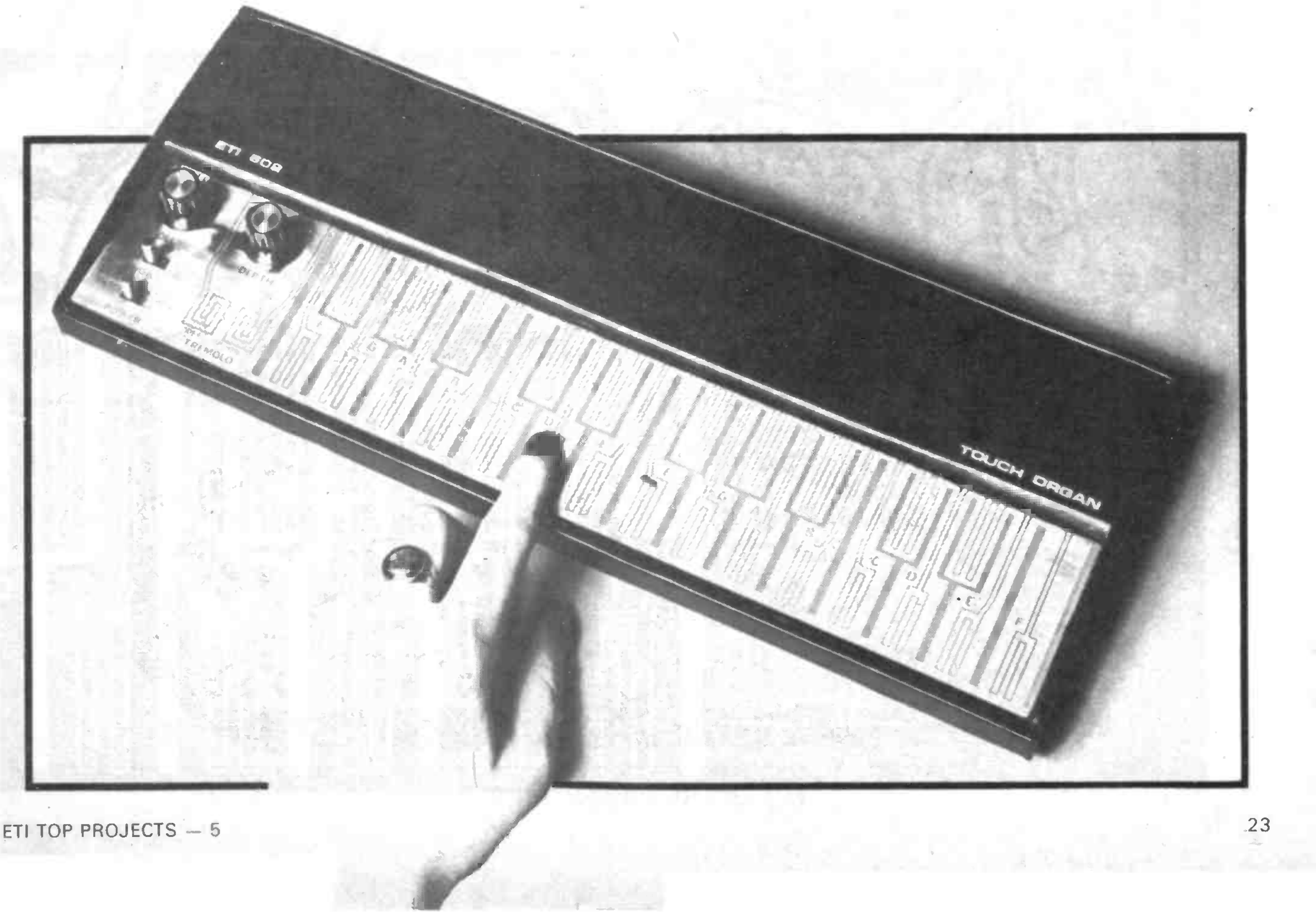
The next improvement is in the accuracy of the tuning, which in the previous instrument varied over the keyboard due to the one-only resistor used to increment between each note. In our new version tuning over the keyboard is much improved by using two resistors, where necessary in series or parallel, to obtain the nearest possible to the correct value of resistance. Finally the instrument is provided with two voices or stops which add greatly to the variety of the music which can be produced.

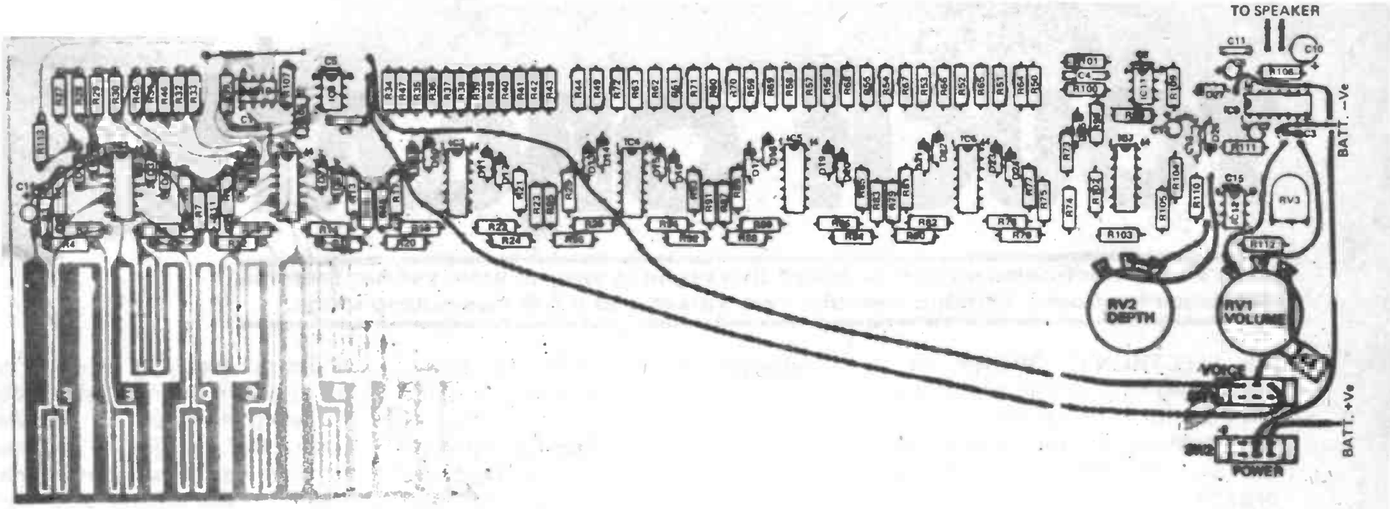
This little organ is relatively inexpensive to build, should provide a great deal of enjoyment and is musically and electronically educational.

DESIGN FEATURES

As mentioned earlier the major feature is the implementation of the keyboard by means of a finger touch system rather than the "probe" type.

This means that some electronics must be associated with each key to detect that it has been touched. Touch control is usually effected by the capacitive, resistive or 50 Hz injection methods. Whilst the capa-





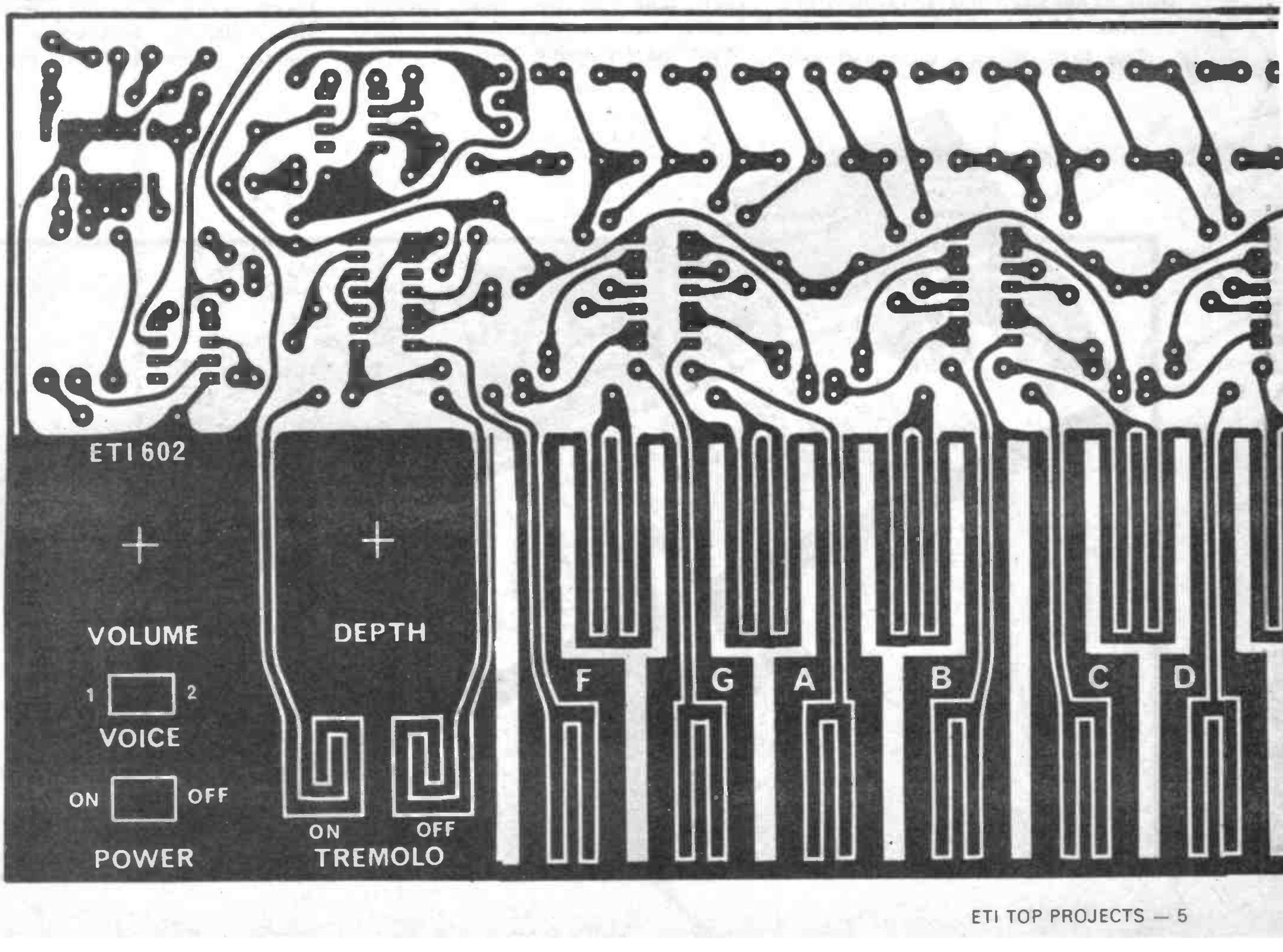
Parts List

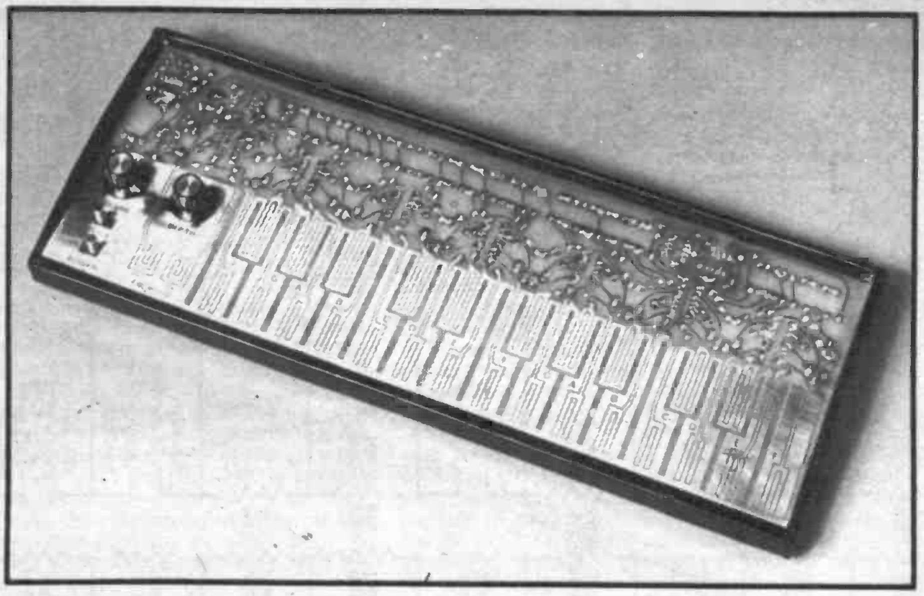
Resistors all ½W 5%

R1,3,5,7	4M7
R9,11,13	4M7
R15,17,19	4M7
R21,23,25	4M7
R2,4,6,8	100k
R10,12,14	100k
R16,18,20	100k
R22,24,26	100k
R27	6k8
R28	330
R29	6k8
R30	390
R31	10k
R32	8k2
R33	1k2
R34,35	10k
R36	270
R37	10k
R38	1k
R39	12k
R40	10k
R41	2k2
R42	8k2
R43	4k7
R44	15k
R45	8k2
R46	68k
R47	220k
R48	330k
R49	120k
R50	180k
R51	560k
R52	270k
R53	180k
R54	22k
R55	390k
R56	4k7
R57	15k
R58	120k
R59	470k
R60	150k
R61	3k3
R62	12k
R63	220k
R64	33k
R65,66,67	27k
R68,69	22k
R70,71	18k
R72	15k
R73,75,77	4M7
R79,81,83	4M7
R85,87,89	4M7
R91,93,95	4M7
R74,76,78	100k
R80,82,84	100k
R86,88,90	100k
R92,94,96	100k
R97	6k8
R98,99,100	100k
R101	820k
R102	4M7
R103	100k
R104	4M7
R105	
R106	
R107	
R108	
R109	
R110	
R111	
R112	
R113	

Potentiometers

RV1	
RV2	
RV3	





100k
5k6
820k
2.7Ω
22k

330k
10k
15k
100k

47k log rotary
47k log rotary
2k trimmer

Capacitors

C1	22n polyester
C2	100n polyester
C3	330p ceramic
C4	100n polyester
C5	33p ceramic
C6,7	4u7 25V electrolytic
C8	33p ceramic
C9	100n polyester
C10	100u 16V electrolytic
C11	100n polyester
C12	4u7 25V electrolytic
C13	100n polyester
C14	100u 16V electrolytic
C15	33p ceramic

Semiconductors

D1-D27	1N914 or similar
IC1 — IC7	4011 (CMOS)
IC 8,11,12*	LM301 or 741
IC9	LM380,SL60745
IC10	NE555

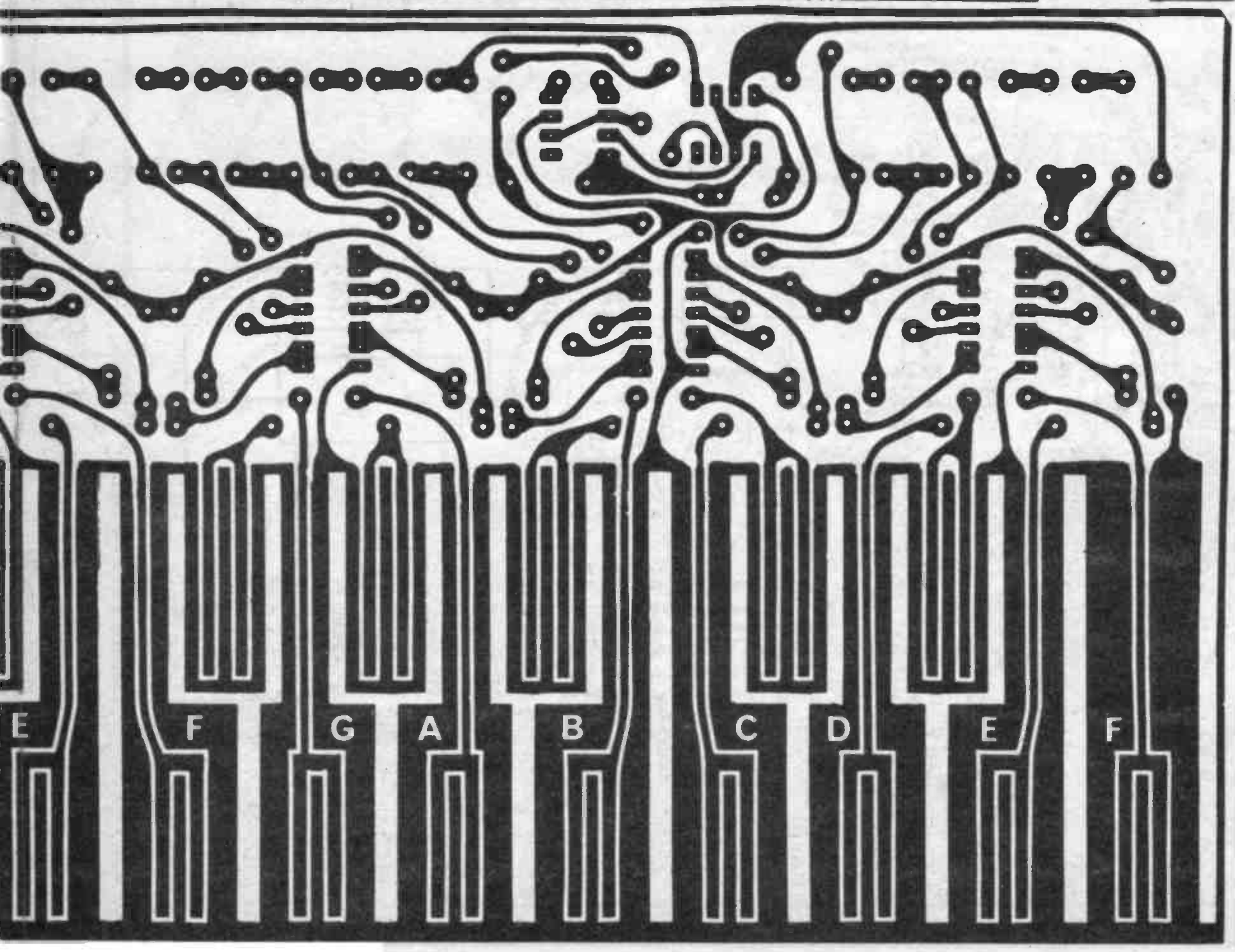
*if 741s are used delete C5,8,15

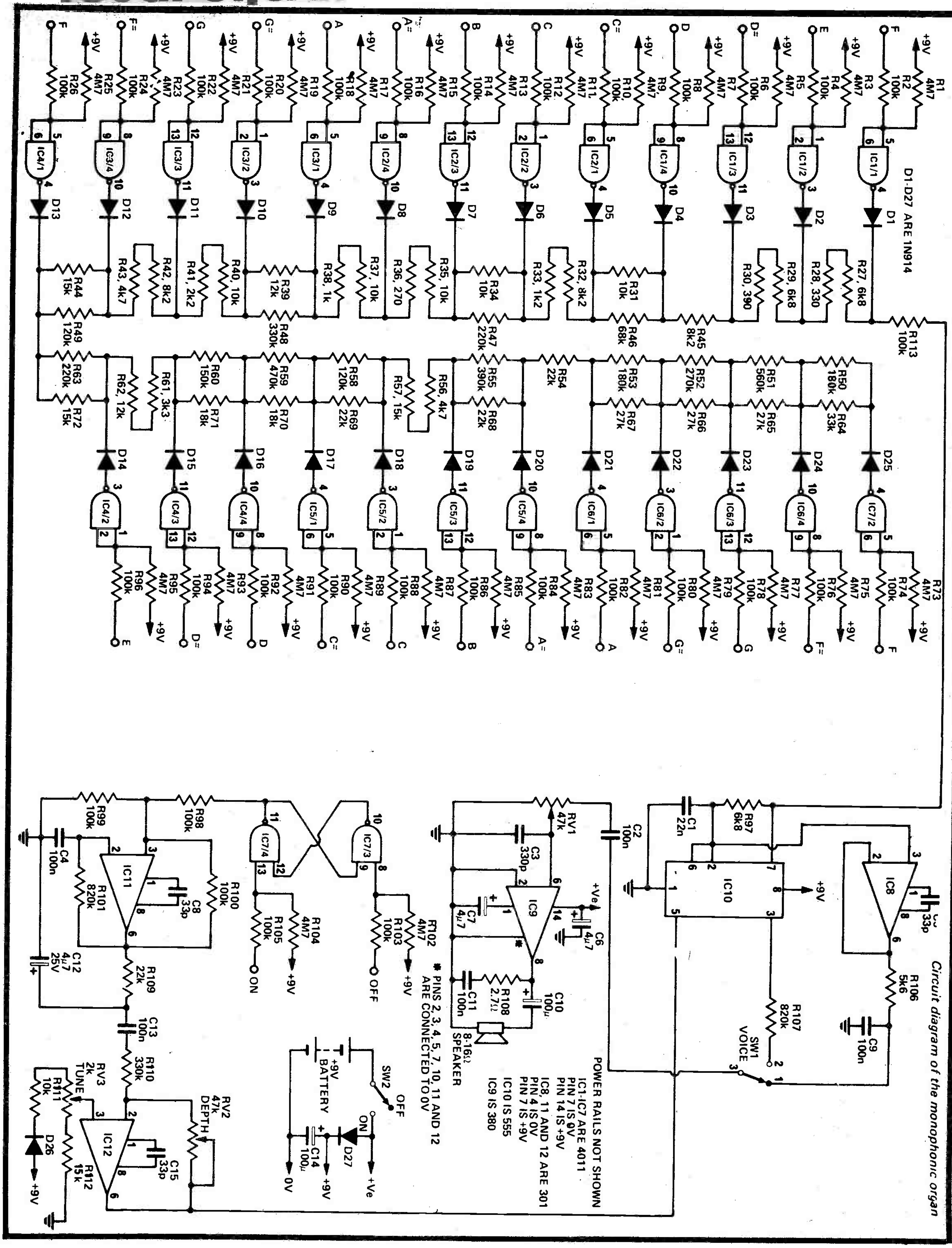
Miscellaneous

SW1,2 single pole, 2 position slide switches
PC board ETI 602
Two knobs
6 way battery holder
Small 8 or 16 ohm speaker
battery clip
case to suit

Frequency of Notes used

F	698.5
E	659.3
D#	622.3
D	587.3
C#	554.4
C	523.3
B	493.9
A#	466.2
A	440.0
G#	415.3
G	392.0
F#	370.0
F	349.2
E	329.6
D#	311.1
D	293.7
C#	277.2
C	261.6
B	246.9
A#	233.1
A	220.0
G#	207.7
G	196.0
F#	185.0
F	174.6





Circuit diagram of the monophonic organ

How it works

Operation of the organ will be described by considering separately the five sections of which it is composed. These are:

(a) Keyboard
(b) Oscillator
(c) Filter
(d) Output amplifier
(e) Tremolo circuit

(a) Keyboard. Unlike the previous organ the keyboard is operated by the contact resistance of the finger and not by a probe. Each key has a CMOS gate associated with it where both inputs to the gate are connected together and to the positive supply via a 4.7 megohm resistor. When the key is touched the inputs of the gate are pulled low (0V) via the 100 k resistor causing the output of the gate to go high. This pulls the corresponding point in the resistor chain high via the diode. Thus by selecting and touching different keys we connect various amounts of resistance between pins 2 and 6 of the 555 oscillator and the positive supply, thus enabling it and varying the frequency determining time constant circuit.

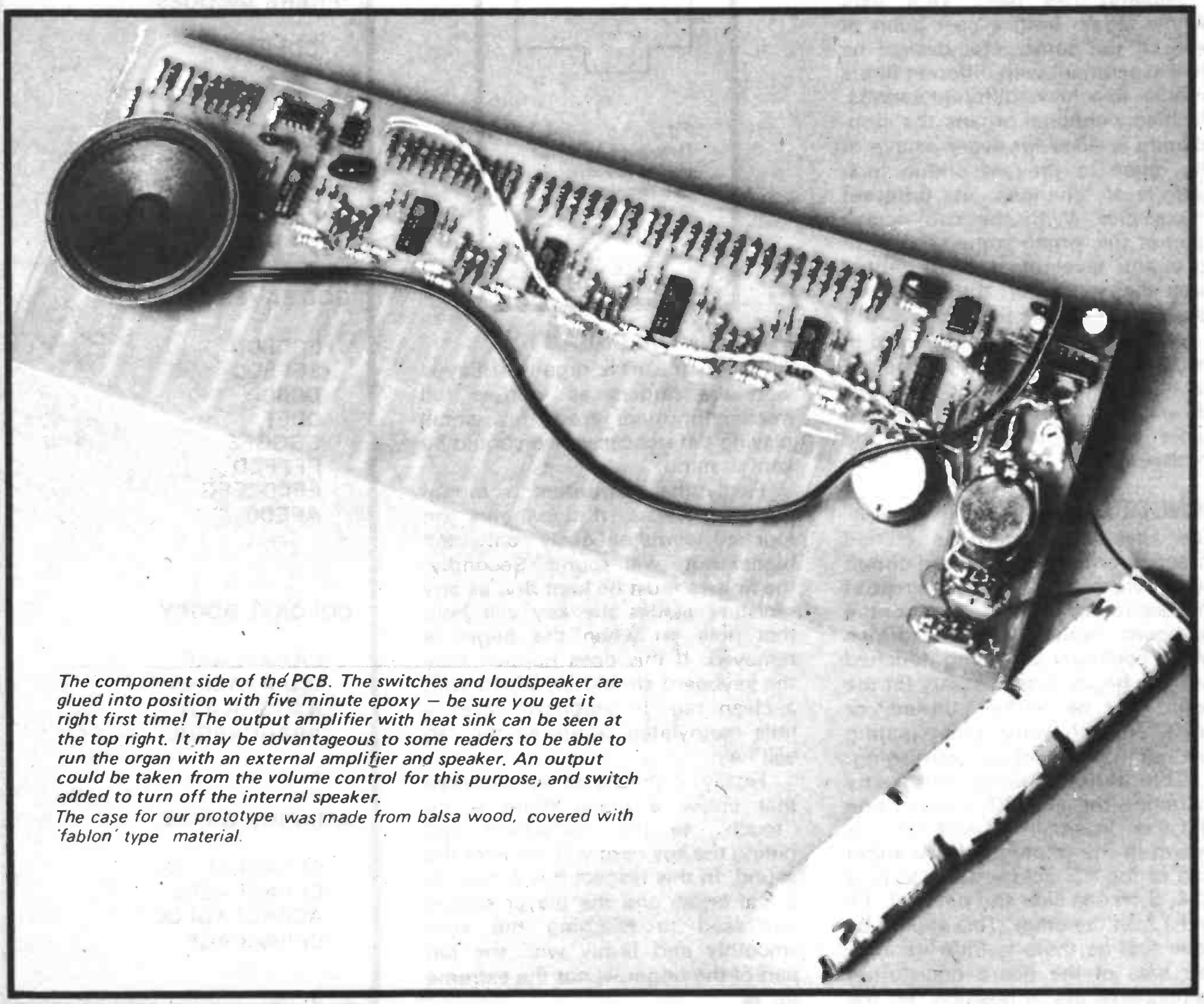
(b) The Oscillator. The oscillator is based on a 555 timer IC. The capacitor C1 is charged up via a section of the resistor chain (as by the keyboard) together with the resistor R113. When the voltage at pins 2 and 6 reaches that set at pin 5, the capacitor is discharged rapidly via R97 and an internal transistor connected to pin 7 of the 555. When the voltage across C1 has dropped to half that set at pin 5, the internal transistor turns off and the capacitor is allowed to charge up again — thus repeating the cycle and generating a sawtooth waveform across the capacitor. This waveform has a high harmonic content but is generated at a high-impedance point. A unity gain buffer is therefore used (IC8) to prevent this output from being loaded by the following circuitry. A second output of a narrow pulse waveform is available at pin 3 of the 555 and this is used to generate a second voice for the instrument.

(c) Filter. A number of different filters were tried but from a cost point of view it was difficult to justify anything more than a simple RC filter on the sawtooth which gives quite a pleasant flute-like effect. As the narrow pulse train sounds somewhat similar to strings it is merely attenuated to match the level of the filtered sawtooth.

(d) The Output Amplifier. The loudspeaker is driven by an LM380. Volume control is provided by means of potentiometers RV1 and the required voice is selected by means of switch SW1. The LM380 should be fitted with heatsink fins as detailed in the construction.

(e) The Tremolo Circuit. Tremolo is produced by means of a low frequency oscillator running at approximately 8 Hz (IC11). The oscillator can be turned on and off by means of the flip flop formed by gates IC7/3 and IC7/4. This flip flop is set to the 'on' or 'off' mode by means of touch switches which operate in exactly the same manner as the main keyboard. To increase tremolo frequency decrease R101 and vice versa.

The output from the tremolo oscillator is filtered by C12 and R109 to give a smoother waveform and the resultant waveform buffered by IC12. The gain of IC12 is adjustable by means of RV2 and this control therefore adjusts the depth of the tremolo modulation. The potentiometer RV3 is a trim potentiometer which effectively sets the output from IC12 to pin 5 of the 555 and thus the frequency of the organ. If it is required to shift the keyboard up or down an octave or so this may be done by changing the value of C1 by a factor of two. If the keyboard tuning is found to be skewed (when tuned correctly at the centre one end of the keyboard is low whilst the other is high) this may be cured by changing the value of R97. If it is sharp at the low end decrease R97 while if flat at the low end increase R97.



The component side of the PCB. The switches and loudspeaker are glued into position with five minute epoxy — be sure you get it right first time! The output amplifier with heat sink can be seen at the top right. It may be advantageous to some readers to be able to run the organ with an external amplifier and speaker. An output could be taken from the volume control for this purpose, and switch added to turn off the internal speaker.
The case for our prototype was made from balsa wood, covered with 'fablon' type material.

citive method is the best of these it is also the most expensive and for this reason is not used. The 50 Hz injection method is also complex and thus the resistive method was considered to be the only practical way from a cost point of view.

As the keyboard is now played by the finger it also needs to be larger than usual although still not quite as large as a full-size keyboard.

In the original concept an OM 802 was used as the tone oscillator. This was replaced by a 555 timer IC as this is cheaper and easier to use. The 555 has two outputs which can be used, a sawtooth wave and a narrow pulse. Both of these outputs are used in our design to provide different voices for the instrument. The sawtooth is filtered by means of a simple RC filter to remove some of the harshness due to the harmonic structure and the resultant voice has a rich flute-like sound. The pulse output is matched in level to the sawtooth by means of a resistive attenuator but is otherwise unfiltered. This voice has a string-like sound.

Filtering has been kept very simple, again from a cost point of view. If the constructor desires he may experiment with different filters in order to achieve different sounds. With conventional organs the stop-filtering is done for every octave of the organ to prevent undue tone and level changes at different frequencies. With the two octave span of this organ some change in tone and level must be accepted over the range of the keyboard when using simple filters.

As attenuating filters are used in the organ plenty of gain is required in the audio stage and for this reason an LM380 is used in the audio output stage to drive the loudspeaker.

CONSTRUCTION

The keyboard pattern is etched directly onto the printed-circuit board which also carries the rest of the electronics. As the copper of the keyboard would rapidly tarnish when continuously being touched with the finger it is necessary for the board to be either tinned or protected with some other plating process that will prevent tarnishing.

Commence construction by mounting the LM380 into position and then fit small heatsink fins, as shown in the photograph, to either side of the IC. Solder them to pins 3, 4, 5 on one side and pins 10, 11 and 12 on the other. This should be done first as there is little room in this area of the board once other components are in position. Fit the two wire links and assemble the low-height components to the board as shown on the overlay.

Mount the remaining ICs last of all and take particular care not to handle the CMOS ICs excessively before insertion. Check the polarities of polarised components such as ICs, capacitors and diodes before soldering them into position.

To avoid having screws showing on the keyboard we glued the two switches into position with five-minute epoxy. Use a piece of printed-circuit board or metal behind each mounting hole to obtain extra glueing surface and extra strength. Mount the potentiometers and wire the complete board as detailed in the overlay diagram.

The complete unit should now be tested to ensure that all notes and functions are operating correctly before mounting into a suitable cabinet.

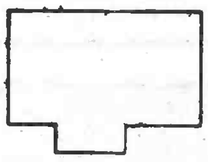


Fig 3
Details of heat sink shown full size, two required material tinplate or thin copper.

PLAYING THE ORGAN

Although the new organ is played with the fingers as with a full instrument there are a few small playing differences which should be kept in mind.

Firstly the instrument is monophonic. That is, if two notes are touched simultaneously only the higher note will sound. Secondly, the fingers must be kept dry, as any moisture across the key will hold that note on when the finger is removed. If this does happen they the keyboard should be wiped with a clean rag. In stubborn cases a little methylated spirits on the rag will help.

Finally, it should be remembered that unlike a piano there is no "touch" to the instrument and hitting the key hard will not alter the sound. In this respect it is similar to a real organ and the player should get used to touching the keys smoothly and firmly with the flat part of the finger — not the extreme tip. ●

TOUCH TUNES

WALTZING MATILDA

VERSE:
EEEDDCDECABC
GCEGGGGGGG
CDEEEDDCDECABC
GCEGFEDDDC
CHORUS:
GGGGE
CCCBA
GGGAGGGFED
CDEEEDDCDECABC
GCEGFEDDDC

HYMM TO JOY (BEETHOVEN'S NINTH)

EFGGFEDCCDEEDD
EFGGFEDCCDEDCC
DECDEFECDEFEDCDG
EFGGFEDCCDEDCC

'FRERE JACQUES'

CDEC
CDEC
EFG
EFG
GAGFEC
GAGFEC
CGC
CGC

GOD SAVE THE QUEEN

CCDBCD
EEFEDC
DCBC
CDEF
GGGGFE
FFFFED
EFEDCEFG
AFEDC

COLONEL BOGEY

CAAA#CAAF
CAAA#ACCA#
A#GGAA#CA
ABAGCABGDC

AMAZING GRACE

CFFAGFAGFDC
CFFAGFAGCC
ACCAGFAGFDC
CFFAGFAGF

—ETI project 446—

AUDIO LIMITER

This simple but effective unit can be used as a limiter, automatic volume control or voltage controlled amplifier.

THE AUDIO COMPRESSOR EXPANDER project described in the May 1976 issue of ETI has proved to be very popular with readers and we have since had many requests for a simpler limiter circuit. Whilst limiters and compressors are similar in operation they are used in completely different ways.

A compressor is normally used in a linear compression mode. That is, for say every 10 dB of input signal level change the output is arranged to change by, for example, 6 dB. The output will change this fixed amount of 6 dB for every 10 dB increment of input. The reverse of this procedure is called expansion. That is, for a 6 dB change in input signal level the output is caused to change by 10 dB.

A compressor/expander is typically used for improving the dynamic range (and hence signal-to-noise ratio) of tape recorders. The signal is first compressed so that its dynamic range can be handled by the tape. On subsequent replay the signal is expanded by a corresponding amount to restore the original dynamic range. As the amount of noise on the tape is constant and the level of signal has been effectively increased, the signal-to-noise ratio has also been increased.

A limiter is a form of compressor which operates only when the signal exceeds a certain predetermined level. For example signals which do not exceed say 80% of the predetermined maximum are not compressed at all and are amplified with their full dynamic range. For signals above the 80% level the limiter begins to operate and very large input signals are required to obtain the extra 20% of output.

Another use of a limiter is in the continuous-limit mode such that it acts as an automatic volume control (AVC). In this mode a 60 dB change in input level can be limited to say, a 6 dB change in output level.

Finally the limiter may also be used as a voltage controlled amplifier having a range of about 55 dB. A typical application of such a device would be a remote volume control. It should be noted, however, that although the transfer function of such a voltage,controlled amplifier is fairly sharp, two of them may not necessarily track perfectly due to differences in the FETs in the ICs. Thus on our prototype the difference between channels when used as a stereo volume control was up to 5 dB at some points with any given input.

DESIGN FEATURES

The first decision to be made when designing a limiter is what type of controlled resistive element to use. Common alternatives are FETs, LDRs, base-emitter junctions of transistors, thermistor or balanced modulator ICs. All of these have their respective advantages and disadvantages and all have been tried in our laboratory at one time or another. We selected FETs because we considered them the most cost effective.

When FETs are used in voltage controlled amplifiers it is essential that the voltage across them is kept as low as possible if the distortion is also to be kept low. This means that the FET must be used as an attenuator where the voltage across the FET can be kept low irrespective of input voltage. The most suitable type of FET for this purpose is the enhancement-mode device but these are not readily available. The commonly available types require a negative voltage to turn them off. However, there is a suitable alternative, the 4049 CMOS IC which contains six inverting buffers. By suitable interconnection the IC may be made to provide six enhancement-mode FETs and this is the approach we decided to use.

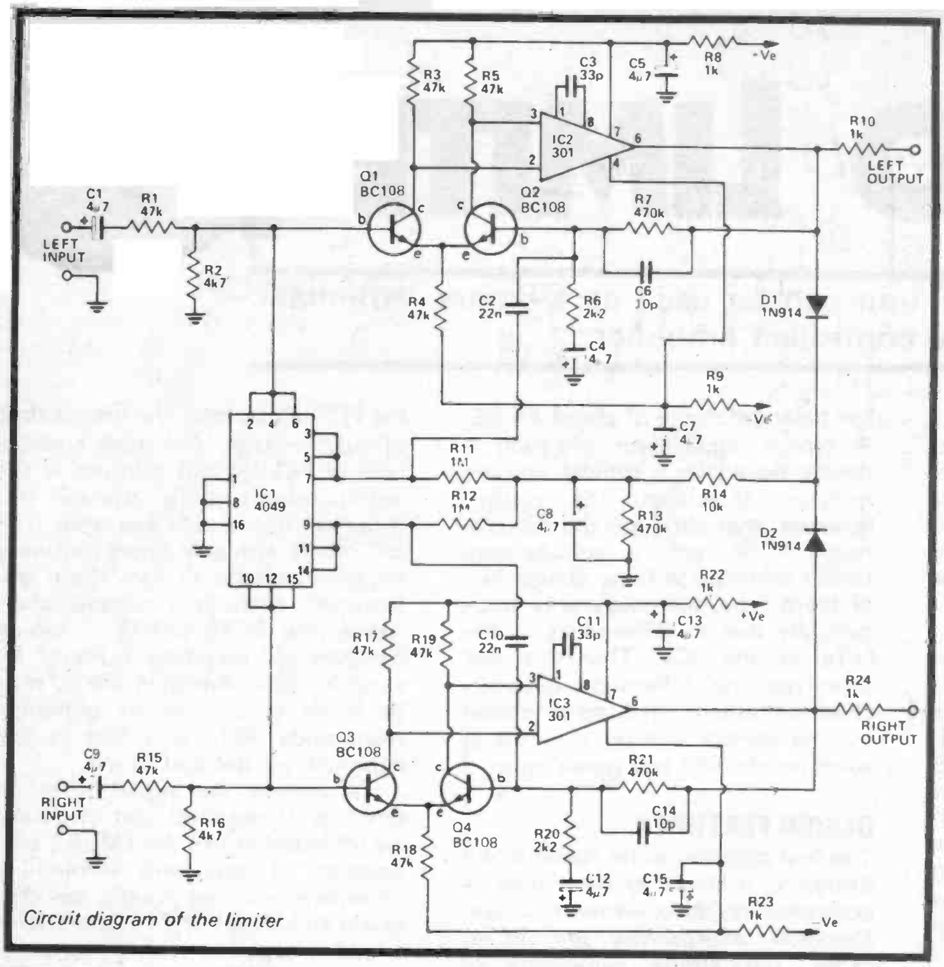
To restore the signal level an amplifier is required and originally we intended to use the LM382 but, because of cost and availability considerations, we finally decided to use an LM301 or 741 operational amplifier together with a transistor pair at the front end. The noise performance of this arrangement was found to be as good as the LM382's and supply voltage to be less critical (although a dual supply is required). If only a single-ended supply is available then a 382 may be used, although a different board layout would be required.

CONSTRUCTION

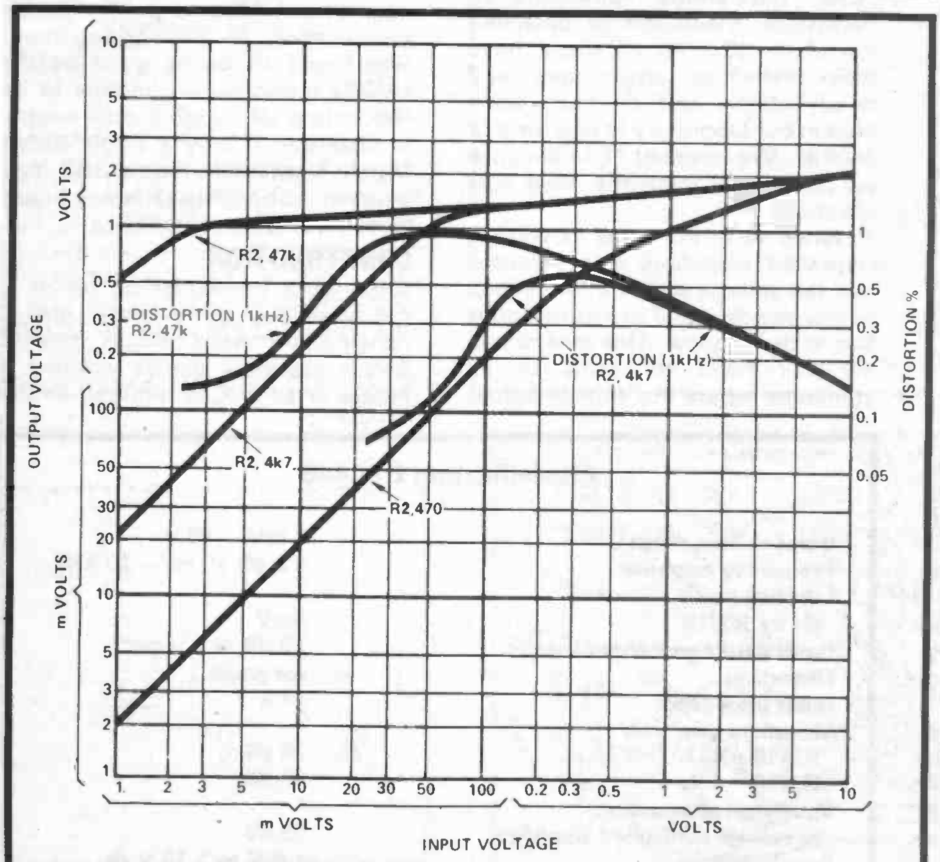
Although a printed-circuit board is not essential it certainly makes construction very much easier. Before assembly decide whether a limiter or an AVC is required as the

Specification ETI 446

Input voltage range	**1 mV – 10 V**
Frequency response	**± 3 dB 10 Hz – 20 kHz**
Limiting point	
set by R2/16	**3mV**
Equivalent signal-to-noise ratio	**70 dB re 1 V out**
Distortion	**see graph**
Input impedance	**47 k**
Maximum gain	
R2/16 = 4k7	**26 dB**
R2/16 = 47k	**40 dB**
Maximum attenuation	
as voltage controlled amplifier	**55 dB**
Supply voltage	**± 8 V to ± 16 V dc at 5 mA**



Circuit diagram of the limiter



Input versus output voltage for various values of R2 (and R16) Distortion at 1kHz for R2=4K7 and R2=47K are also shown.

values of R2 and R16 will vary accordingly. Use 47k for R2 and R16 in the AVC mode and in limit mode, depending on limit point, between 470 and 4k7. The transistor type specified is available from a number of different manufacturers but pin connections are different. If a different brand is used the transistor should be reversed (emitter and collector interchanged). The overlay also shows the arrangement for using the LM301 ICs — these may be directly replaced by 741s simply by omitting the 33 pF capacitors.

Although the CMOS ICs 4449 and 4009 are electrically similar to the 4049 and are interchangeable with it when the devices are used as hex-inverters, they cannot be used as replacements in this circuit. The 4049 must be used. The 4449 and 4009 have different circuitry and will not work in this mode.

How it works

The circuit basically consists of a voltage-controlled attenuator followed by a low-noise amplifier with a gain of 46 dB. The output of this amplifier is rectified to generate a dc voltage which is used to control the attenuator.

The variable element in the attenuator is an enhancement mode FET. This is made from a CMOS hex-inverter IC, the 4049, by special interconnection. The difference between enhancement mode FETs and the normally available depletion-mode junction FETs is as follows: The enhancement mode FET has a high resistance between source and drain when the gate is at zero volts, but this decreases as the gate is taken more positive. A JFET (N type) is hard-on with the gate at zero volts and turns off as the voltage is taken negative.

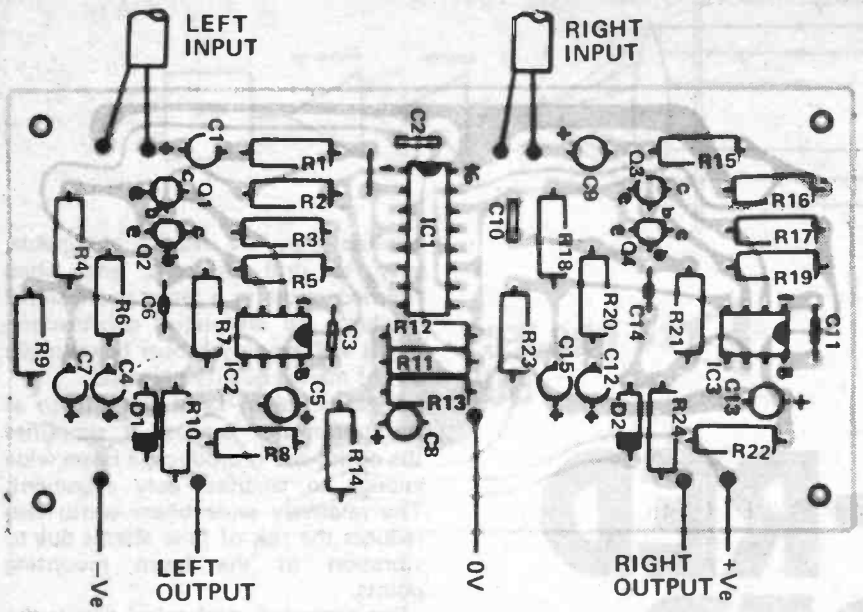
The amplifier is required to have high open-loop gain and have fairly low noise. The gain requirement is provided by an LM301 operational amplifier and the low-noise requirement by a pair of transistors (connected as a differential pair) placed before the operational amplifier. The gain is set, by the combination of resistors R6 and R7, to 215 (or 46 dB). The lower 3 dB point is set at 15 Hz by C4 and R6 whilst the upper 3 dB point is set at 33 kHz by C6 and R7.

The outputs of both channels are summed and rectified by diodes D1 and D2 to charge C8 via R14. The voltage on C8 is coupled to the gate of the FETs (three in parallel on each channel) via R11 and R12.

As the input voltage increases the output also tends to increase and voltage on capacitor C8 also increases and this increase is applied back to the gates of the FETs. This reduces the resistance of the FETs and thus increases the attenuation, tending to prevent the output from changing as much as the input does.

With all FETs the resistance changes with applied voltage and this gives rise to distortion. However by modulating the gate voltage with a signal equivalent to the voltage across the FETs the distortion is greatly reduced (3.5% down to 0.8%).

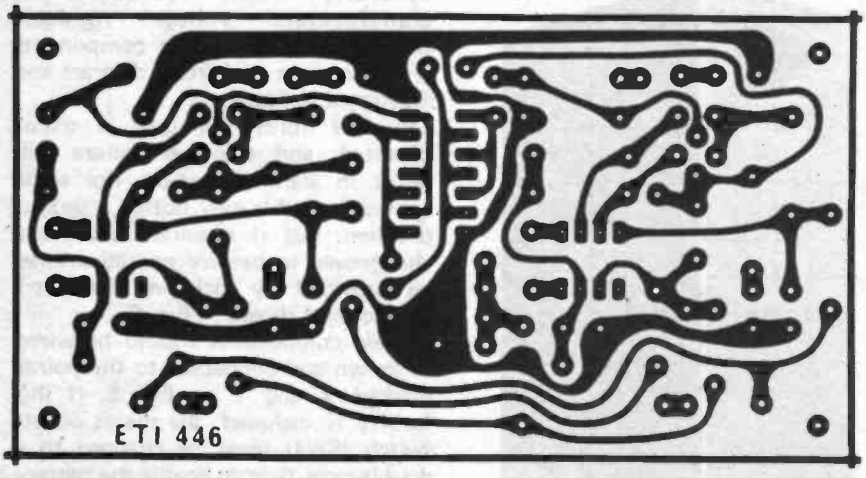
The attack and release times can be adjusted by varying R14 for attack and R13 for release.



Component overlay.

Parts List

Resistors					
R1	47k	½ W	5%	C4,5	4µ7 25 V electrolytic
R2	4k7	"	"	C6	10p ceramic
R3-R5	47k	"	"		
R6	2k2	"	"	C7-C9	4µ7 25 V electrolytic
R7	470k	"	"	C10	22n polyester
				C11	33p ceramic
R8-R10	1k	"	"	C12,13	4µ7 25 V electrolytic
R11,12	1M	"	"	C14	10p ceramic
R13	470k	"	"	C15	4µ7 25 V electrolytic
R14	10k	"	"		
R15	47k	"	"	**Semiconductors**	
				Q1-Q4 Transistors BC108	
R16	4k7	"	"	D1,2 Diode 1N914	
R17-R19	47k	"	"	IC1 Integrated circuit 4049 *	
R20	2k2	"	"	IC2,3 " " LM301	
R21	470k	"	"		
R22-R24	1k	"	"	**Miscellaneous**	
				PC board ETI 446	
Capacitors				9 PC board pins	
C1	4µ7 25-V electrolytic				
C2	22n polyester			**Do NOT substitute a 4009 or 4449*	
C3	33p ceramic			*as the input protection is different.*	



Printed-Circuit layout for the limiter. Full size 58 mm x 110 mm.

As this unit will normally be used in association with another piece of equipment, and most likely built in to it, a case has not been described. When installing the unit make sure that the input cables are coaxial or shielded cable -- outputs are not important and can be normal hookup wire.

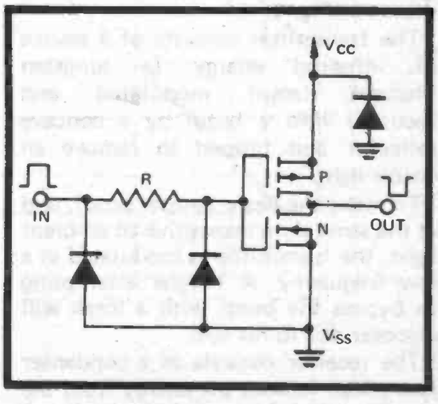
USES OF A LIMITER

Peak Limiting. In this mode only signals above 85% of maximum level are attenuated. This is useful for preventing amplifier clipping (for pop groups or other live shows) which gives rise to objectionable distortion. It may also be used when tape recording the same type of programme material as above, to prevent the tape being saturated, which again would give rise to distortion.

AVC. In this mode, the limiter is used typically to drastically reduce the dynamic range of a programme being recorded. For example, when recording a lecture the 60dB dynamic range of lecture room speech may be compressed to 6dB

Voltage Controlled Amplifier. As a voltage-controlled amplifier the unit lends itself to a variety of remote or automatic control applications. For example, it may be used as a remote control for stereo amplifier volume. Alternatively, it may be adjusted to increase car radio volume as ambient noise level rises.

**IMPORTANT: PLEASE NOTE THAT SOME BRANDS OF CMOS WILL NOT OPERATE IN THIS CIRCUIT. BRANDS THAT WILL OPERATE CORRECTLY ARE:
NATIONAL SEMICONDUCTOR
R.C.A.
'B' SERIES DEVICES WILL NOT WORK.**



Internal circuit diagram of one of the six inverter stages in the CMOS 4049 IC

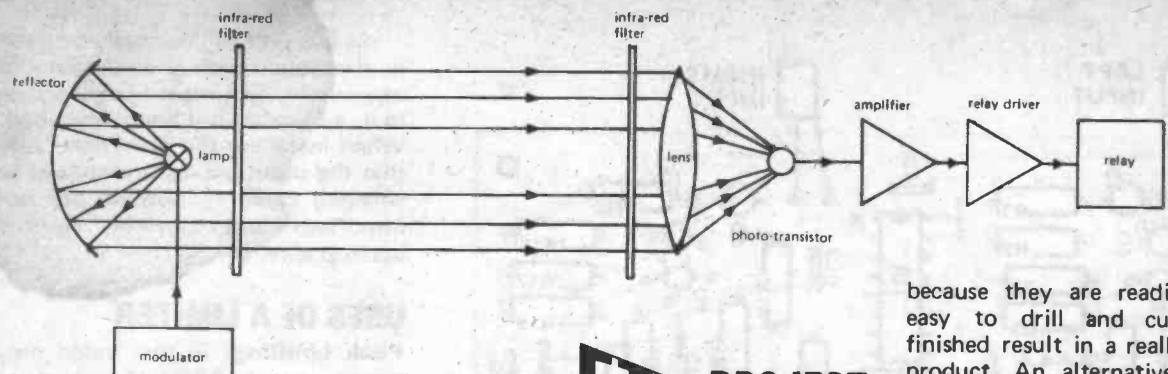


FIG. 1. PRINCIPLE OF OPERATION

ETI PROJECT 506

INFRA-RED INTRUDER ALARM

Sophisticated infra-red intruder alarm has over 200ft. range.

One of the most reliable and efficient devices that can be used to detect the presence of a burglar is the infra-red beam.

The beam described in this project is fail safe and virtually tamper proof. It can be constructed from readily available parts, is easily installed and can be used over a range of at least 200 feet.

An alarm will be given the instance that an intruder passes through any part of the beam.

PRINCIPLE OF OPERATION

The basic principle of operation is shown in Fig. 1.

The transmitter consists of a source of infra-red energy (a tungsten filament lamp) modulated and focussed into a beam by a concave reflector and filtered to remove all visible light.

To make the beam tamper proof, and at the same time insensitive to ambient light, the transmitter is modulated at a low frequency. A burglar attempting to bypass the beam with a torch will discover this to his cost.

The receiver consists of a condenser lens which focuses the energy from the transmitter onto a phototransistor. The output of the phototransistor is amplified and used to drive the alarm relay. A filter is fitted in front of the lens to eliminate unwanted ambient light (such as that from fluorescent tubes).

CONSTRUCTION DETAILS

(a) Mechanical

An excellent method of construction is to build this alarm unit into a pair of diecast boxes. These were chosen

because they are readily obtainable, easy to drill and cut, and when finished result in a really professional product. An alternative construction might well employ timber boxes made out of marine quality plywood.

A sealed beam lamp was chosen as the transmitter because it simplifies the optics and it produces a beam wide enough to facilitate easy alignment. The relatively wide beam width also reduces the risk of false alarms due to vibration of the beam mounting points.

For suggested mechanical details the reader is referred to Fig. 2.

The lamp can be glued to its mounting platform using silicone rubber, Plastibond or Permabond. Although this is a difficult glass to metal joint, we have found the Dow Corning silicone rubber in particular, to be very effective.

(b) Electrical

The electronic components for both transmitter and receiver are contained in the receiver unit. This results in compactness, and because only one printed circuit board is used, construction is relatively easy.

The circuit diagram of the complete unit is shown in Fig. 3.

The component layout, and copper foil side of the printed circuit board are shown in Figs. 4 and 5.

While assembling the board, check carefully the polarity of the electrolytic capacitors, and avoid overheating the transistors whilst soldering.

When the board is complete, recheck carefully, and connect the transformer, voltage regulator transistor Q2, and other components — as shown in the circuit diagram and illustrated in Fig. 7.

In this form the unit is mains operated, and a power failure will result in alarm operation. For some applications this may not be a serious problem; but if required, automatic changeover to battery operation may be provided by including the extra components shown in Fig. 6.

These components should be wired as shown and connected to the points marked X and Y on Fig. 3. If this facility is included, the mains on/off switch (SW1) must be changed to a double-pole type to enable the battery as well as the 240V supply to be switched off when the beam is not required to be in use. The recommended batteries are two Eveready type 731 in series.

TESTING THE UNIT

1. Contact the lamp supply on the printed circuit board to the lamp in the transmitter.
2. Temporarily remove the filters from both transmitter and receiver.
3. Locate the transmitter some 10 to 20 feet from the receiver.
4. Set the latching switch on the receiver to the 'non-latch' position.
5. Connect the 240V supply to the receiver unit and switch on. The lamp in the transmitter should be flickering at a fairly high rate.
6. Align the transmitter so that the beam falls onto the lens of the receiver.
7. Adjust the receiver lens so that the light beam is focussed squarely onto the photo-transistor.
8. Adjust VR1 so that the relay is held closed by the light beam. The relay should open when the light beam is interrupted, but should reclose when the beam again falls on the receiver.
9. Switch the latching switch to the 'latch' position, and again momentarily interrupt the beam. This time the relay should open and stay open.

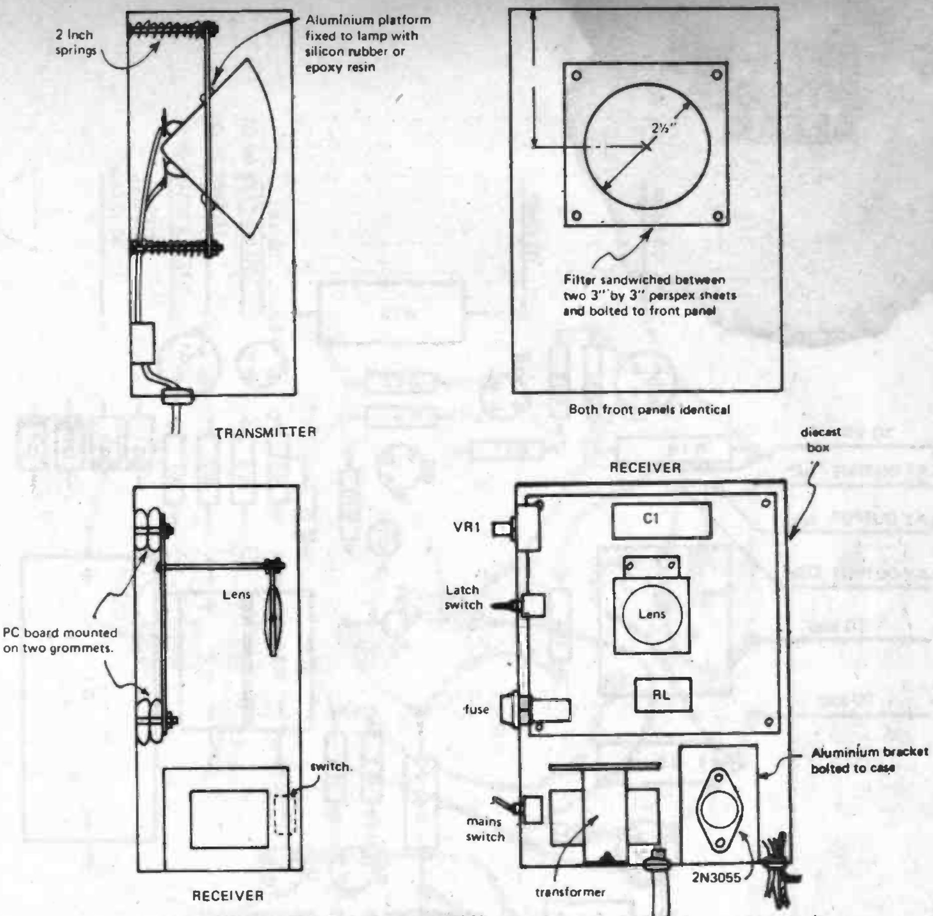


FIG. 2. MECHANICAL CONSTRUCTION

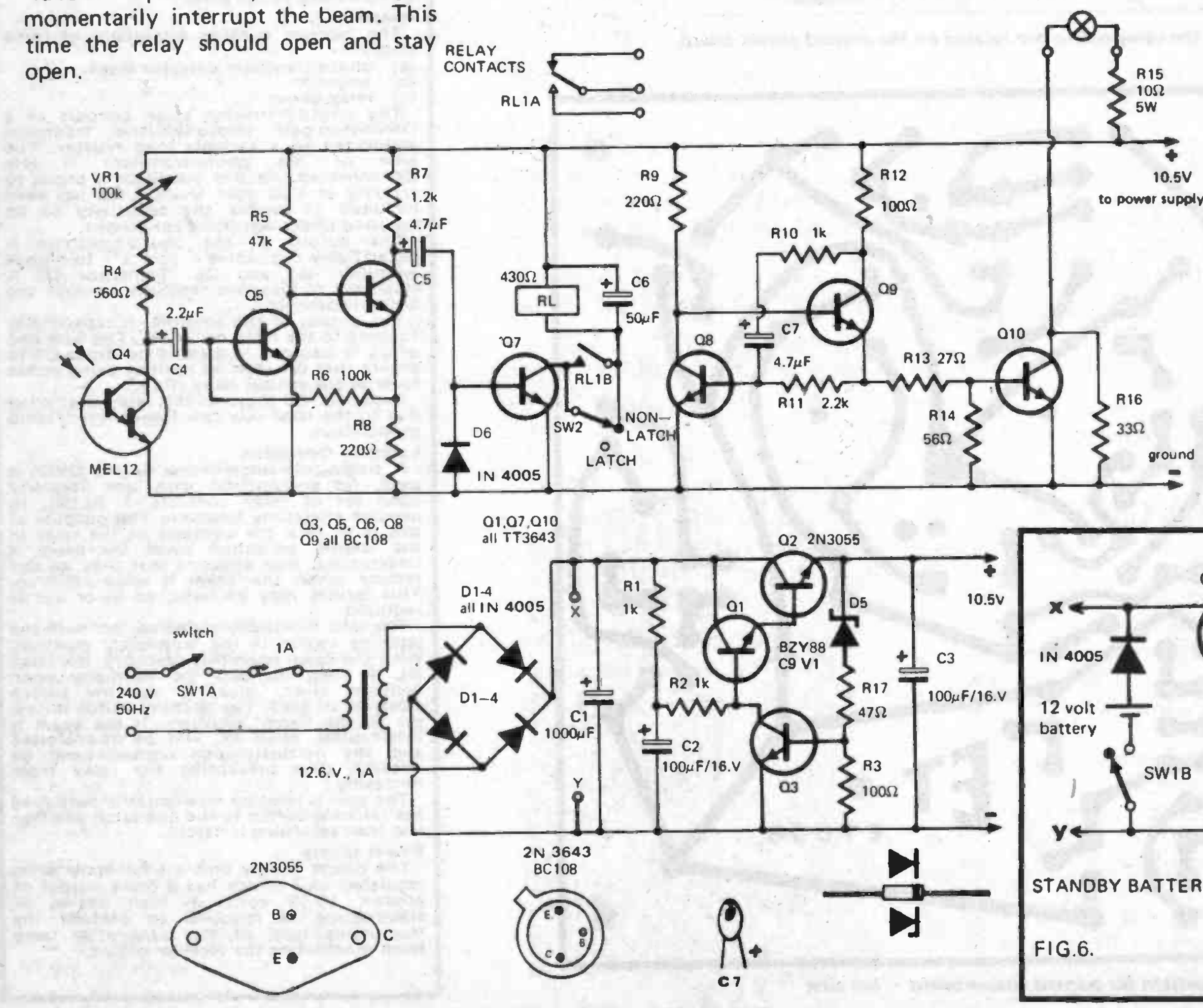
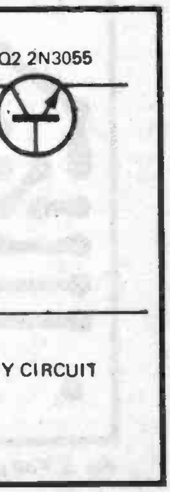


FIG. 3. CIRCUIT DIAGRAM OF COMPLETE UNIT.



STANDBY BATTERY CIRCUIT

FIG.6.

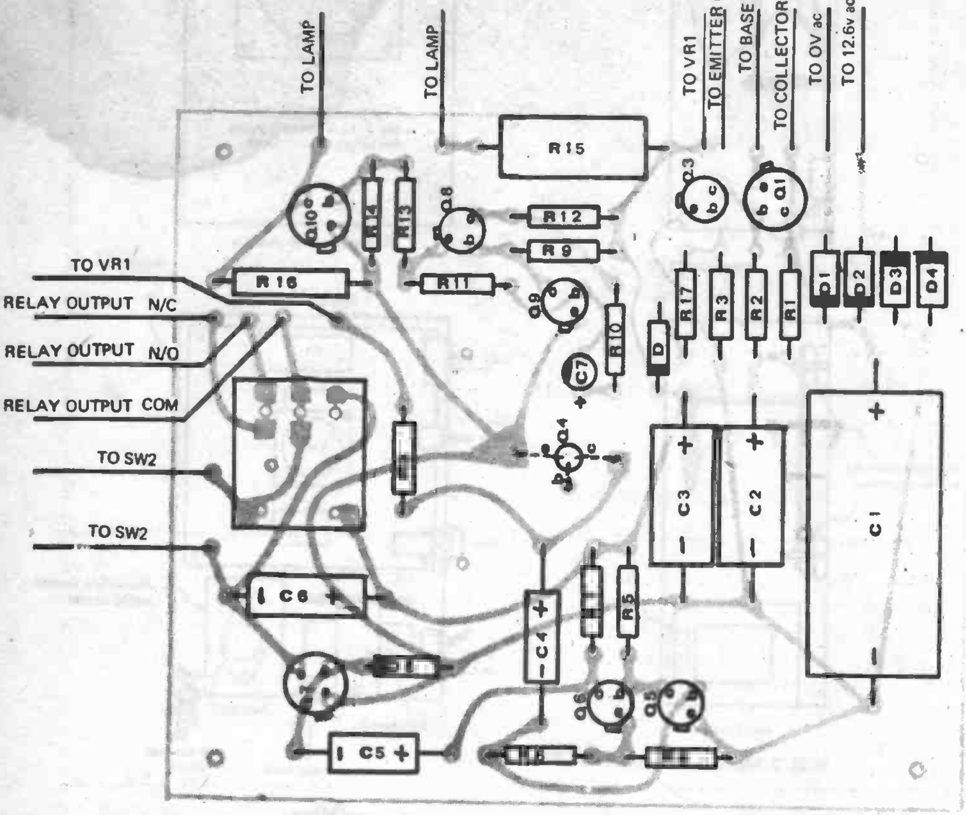


Fig. 4. How the components are located on the printed circuit board.

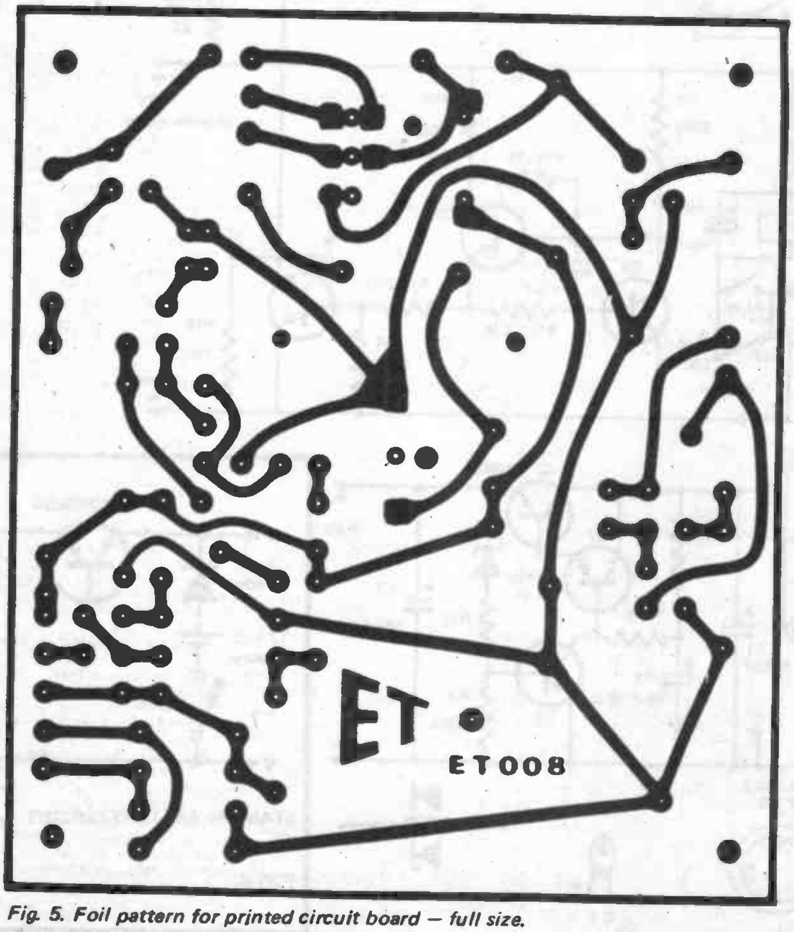


Fig. 5. Foil pattern for printed circuit board — full size.

INSTALLATION

The lamp mounting platform has been mounted on springs to enable the beam alignment to be adjusted after the transmitter box has been finally located.

However a useful precaution is to temporarily locate the transmitter at the designated point, connect the beam, and with the filter removed, ensure that the light beam falls on the point designated for the receiver.

Temporarily remove the filters from both transmitter and receiver and align the beam so that it falls squarely onto the photo-transistor.

Refit the filters and with the latching switch in the non-latch position adjust RV1 so that the relay is held in by the

HOW IT WORKS

Transmitter

Transistors Q8 and Q9 form a type of astable multivibrator of which the frequency of oscillation is determined primarily by C7.

Lamp driving transistor Q10 is switched by the positive pulses appearing across potential divider R13/R14. Resistor R16 biases the lamp, and by so doing, reduces the current flow through Q10.

For the lamp specified in this project, R16 should be approximately 33 ohms. The correct value should be such, that with the base of Q10 disconnected, the lamp filament can be seen just barely glowing when viewed in the dark.

Receiver

The receiver consists essentially of three stages:—

(a) photo-transistor detector stage
(b) amplifier
(c) relay driver

The photo-transistor stage consists of a Darlington-pair photo-sensitive transistor connected to a variable load resistor. The base of the photo-transistor is left disconnected. As this transistor is prone to saturate at high light levels, VR1 has been included to enable the sensitivity to be adjusted under operating conditions.

The output of the photo-transistor is capacitively coupled to a two-stage amplifier, Q5 and Q6. Transistor Q5 is stabilised by negative feedback through the 100k resistor R6.

The output of the amplifier is capacitively coupled to the relay driver Q7. The base end of C5 is clamped to ground by diode D6 to ensure that Q7 receives positive going pulses to drive the output relay (RL).

Capacitor C6 prevents this relay chattering due to the relatively low frequency of lamp modulation.

Latching Operation

A single-pole single-throw switch (SW2) is used, (in conjunction with one normally open set of relay contacts — RLIB), to provide a latching function. The purpose of this is to lock the contacts of the relay in the 'alarm' condition when the beam is interrupted, thus ensuring that they do not reclose when the beam is again restored. This facility may be switched in or out as required.

The unit is initially switched 'on' with the latching switch in the 'non-latch' position. With the beam operating normally, the relay RL is held in, and the normally open contacts close, shorting out the switch contacts of SW2. The latching switch is now set to the 'latch' position. If the beam is interrupted, relay RL will be de-energised and the normally-open contacts will be released thus preventing the relay from re-closing.

The unit is reset by momentarily switching the latching switch to the non-latch position and then returning it 'latch'.

Power supply

The power supply unit is a full-wave series regulated unit which has a fixed output of approx 10.50 volts. A high degree of stabilisation is required to prevent the fluctuating load of the transmitter lamp from modulating the receiver circuit.

beam; check that there is some reserve 'power' by momentarily blanking off part of the receiver lens. The relay should not drop out.

Set the latching switch in the 'latch' position and check that the relay remains locked out when the beam is momentarily interrupted.

The relay specified has two sets of change-over contacts. One set (RLIB) is used for the latching function, the second set (RLIA) is used for the alarm output. These latter contacts may be used in the conventional way to switch an external battery and bell circuit, or may be wired to the normally closed inputs of any commercial alarm system.

The maximum range of the beam depends upon whether or not it is to be used in daylight. The range at night may exceed 500 feet, but if daylight operation is required the range may be restricted to 100 feet to 200 feet.

Try to arrange the receiver so that direct sunlight never falls onto the lens. If necessary fit a round metal or cardboard tube, (the diameter of the lens and about 6" to 12" long), to shield the receiver lens from ambient light. The inside of the tube should be painted matt black.

Final alignment should be carried out at night as it is easier to see the beam (with the filters removed).

Infra-red radiation behaves much as visible light, and so mirrors may be used if it is necessary to direct the beam around corners. Shaving mirrors are ideal for this purpose.

Interior of prototype unit.

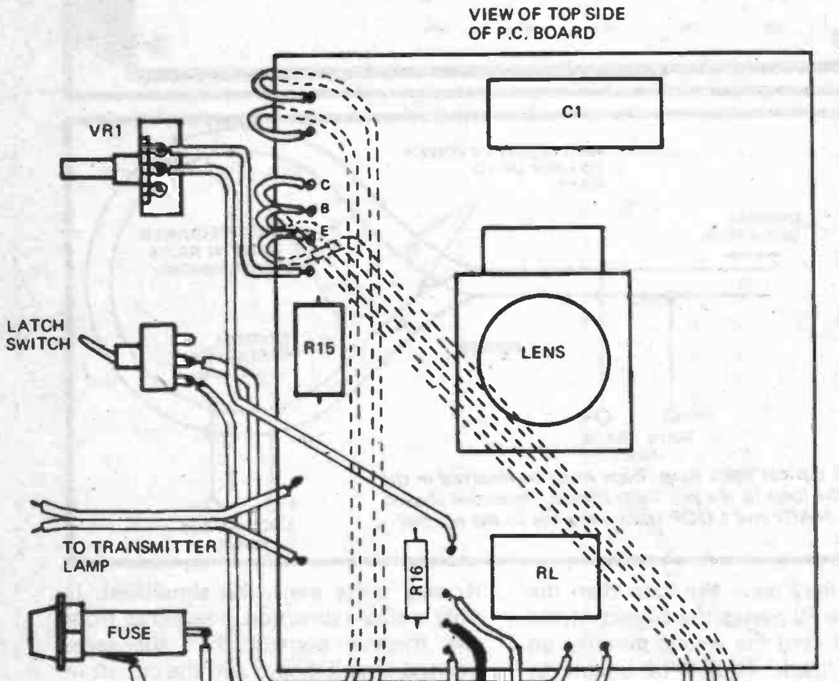


Fig. 7. Connections to and from the printed circuit board.

PARTS LIST

R1	—	resistor	1k,	½W,	5%
R2	—	"	"	"	"
R3	—	"	100 ohm	"	"
R4	—	"	560 ohm	"	"
R5	—	"	47k,	½W	5%
R6	—	"	100k,	"	"
R7	—	"	1.2k	"	"
R8	—	"	220 ohm	"	"
R9	—	"	"	"	"
R10	—	"	1k	"	"
R11	—	"	2.2k	"	"
R12	—	"	100 ohm	"	"
R13	—	"	27 ohm	"	"
R14	—	"	56 ohm	"	"
R15	—	"	10 ohm	5W	"
R16	—	"	33 ohm	1W	"
R17	—	"	47 ohm	½W	"
VR1	—	potentiometer	100k	linear	
C1	—	capacitor	1000μF,	25V.	
C2	—	"	100μF,	16V.	
C3	—	"	100μF,	16V.	
C4	—	"	2.2μF,	25V.	
C5	—	"	4.7μF,	25V.	
C6	—	"	50μF,	16V.	
C7	—	"	4.7μF,	16V.	
Q1	—	transistor	2N 3643		
Q2	—	"	2N3055		
Q3	—	"	BC108		
Q4	—	phototransistor MEL 12 or equivalent			
Q5	—	transistor	BC108.		
Q6	—	"	BC108.		
Q7	—	"	2N 3643		
Q8	—	"	BC108		
Q9	—	"	BC108		
Q10	—	"	2N 3643		
D1 through D4	—	silicon diode 1N 4005or equivalent.			
D5	—	zener diode BZY88/C9V1			
D6	—	silicon diode 1N 4005			
Transformer	—	transformer 12.6 volt, 1 amp output.			
Relay	—	Cradle type relay – double pole changeover. 430 ohm coil, Varley VP2 or equivalent.			
SW1	—	switch toggle type, 240 volt single or double pole (see text).			
SW2	—	switch toggle type, single pole, single throw.			
Lamp	—	G.E. Sealed beam lamp type GE 4546. Infra-red filters —			

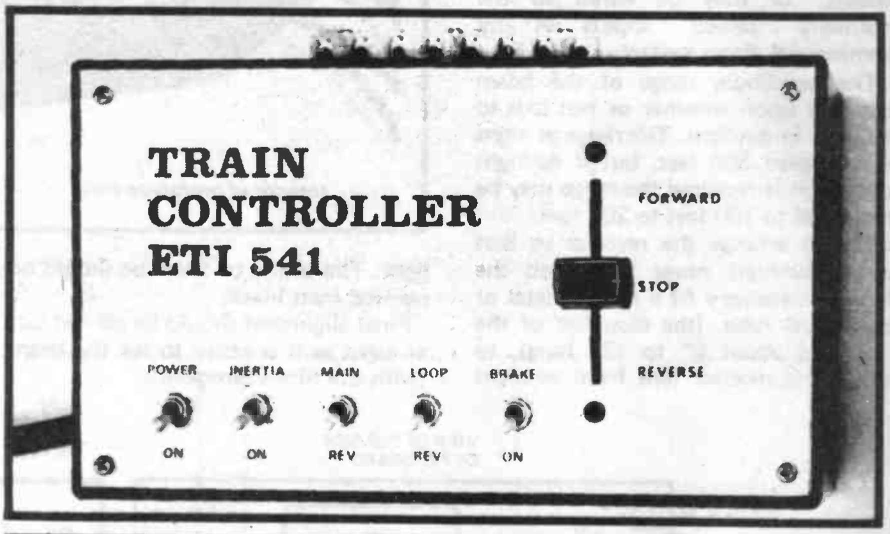
Infra-red filters — Kodak type 87 or 88A. Sundries, two diecast boxes, one 2 way connecting block, rubber grommetts, printed circuit board, three core cable and plug, four 2" compression springs, front loading fuse holder and one amp fuse, one small condenser lens, (2" focal length), perspex sheet, pointer knob, hook-up wire, assorted nuts and bolts.

—ETI project 541

TRAIN CONTROLLER

A simple project offering auto-reverse, inertia, emergency brake and loop track facilities

MODEL TRAINS HAVE ALWAYS BEEN popular with both lads and dads — with dads perhaps coming first. Many a boy has complained "Daddy won't give me a turn". It seems there is some inexplicable attraction in playing trains which never dims with the passing years. A couple of our friends have recently decided to buy train sets — for the kids (they say). Our model train controller project was designed to give them many features that are not found in commercially available controllers (for roughly the same cost). Most commercial devices consist of a transformer followed by a selenium rectifier, a high power rheostat and an automotive globe. Such controllers have numerous operating disadvantages mainly due to their very poor voltage regulation.



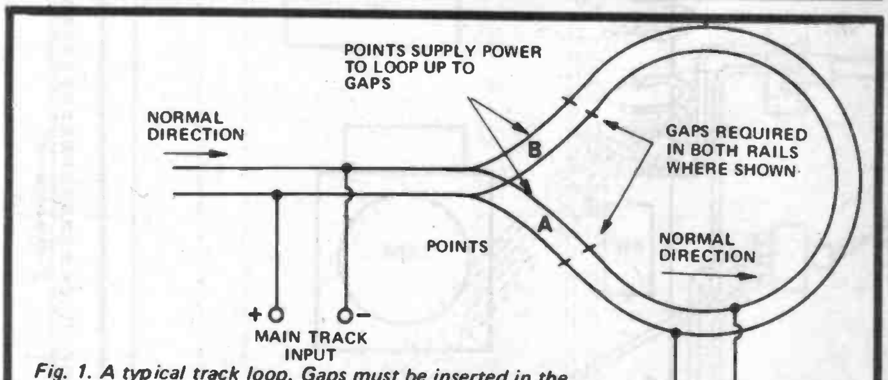


Fig. 1. A typical track loop. Gaps must be inserted in the rails of the loop in the positions shown. Polarities shown are with MAIN and LOOP track switches in the normal position.

Our controller It may look a little complex but in fact it is very simple to build and quite inexpensive. If the full capability is used the features of the controller are:

- Forward or reverse control by a single slide potentiometer (centre for stop)
- Separate reversing switch for the main track
- Short-circuit proof
- Regulator-type control circuitry
- Emergency brake (which stope the train instantly regardless of the position of other controls
- Simulated inertia (gives more realistic starts and stops)
- The facility to operate with track loops

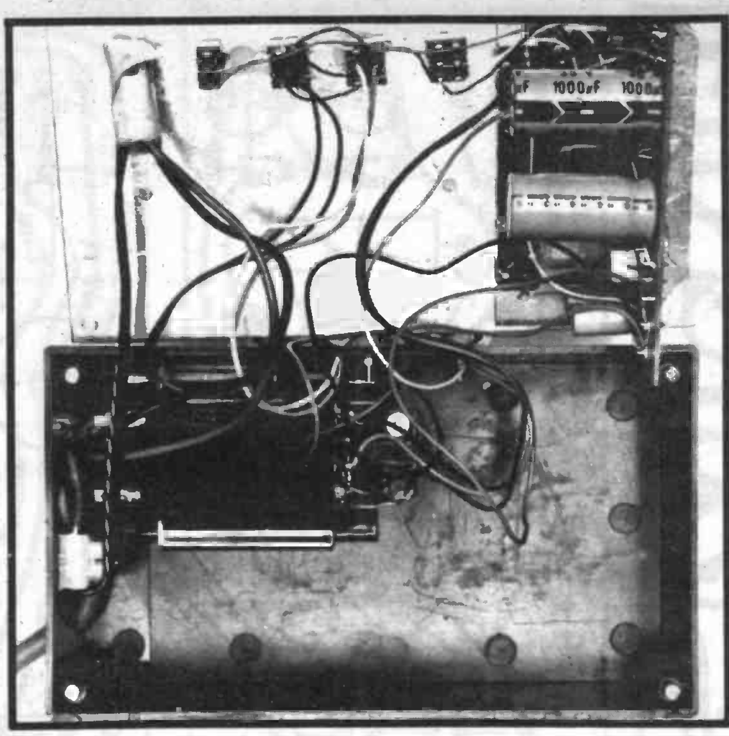
Loops operation Although not possible with simple controllers, loop operation adds much operating fun and realism to any model railroad and the feature is well worth including. A typical loop is shown in Fig. 1. and the operational problems of such a loop are as follows:

If a train is approaching the loop and the 'main' and 'loop' switches are both set at normal, the polarity of the voltages to the track will be as shown. If the points are set so that the train enters the loop towards 'A' it will continue normally around the loop. If the points are now set to 'B' sp that the train may leave the loop then the train, once it passes the breaks in the track, will find the wrong polarity on the main track. It will be unable to continue in the same direction. To overcome this problem the main-track switch must be changed to 'reverse' whilst the train is within the loop. If the train enters the loop towards 'B' then the loop switch must be reversed before the train enters the loop. Once again the mainline polarity is reversed whilst the train is within the loop. Providing the section of the loop between 'A' and 'B' is longer than the train, loop operation will be simple and trouble free.

Simpler versions If all the facilities of the controller are not required then it may quite easily be simplified. If only a single direction is required from the throttle control then the same printed circuit board and the circuit in Fig. 5. may be used. If loop operation is not required then the controller may be further simplified by deleting SW5 and the associated wiring.

CONSTRUCTION

We built our controller into a plastic box with an aluminium lid. Some people may wish to build the controller into a complete control panel or some other box. This is quite acceptable as the method of construction is not critical. We suggest however that the printed circuit board specified be used as this greatly simplifies con-



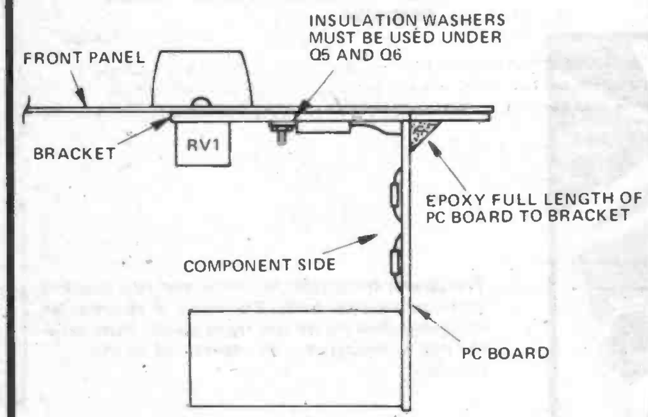


Fig. 6. Assembly of the printed-circuit board and bracket to the front panel.

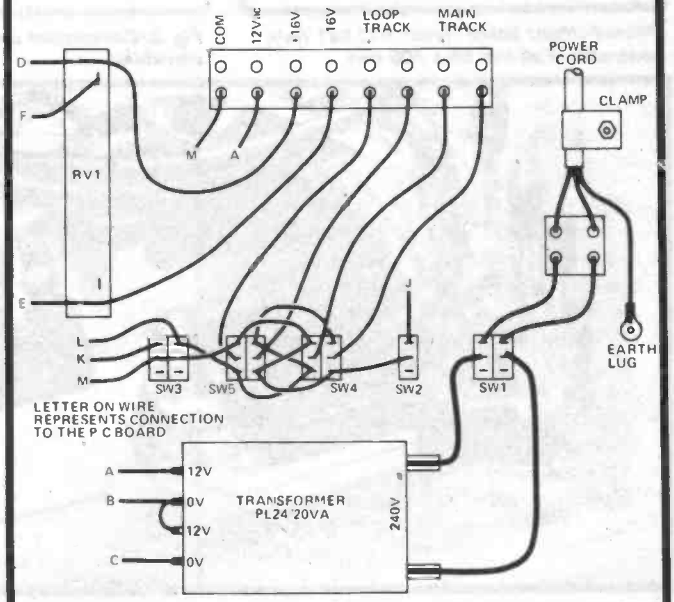


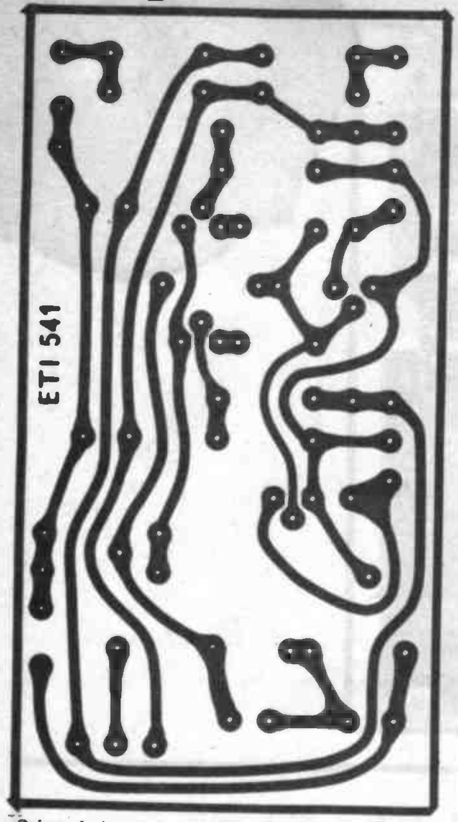
Fig. 7. Interconnection diagram for the auto-reverse controller given in the circuit of Fig. 2.

struction and minimizes the possibility of wiring errors.

Assemble the components to the printed circuit board in accordance to the relevant component overlay. Watch that the polarities of components suchs as diodes, capacitors, and specially transistors, are correct. Note that two different pin connections are available in the BC108 and BC178 transistors, depending on the manufacturer. The Philips type is the one shown on the overlays.

A small bracket was used to hold the printed circuit board in such a way as to hide the two screws which hold the power transistor. If two extra screw-heads on the front panel do not worry you, then this bracket need not be used. Bolt the power transistor onto the bracket using the insulation kit provided. Mount the bracket to the rear of the front panel by means of the slide potentiometer and its mounting screws and then mount the rest of the switches. Drill a hole through the side of the plastic box for the power cord and then fit the cord, the cable clamp and the transformer into the box. Then mount the terminal block to the box and drill small holes for the wires from inside the box to be terminated to it. Finally wire the complete unit and test it.

Once sure that the controller works as it should the board edge should be glued to the front panel (or bracket) with a little epoxy glue. Once this has dried, and you are sure that there is a seal all along the edge of the board, pour epoxy glue along the join so as to form a fillet of glue about 5 to 10mm wide. (A piece of sticky tape at either end will prevent the glue from running out at the ends). Once the glue has dried the completed front panel assembly may be screwed into the box.



Printed-circuit board layout ETI 541 train controller. Full size 65 x 105 mm.

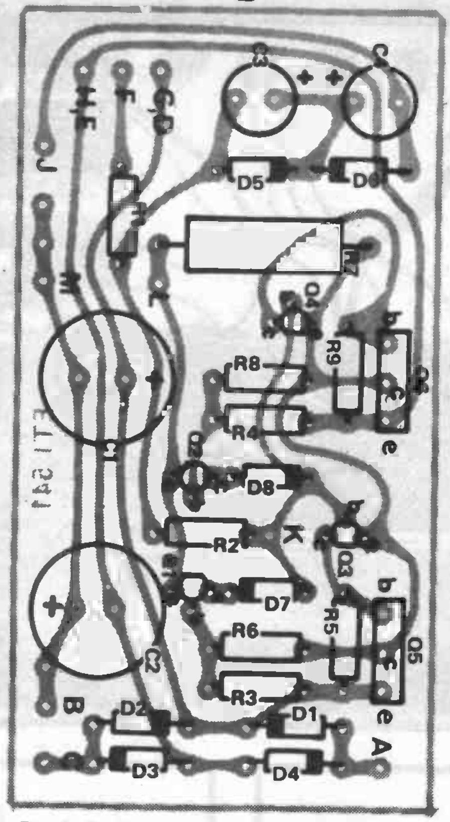


Fig. 3. Component overlay – auto reverse controller.

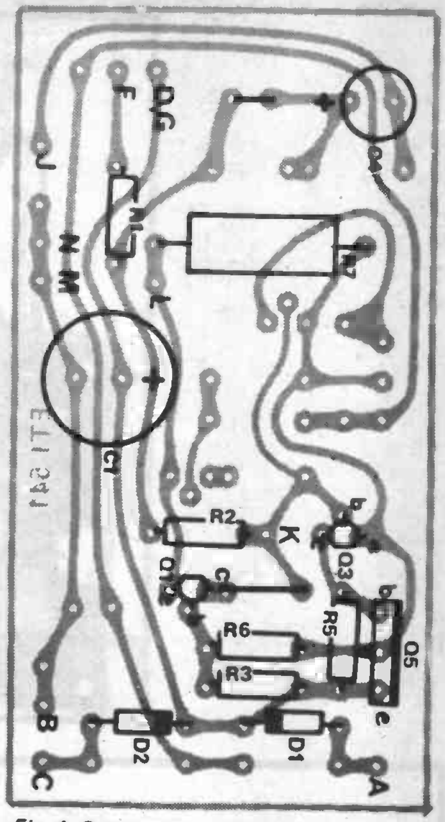
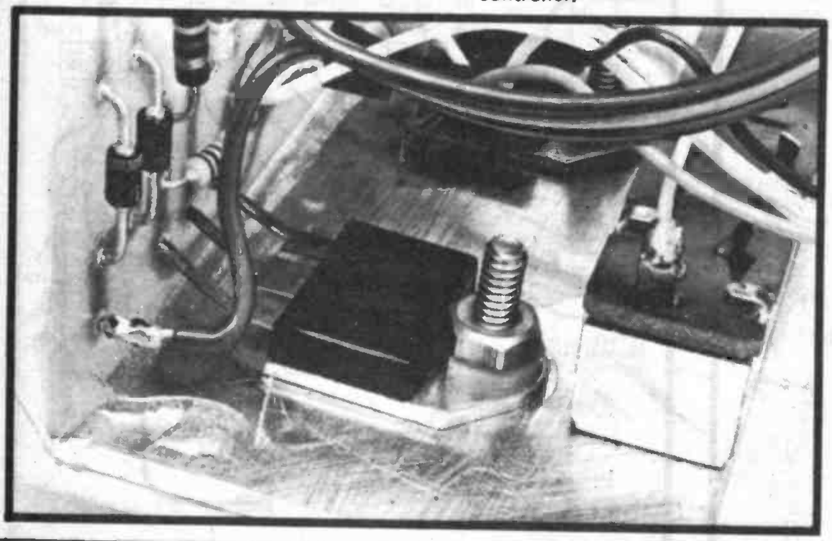


Fig. 4. Component overlay – simple controller.



The power transistors are mounted to a bracket with countersink bolts. They can, if desired, be mounted directly on the front panel. Note how the pcb is mounted – by epoxying to the bracket.

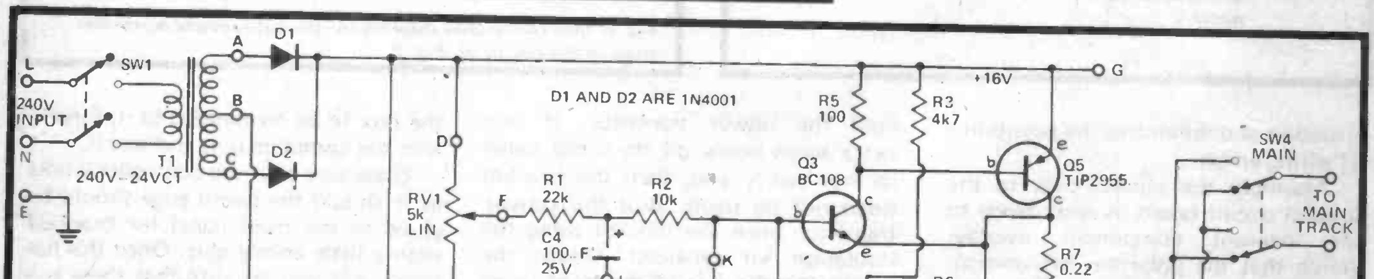


Fig. 5. Circuit diagram of simplified controller without the auto-reverse facility.

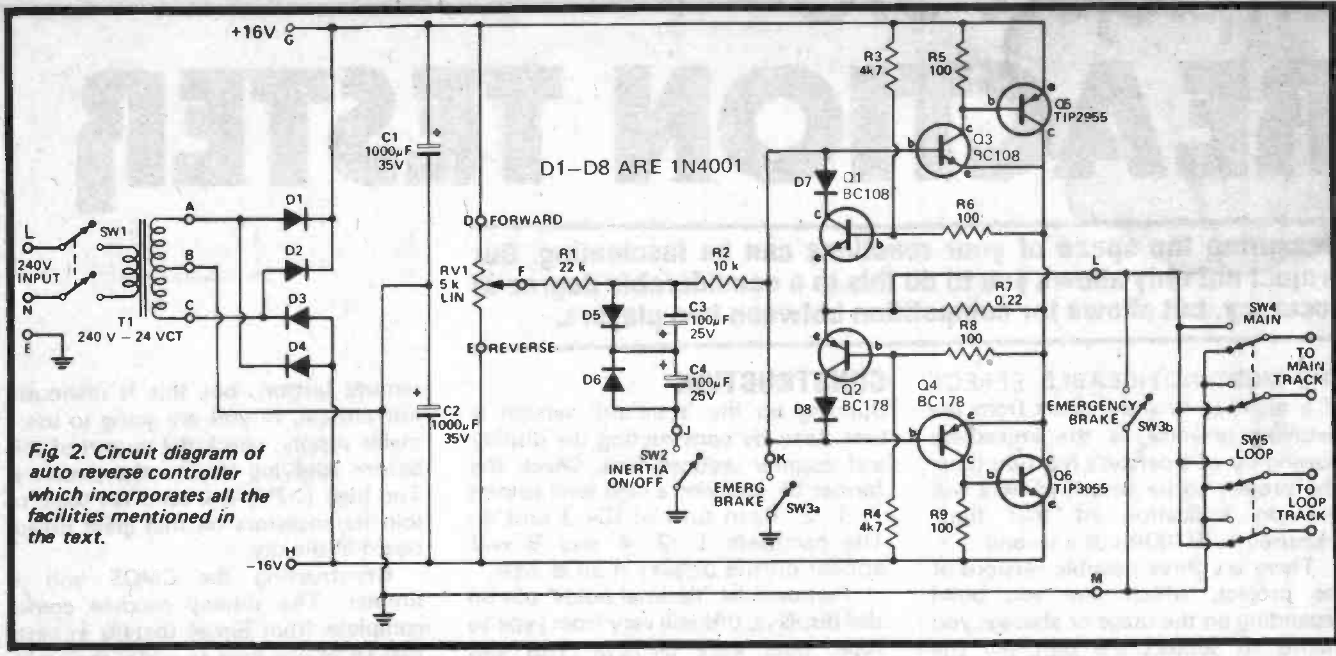


Fig. 2. Circuit diagram of auto reverse controller which incorporates all the facilities mentioned in the text.

How it works

TRANSFORMER T1 reduces the 240 volt mains to a supply of 24 volts (centre tapped) which is then rectified by D1 to D4 to provide supplies of +16 and −16 volts dc. The speed control potentiometer is connected between these supplies so that its wiper may select any potential between plus and minus 16 volts depending on setting.

The output of the potentiometer must be well buffered before it can supply enough power to run a train. This is achieved by transistors Q3 and Q5, for the forward direction (that is for output voltages between zero and +15 volts), and by Q4 and Q6, for the reverse direction (that is for output voltages between zero and ..15 volts). The output voltage at the collectors of Q5 and Q6 will be about 0.6 volts closer to zero than the voltage at point 'K' (providing the voltage at point 'K' is more than .6 volts away from zero). This means that the control potentiometer will have a small dead band in the centre of its travel where the output voltage remains at zero. Tnis is an advantage because it is frequently necessary to set the controller for exact zero output.

To protect the transistors from damage in the event of an overload or a short circuit, transistors Q1 and Q2 are used to monitor and output current (by measuring the voltage across R7) and the voltage across the output transistors. By this method the power dissipation in the output transistors is controlled such that when driving into a short circuit only about one ampere is available. Yet when set to about 12 volts, about two amps is available to drive normal loads. The diodes D7 and D8 are included to protect the transistors Q1 and Q2 against reverse bias which can occur under certain conditions.

To add the 'inertia' facility or 'momentum' as it is sometimes called the control voltage from RV1 is filtered by C3 and C4. This means that if the potentiometer is suddenly moved from stop to full forward (for example) the voltage applied to the transistor buffer rises only slowly. The train accelerates at a realistic rate without wheel spin. A similar action takes place when the train is stopped. If the controller is moved from full forward to full reverse the train will slow down then stop for a short time and then start off and increase speed in the reverse direction. The diodes D5 and D6 allow normal electrolytics to be used in this position.

If inertia is being used and an emergency situation occurs, eg train moving into a siding that it should not be entering, the brake facility may be used to short the track (SW3B) and also the input to the buffer stage (SW3a). The brake over-rides the speed control and by its use the train will be stopped in a much shorter distance than it would if the power were simply switched off.

When loops in the track system are used, as described in the introduction, a separate reversing switch is used to control the polarity in the loop with respect to the main line so that the train may go into and come out of the loop without any change in speed. The two controller outputs required for this mode of operation must each be reversible and this is performed by SW4 and SW5.

If a second controller is required for another train in the system then it may be built without the power supply. The second controller may be powered by linking the +16, 0 and −16 volt lines between the two controllers.

Parts List

AUTOMATIC-REVERSE CONTROLLER

Resistors

R1	22 k	½ W	5%
R2	10 k	"	"
R3,4	4 k7	"	"
R5,6	100 ohm	"	"
R7	0.22 ohm	5 W	"
R8,9	100 ohm	½ W	"
RV1	5 k lin 45 mm slide potentiometer		

Capacitors

C1,2	1000 µF 35 V pc mounting electro
C3,4	100 µF 25 V pc mounting electro

Transistors

Q1, 3	BC108
Q2, 4	BC178
Q5	TIP 2955 *
Q6	TIP 3055 *

* with insulation kit

Diodes

D1-D8 1N4001 or similar

Miscellaneous

PC board ETI 541
Transformer 24V, 1A
SW1 toggleswitch DPDT 240 V rated
SW2 toggle switch SPDT
SW3-SW5 toggle switch DPDT
Plastic box 196x113x60 mm
12 Pc board pins
3 core flex, plug and clamp
Heatsink/support to Fig. 8.
8-way connector strip
2-way connector strip
2 6BA c/s screws & nuts 10 mm long
Front panel

FOR MANUAL REVERSE CONTROLLER

Delete

R4, R8 and R9
C2 and C3
Diodes D3-D8
Transistors Q2, 4 and 6

If no loops are involved in the track layout SW4 and SW5 can be deleted on automatic reverse controller and SW5 on manual reverse controller.

For a second controller delete T1, SW1, D1-D4 and the power cord in the second controller.

GETTING HOLD OF THE COMPONENTS
Nothing here to trouble the constructor — all the semiconductors are common, and the boxing is not critical.

ETI project 570

REACTION TESTER

Measuring the speed of your reactions can be fascinating. Our project not only allows you to do this to a considerable degree of accuracy, but allows for competition between two players.

THE MOST NOTICEABLE EFFECT of a night on the ale, apart from the revolving universe, is the immediate slowing up of a person's reaction time. The project to be described here will give an indication of that time, measured to 1/100ths of a second.

There are three possible versions of the project; which one you build depending on the usage or abusage you intend to subject the unit to. The CMOS version is much more expensive initially, but draws under half as much current from the batteries, and will thus even up its cost over a period. The 'standard' version if you like, is the TTL circuit of Fig.1, which can be run from a battery pack as a portable unit.

PLAYING THE GAME

The tester provides an intriguing party game which will cause many an argument. It is set up as a contest between two people, with indication of who has won - and the winning time. It might be an idea to take some readings on the known drinkers at the start of that party - and when their reactions have slowed to half, pack 'em off in a taxi!

Playing the game is simple. The contestants man the switches on the front panel, and a 'referee' takes the remote start switch. By pressing this he lights the 'GO' lamp on the panel, and starts the timer. Whichever of the players pushes his button first, lights his own 'WIN' lamp, and stops the count at his/her (equality year after all!) reaction time.

CONSTRUCTION

Building up the 'standard' version is best done by constructing the display and counter sections first. Check the former by applying a high level to pins 7, 1, 2, 6, in turn of ICs 3 and 4. The numbers 1, 2, 4 and 8 will appear on the display if all is well.

Remove the 'decimal point' pin on the displays, this will vary from type to type, ours were DL707s. This aids location on the P.C.B. The lead from the hand-held unit to the main unit *must* be screened - four-core individual screen recording lead is ideal - otherwise stray capacitance can 'clock' the 7490 without the switch being operated. Earth one end to pin 2 of the DIN socket on the unit, and the switch end to the output earth side.

We used a small Verobox for the remote button, but this is obviously not critical. If you are going to use a mains supply, check the output of this before applying Vcc to the circuitry. Too high (>7V) will send the logic to join its ancestors on that great breadboard in the sky.

Constructing the CMOS unit is simpler. The display module comes complete from Sintel (details in parts list) so all you have to add is the oscillator and switching circuits, as shown in Fig.3. Once more - be careful with the CMOS chips: don't handle them if you can help it.

Possible modifications and additions to the basic unit are legion. We originally used a 7400 as the oscillator, but settled on the discrete circuit for simplicity. No doubt the logic hounds will return it, but watch out for resistance values, no higher than 20k with TTL. The frequency is a little low for TTL to be entirely at home in any case.

A 'self-test' facility could be added, using an 'almost random' start circuit employing say, a 7413 device. Wire three of the inputs to the gate high,by a potential divider, and the fourth goes to the mid-point of a series R-C combination across the supply. Make the R variable, then if the C is large enough, an appreciable time will elapse until the voltage at the fourth input rises enough to turn on the gate. When it does the Schmitt will turn hard on, and provide a suitable pulse to gate the output of the oscillator into the counter. Leave the pot uncalibrated, and there really is no way of knowing

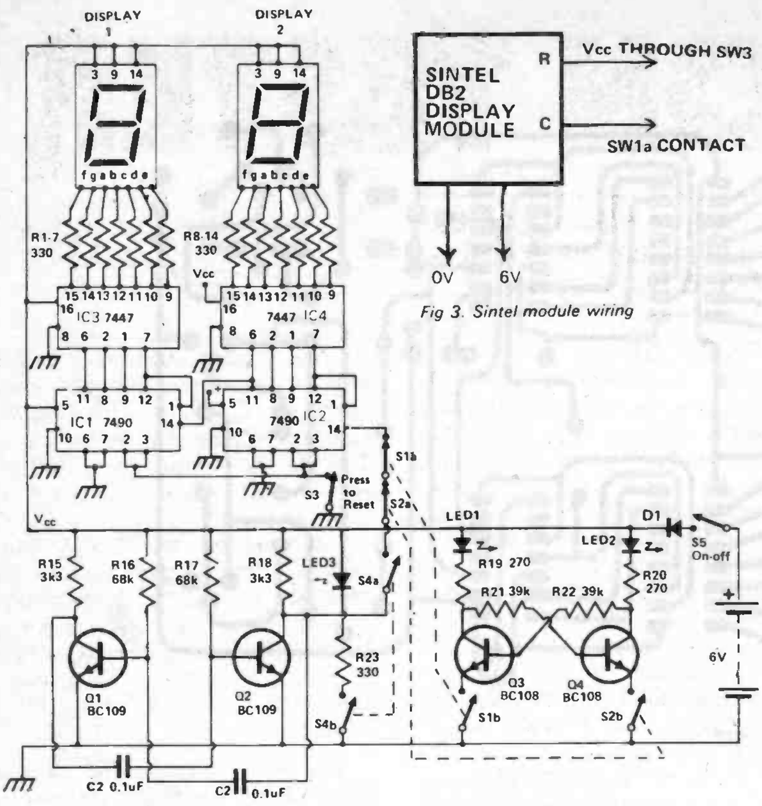


Fig 3. Sintel module wiring

How it works

If we consider the TTL circuit (the CMOS version functions in exactly the same manner) and begin with the display driver/counter section, we see that the counting is done by two cascaded 7490 devices. These are working as ÷10 BCD counters, and the outputs feed two 7447 BCD decoders/display drivers. The input pulses, 4.2V p.t.p. square waves, are generated by Q1 and Q2 in a multivibrator mode at a frequency of approximately 100Hz. Greater accuracy can be obtained by making one of the charging resistors (R16 or R17) variable, and tuning the oscillator to exactly 100Hz. In this way the tester will read exact reaction times, ±.01 secs.

When the 'Go' button is pressed, green LED3 in the front panel lights, and pulses are fed into the counter chain. When either contestant's switch (S1a, S2a) is pushed, the link between oscillator and counter is broken and the counter will 'hold' the number of pulses that have entered i.e. time in 100ths of a second.

At the same time S1b and/or S2b operate the 'Windicator' circuit comprising Q3 and Q4. Either one of the LEDs can lock on turing off the other transistor, and so ensuring only one light can be on at any given time - that corresponding to the first button pushed. Diode D1 serves both as a voltage dropper to bring Vcc down to a logic supply level (5.4V) and also to prevent damage due to supply reversal.

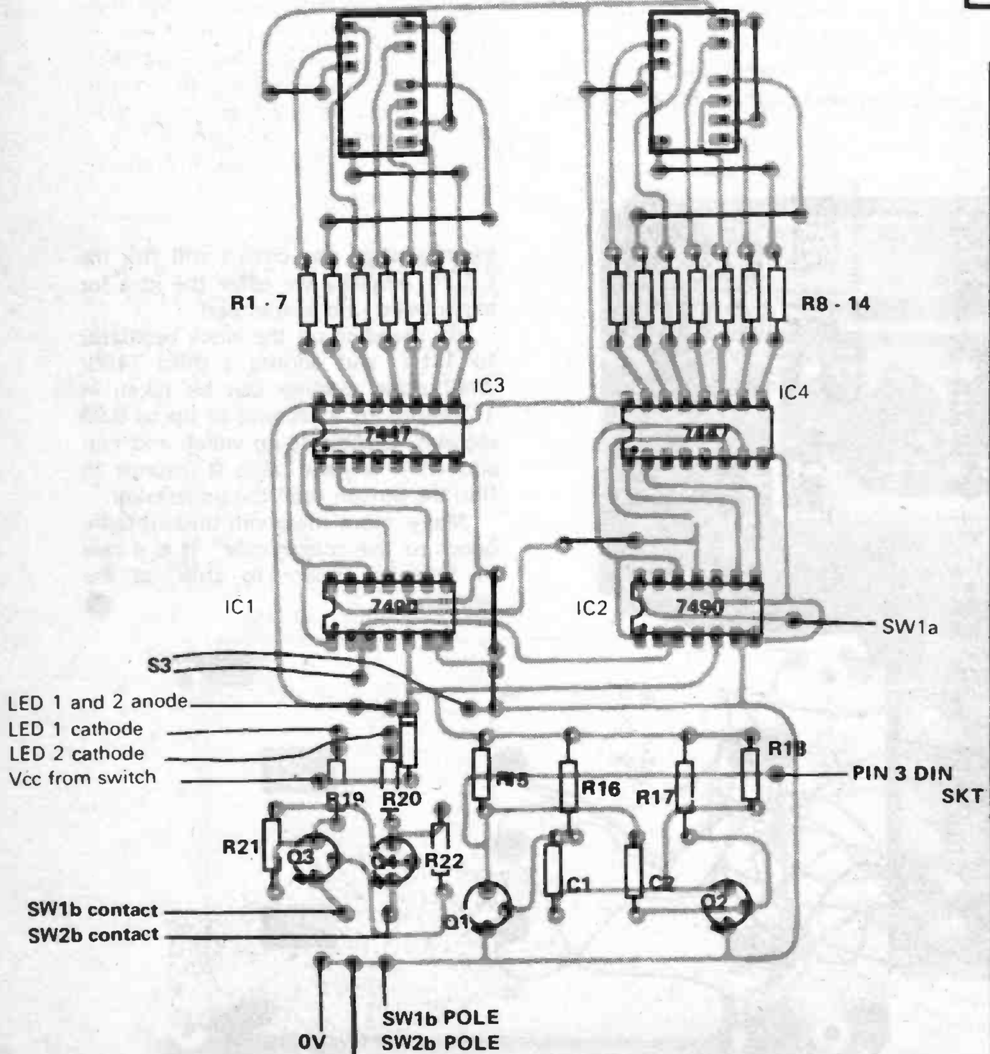


Fig 4. Component overlay.

Parts List

Resistors

R1-14, 23	330R
R15, 18	3K3
R16, 17	68K
R19, 20	270R
R21, 22	39K

All ¼W 5%

Capacitors

C1, 2	0.1µF minifoil etc.

Transistors

Q1, 2	BC109 or similar
Q3, 4	BC108 or similar

Diodes

D1 IN 4001 or equivalent
LED 1, 2 RED 0.2"
LED 3 GREEN 0.2"

Integrated Circuits

IC1, 2	7490
IC 3, 4	7447

NOTE: CMOS version uses Sintel Module DB2 in place of IC1-4 and displays. This is available as a complete kit from Sintel

Switches

SW1, 2	Double Pole Changeover—Push On, Push Off.
SW3	Single Pole, Single Throw—Push to Break, non locking.
SW4	Double Pole Changeover—non locking.
SW5	Single Pole, Single Throw—rocker type.

Misc

I.C. sockets
Verobox 75-1413E
Verocase 65-2522K
Battery holder to suit
(Use 4 x HPII Alkaline version)
5 pin DIN 180° chassis skt
5 pin DIN 180° in-line plug
1m 4 core individual screened lead
Board spacers etc.

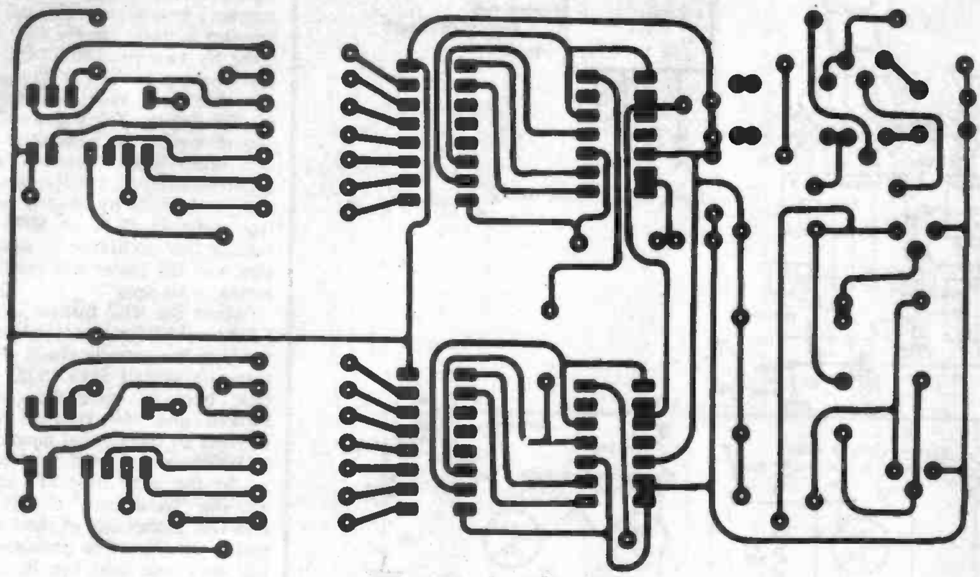
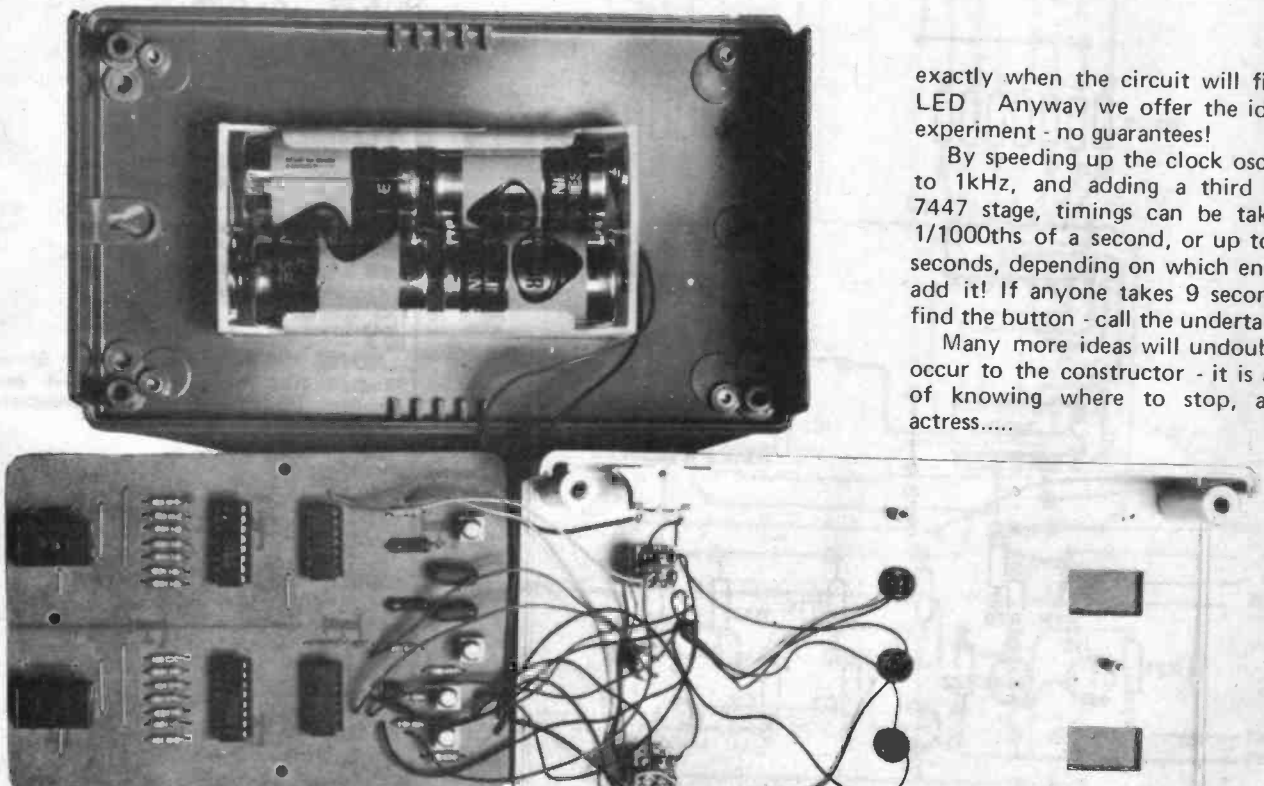


Fig. 2: PCB foil pattern — full size.



exactly when the circuit will fire the LED Anyway we offer the idea for experiment - no guarantees!

By speeding up the clock oscillator to 1kHz, and adding a third 7490/7447 stage, timings can be taken in 1/1000ths of a second, or up to 9.99 seconds, depending on which end you add it! If anyone takes 9 seconds to find the button - call the undertaker.

Many more ideas will undoubtedly occur to the constructor - it is a case of knowing where to stop, as the actress.....

HEADPHONE RADIO

WHILST IT MIGHT BE argued by some of our readers (and our competitors!) that this project is merely a cheap trick to boost sales by giving us an attractive (well isn't it?) cover, we think that the 251 headphones radio stands on its own merits as a good but simple project. It was designed simply because it seemed like a fun project which readers would enjoy building, and it was also a good trick to boost sales by giving us an attractive cover. (You bought it, didn't you?)

With summer upon us already people have taken up such worthwhile pursuits as sunbathing, walking in the park, or slaving over a hot soldering iron conjuring up projects like this one. It is only natural, in this solid state age, to grasp for one's personal pocket radio as one exits into the summer sunshine, in order to do whatever it is one intends to do, to music. The trouble is, a lot of people believe that transistor radios are unnatural devices, especially when efficiently radiating a watt or so into the air around their earhole.

SPOT THE . . .

This project then, is dedicated to those electronic ecologists who regard noise as pollution and who, in order that their fellow men (and women!) shall not suffer are willing to walk about looking completely loony with this contraption on their heads. On, then to the project itself.

In the interests of keeping the cost down, and the designer sane, it was decided not to include facilities for FM stereo reception in the 251. Consequently, the circuit is (ridiculously?) simple, using our old friend the ZN414, and we were going to use another well-known chip, the MFC4000B for audio output except that it's gone the way of all silicon, and so we used what the man in the shop gave us instead, an MC1306P. This is quite a nice little device which will deliver ½ a watt for around 3mV input. Great, we said, and off we went, with a hey-ho, the ZN414 and the MC1306P, to buy a pair of headphones. We got ours from the local branch of a large photographic/hi-fi chain, called D'x'ns, and very cheap they were too. The assistant couldn't understand why we didn't want to buy the model XYZ1001¾s with volume and tone controls plus built-in cocktail cabinet and binoculars, but we explained that we were mad electronics enthusiasts with journalistic aspirations, so he stopped the sales talk and humoured us.

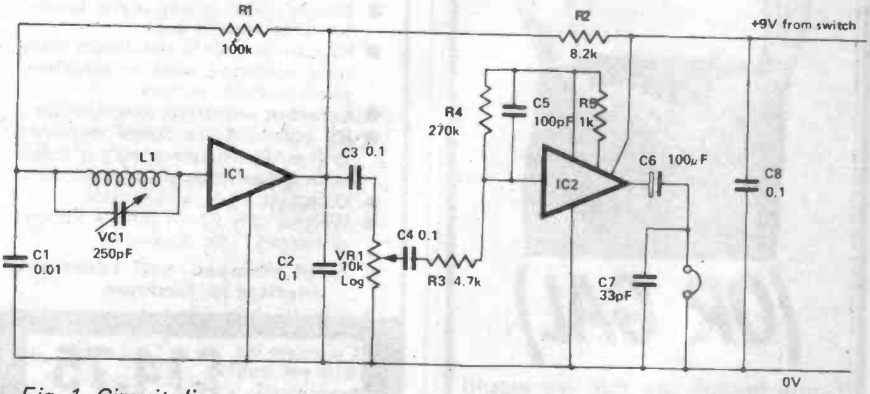


Fig. 1. Circuit diagram.

Virtually any pair of 'orrible 'eadphones will do, and obviously the size will vary enormously so that we have only given a generalized PCB layout as the PCB may have to be smaller or larger to suit your phones

CONSTRUCTION

Construction is straightforward, with virtually all components mounting on the board except for the loudspeakers, on-off switch, and the 9V battery which we mounted together in the other earpiece. This meant that we had to replace the cable in the headband, with a three-core type, to carry +9V, speaker connection and earth/common. The speakers were wired in series since we didn't know how the MC1306P would like a 4 ohm load and didn't want to find out the hard way! Of course, if you want to try it . . .

The ZN414 is a 3-terminal TRF radio which suffers from one major bugbear: instability. If R2 is too low it will take off like a bat out of *&%+, whistling as it goes. If you do have a problem with instability, try increasing R2, and this may cure it. On the other hand, if you have a particularly docile 414, it could need just that little extra bit of oomph that a 6.8k for R2 might give it.

Apart from that, the only piece of advice is don't wear the things in public or you'll have a lot of explaining to do! Incidentally, these things are great for doing that old trick of getting people to put them on and then . . .

PARTS LIST – ETI 251

R1	100k
R2	8.2k
R3	4.7k
R4	270k
R5	1k
VR1	10k log
C1	0.01pF
C2	0.1pF
C3	0.1pF
C4	0.1pF
C5	100pF
C6	100µF
C7	33pF
C8	0.1pF
IC1	ZN414
IC2	MC1306P

L1 80 turns close-wound 32swg enamelled wire on 42 x 9mm ferrite rod
VC1 250pF (Home Radio type TP4 is suitable)
PCB ETI 251 Knobs, switch, 9V battery (PP3), etc..

Fig. 2. Printed circuit board (full size).

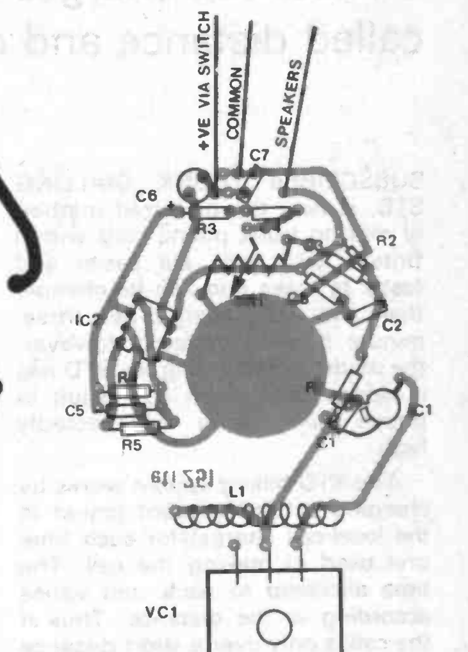


Fig. 3. Component overlay.

—ETI project 541

STD TIMER

This compact unit calculates the total cost of STD phone calls by counting the number of local-call charges appropriate to the called distance and duration of the call

SUBSCRIBER TRUNK DIALLING STD, is now the preferred method of making trunk phone calls within Britain. STD calls are easier and faster to make and can be cheaper than the old "charge per three-minute period" system. However, the method of charging for STD has a hidden trap which can result in phone bills being unexpectedly high.

The STD billing system works by charging a fixed amount (equal to the local-call charge) for each time unit used in making the call. The time allocated to each unit varies according to the distance. Thus if the call is only over a short distance and at night you may be charged one local call every 180 seconds, but if over a long distance and during the day the charge may be as much as one local call every eight seconds. The disadvantage of this method as far as the subscriber is concerned is that he loses track of time when talking — there are no pips to warn him.

The ETI 543 STD Timer operates by counting the number of local call periods used. Thus at the end of the call you simply multiply the number held in the counter by the local call charge to get at an accurate cost. Local-call charges are frequently reviewed, so the timer is designed to count the number of local-call charges only.

To use the timer simply check the phone book before making the call to determine the number of seconds per charge applicable, then set this time on the selector switch of the timer. Now dial the number and when the called party answers press the start button. The timer will switch on, "1" will be added to the display and the display will be incremented by "1" at the end of each time period (as selected). When the call is finished, you press the stop button and read the total units used. After about five seconds the timer will switch off automatically.

Note that although the power is still connected in the off-state the power consumption (in this state) is so low that battery drain doesn't affect battery life. In fact on the prototype the current drain was 2×10^{-10} amps! Yes, we actually measured it — guess how?

CONSTRUCTION

As the unit will be used on the phone table small size and neat appearance is necessary. We therefore built our unit into a zippy box which although looking neat does become a little crammed inside. For this reason it is important to use the printed circuit boards specified if all the electronics is to fit.

Commence construction by assembling components to the display board, ETI 543A, starting by installing the tinned-copper wire links as shown on the overlay diagram. Watch the orientation of the integrated circuits: the two 4511s have opposite orientations.

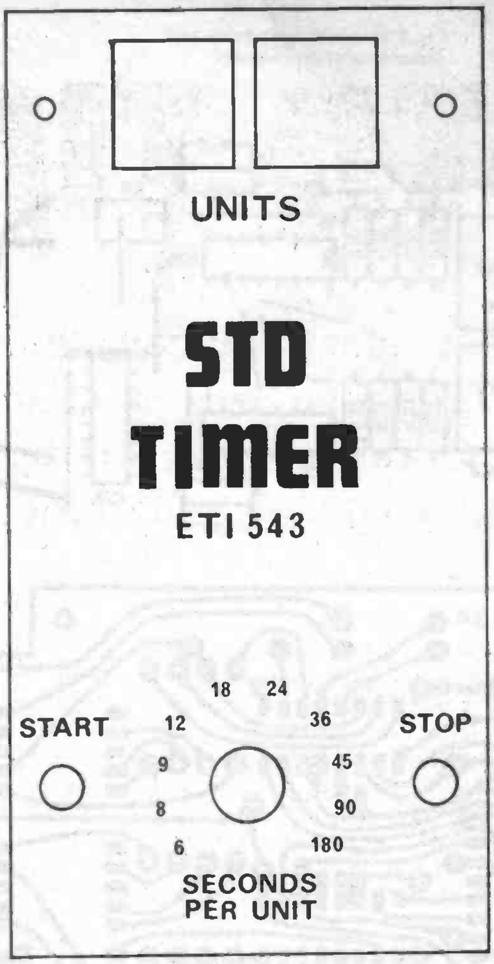
Now assemble the second board, again installing the links first. Do not mount R1 to R16 just yet. The rotary switch used for range selection must now be modified by removing the wafer, cutting the spacers in half and then reassembling (as shown in Fig. 2) on the printed-circuit board. The terminals of the switch should now be connected to the board by threading tinned-copper wire through the appropriate hole in the board (from the copperside) and through the terminal and then soldering to the terminal and the board. The resistors R1 to R16 may now be mounted into position and soldered, noting that they are mounted on-end — not flat.

Mount the two push-buttons to the front panel temporarily and then mount the completed second board and switch assembly to the front panel. Use spacing washers between the switch and the front panel. Connect the push-buttons to the board using tinned-copper wire and then remove the front panel.

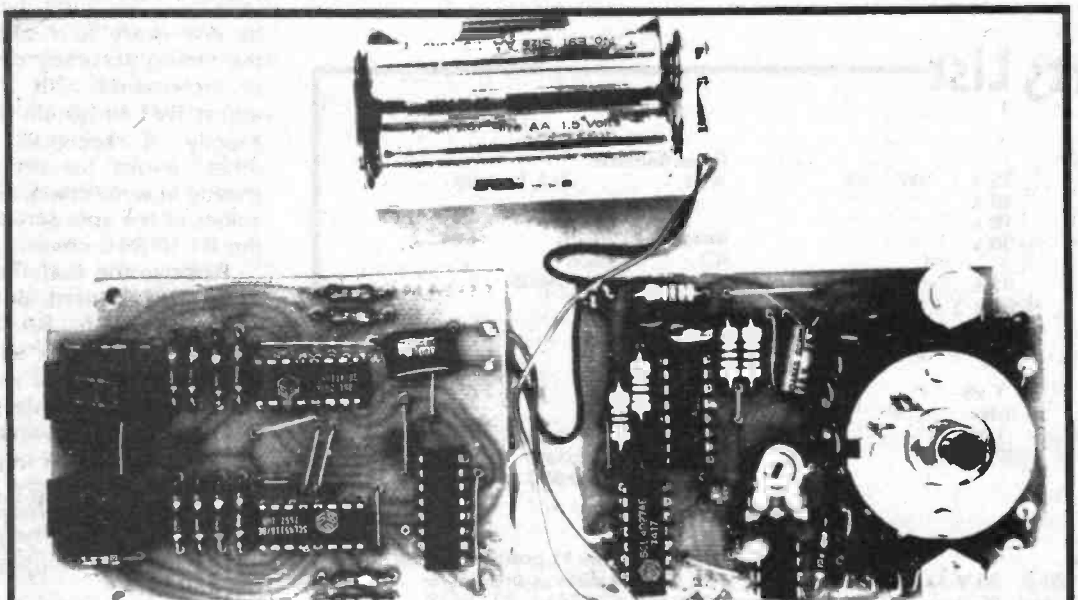
Now place the two boards end-to-end about 50 mm apart and wire them together as shown in Fig. 3. The 50 mm spacing ensures that when the boards are folded later the spacing will be OK. The battery holder may now be connected. However, note that there is insufficient room to allow a conventional battery power clip to be used. You have to solder the leads directly to the terminals.

Impedances around the switch are fairly high, and leakage through flux could affect timing accuracy.

So clean the copper side of the boards with turps or methylated spirits to remove excess flux. Insert the batteries in the holder and select the four second range. If the display is on press the stop button and after about five seconds the display should extinguish. Now press the start button and note that the display is "01" and should increment

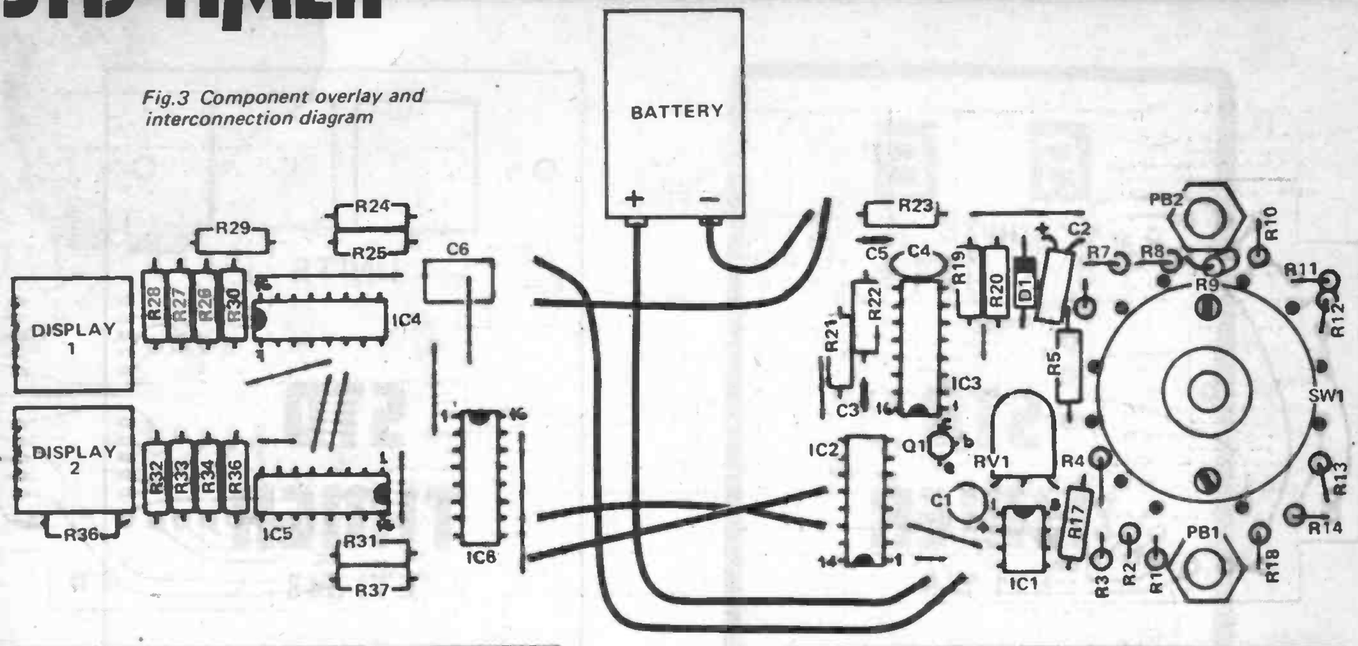


Front panel for the timer. Full size



The two boards and battery assembly before being mounted in the case

Fig.3 Component overlay and interconnection diagram



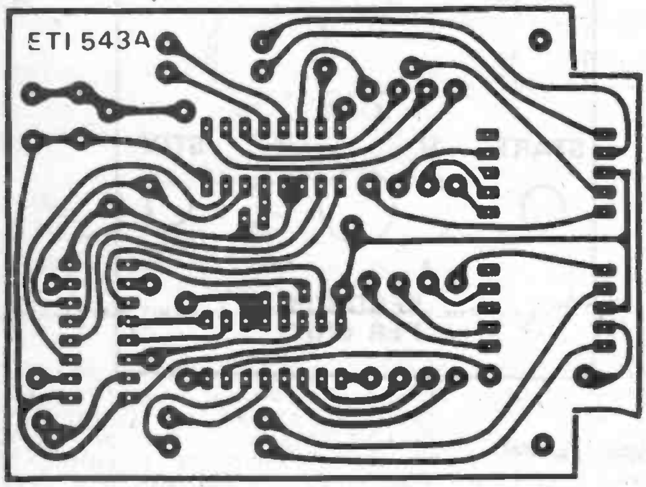


Fig.5 Printed circuit pattern for the display board. Full size 83 x 61mm

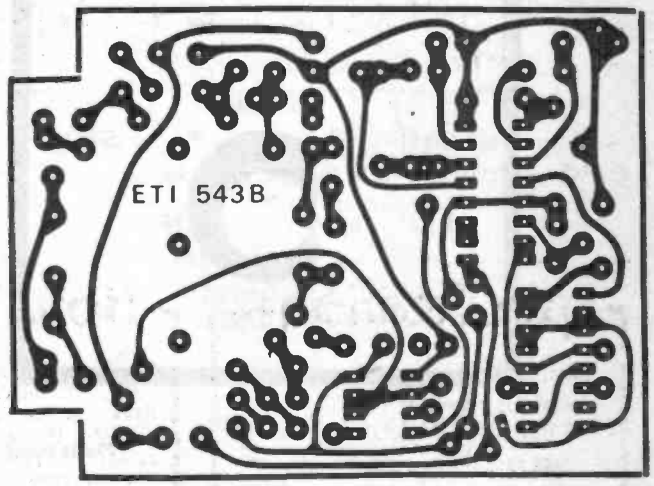


Fig.6 Printed circuit pattern for the timing board. Full size 83 x 61mm

Parts List

Resistors

R1,2	15 k	½W	5%
R3,4	10 k	"	"
R5-R7	15 k	"	"
R8-R10	30 k	"	"
R11	47 k	"	"
R12	220 k	"	"
R13	1 M	"	"
R14	820 k	"	"
R17	1 k5	"	"
R18	10k	"	"
R19-R23	1 M	"	"
R24-R37	330	"	"

Capacitor

C1	33 µ	10 V Tantalum
C2	4µ7	25 V electrolytic
C3	10 n	polyester
C4	47 n	"
C5	10 n	"
C6	47 n	"

Potentiometer

RV1 2k2 Trimpot

Integrated Circuits

IC1	NE555
IC2	4027 (CMOS)
IC3	4050 "
IC4,5	4511 "
IC6	4518 "

Semiconductors

D1 IN914 or similar
Q1 BC108 or similar
Display 1,2 FND 500

Miscellaneous

SW1 single pole 11 position switch
PB1,2 single make push buttons
PC Boards ETI 543A, ETI 543B
six pc board pins
plastic box
knob
4xAA size battery holder

by one every four seconds. Check the timing accuracy over a number of increments with a watch and adjust RV1 to obtain increments of exactly 4 seconds. Check the other ranges for accuracy and if greatly in error check and adjust the values of the appropriate resistors in the R1 to R16 chain.

Remove the batteries and mount the display board onto the front panel using 6 BA screws and spacers. If the box as specified is used the front panel will have to be cut to allow the displays to protrude through, thus allowing more room for the batteries. A quick assembly check will show how much extra room is required. Now mount the second board and the push buttons and mount the completed unit into the box.

That completes the unit; the only thing to do is to instruct the family how to use it and to persuade them to do so on every STD call. Best of luck. ●

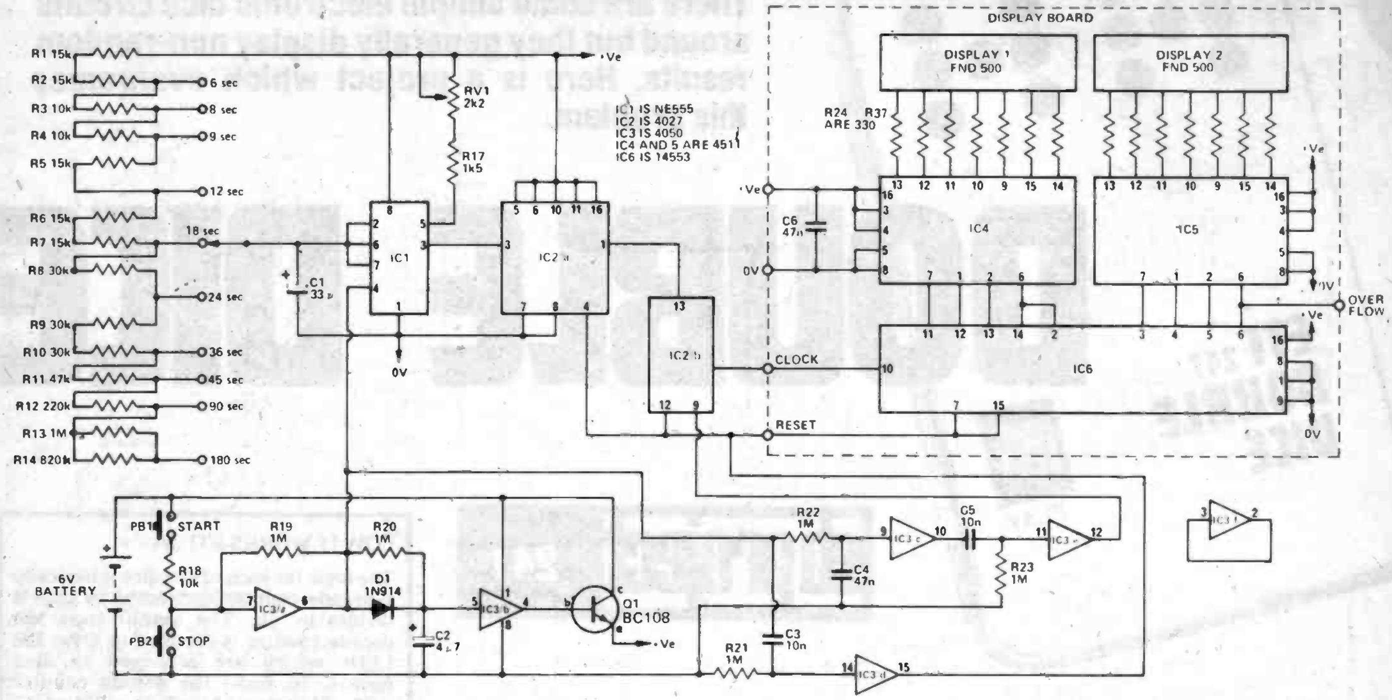


Fig.1 Circuit diagram of the STD timer unit

Specification

TIMING
Periods provided
6,8,9,12,18,24,36,45,90 and 180 seconds
Accuracy
first count −20%
successive counts ± 5%

DISPLAY
2 digit, seven-segment LED

POWER
Batteries
4 x pen cell (6V)
Battery drain
approx 50 mA in 'ON' state
" 1 µA in 'OFF' state

START AND STOP
by separate push buttons

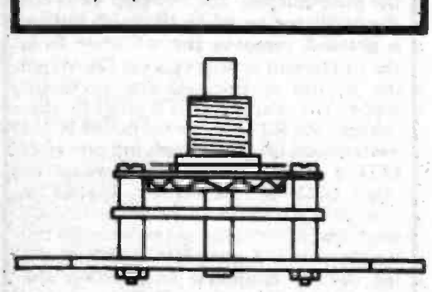


Fig.2 The switch must be disassembled, the spacers cut in halves and then reassembled to the PC board as shown in this diagram

How it works

The basic timing element is the familiar timing IC the 555. This is a convenient device as the timing may be altered by changing the value of a single resistor. The resistor in question is selected by switch SW1 to provide timing periods from one to 45 seconds in duration. As the timing of long intervals is difficult due to the leakage encountered in practical large-value capacitors, a divide by four stage is used to obtain the 6 to 180 second period required. To compensate for differences in the value of capacitor C1 a variable resistor is provided between 5 of the IC and the positive rail. Adjustment of this resistor varies the threshold voltage of the IC and thereby corrects the timing.

The first timing period of the 555 is about 50% longer than those following and to compensate for this the divider stage provides a by-three division, instead of the normal by-four division, on the first sequence. This is not, however, a problem: it can be an advantage. If a call is terminated just at the time the display changes the charge will be within the cheaper period.

The output of IC2 clocks the dual-decade counter IC6 which has a four-line BCD output code. This is decoded to seven-segment format by ICs four and five to drive the seven-segment LED displays. These decoders also have a store facility which is not used in this application. A link is therefore used to connect the store input to zero volta thus disabling it. The use of a link allows the store to be made available if the board is to be used for another application.

The timer is controlled by IC3 which is a hex (6) non-inverting buffer (if input is high, output is high etc). The cycle commences when pushbutton PB1 is pressed. This pulls pin 7 of IC3/1 high causing the output of the IC to go high (pin 6). IC3/1 latches in this state and stays there until the stop button is pressed — when the output goes low again. When the start button is pressed and the output of IC3/1 goes high the input of IC3/2 is also pulled high via diode D1 causing the output of IC3/2 to go high. This high turns on emitter-follower Q1 which then provides power to all circuits with the exception of IC3 which is permanently powered. The off-state current drain of IC3 on the prototype was measured at 200 nanoamps! Thus by using this technique the need to switch the unit on and off has been avoided as battery life in the OFF state will exceed the shelf-life of the battery.

When the 'start' push button is pressed the high at the output of IC3/1 is also fed to pin 4 of the 555 timer IC which starts to cycle at the rate selected by SW1. Pin 14 of IC3/4 also goes high until C3 is discharged by R21. This causes a 10 millisecond pulse to be generated at pin 15 of IC3/4 and this pulse is used to reset the display decade counter, IC6, and also IC2 at initial switch-on. In addition, after a 50 millisecond delay (due to R22 and C4) the output of IC3/3 goes high and this transition in conjunction with C5 and R23 produces another 10 millisecond pulse from IC3/5 which sets IC2/3 causing IC6 to be incremented by one.

When the stop button is pressed the 555 timer is disabled and the timing stops. However, due to the charge on C2, the power remains on for a further 5 to 10 seconds.

There are some simple electronic dice circuits around but they generally display non-random results. Here is a project which overcomes this problem.

DOUBLE DICE

eti project 241

ELECTRONIC GAMES ARE VERY popular today and we have published quite a few which vary in complexity from simple switch logic games, like the Family Ferry, to very complex ones. We have had many requests for an electronic dice and several designs have been submitted by readers. However, all the circuits, submitted had a common failing. This was that, although they operated correctly, the distribution of numbers was not random. That is, if a few hundred 'rolls' were made it would be found that, for example, sixes ocurred far more frequently than they should do. In most cases this was due to the fact that currents in the logic modulated the power supply thus causing bias in the dice.

Bias. We had the same problem in our dice initially, even though CMOS logic was used. It had been intended to design dice which roll fast when the button is pressed, roll slowly when the button is released (for more realism) and then stop to display the result. We designed a system to this specification but found that it too was biased. The cause was current variations due to the differing number of LEDs being switched on and off during the slow roll. The resulting modulation of the power supply causes instability of the oscillator and also acceptable variations in the delay circuitry. This would have been cured but by increasing the complexity of the unit. It was decided instead to delete the slow roll feature and to blank the display during the fast roll. The resulting circuit has been thoroughly checked for randomness and is found to have no bias.

With the CMOS logic used the power consumption is so low that a power switch is not required. The circuit is activated simply by pressing the roll button. The roll result is displayed and after about seven seconds the display will switch off automatically. The current drawn from the battery in the off state was measured and found to be 600 nanoamps! And of that 500 nanoamps was due to leakage in the capacitor across the battery.

CONSTRUCTION

The CMOS devices used in this project should be handled with care as they may easily be damaged by static electricity. They should be the last components to be installed on the printed circuit board they should be left in the protective foam until installation and they should be handled as little as possible.

Begin assembly of the board by fitting the links (we regret that there are so many but it was unavoidable on a one-sided PCB) then resistors and other low-height components and then finally the IC's. Drill holes in the front panel for the LEDs and for the push button. The cathode terminal of the type of LED specified is marked by a small flat on the body flange and the cathode lead is also slightly shorter. Cut the leads of the LED so that they are 5–7mm long leaving the cathode just a little shorter so that it may be identified easily after installation. Mount the LEDs and position them so that the anode lead points towards the centre of the box (between the two dice groups) and

HOW IT WORKS ETI 241

The logic for each of the dice is basically a decade counter connected so that it divides by six. The output from the decade counter is decoded to drive the LEDs which are arranged in dice format. To make the decade counter (IC5, 4518) divide by six, the 'B' and 'C' outputs are taken to a two-input HAND gate and then through a second NAND gate to the reset te rminal of the decade counter. When the 'B' and 'C' outputs first both go to '1' (decimal count six) the reset terminal goes high which resets the counter outputs to '000' thus removing the high to the rest terminal. Thus as a result at the reset terminal of the decade counter a pulse about 100 nanoseconds wide is generated. This pulse from the first dice is used to clock the second one. The decoding of the output from the decade counter is performed by ICs 2/3, 3/3 and 3/4 together with some associated resistors and transistors the truth table of which is shown in Table 2.

The power required by the LEDs is more than can be supplied by the CMOS and the transistors are therefore required to buffer the outputs as well as forming part of the decoding process. Transistors Q3 and Q5 (Q6 and Q9 for dice 2) act as logic gates for decoding.

The counters are clocked by an oscillator constructed from ICs 2/1 and 2/2. The output from the oscillator, about 8 kHz, can be gated on and off by a control input as follows. The push button controls a flip-flop, constructed from the gates IC1/1 and IC1/. The purpose of this flipflop is to remove any contact bounce from the operation of the push button. The flip-flop switches the oscillator on when the push button is pressed, removes the +6 volts from the LEDs, and charges C3 via D1. When the button is released the oscillator stops, the capacitor C3 slowly discharges via R3, and the output of IC1/4 switches on Q1 thus supplying power to LEDs 1 and 6. Power is supplied to the other LEDs by the switch. The LEDs now indicate the outputs of the decade counters. After about seven seconds the output o IC1 3 goes low which resets the decade counters. In addition the transistor Q1 is turned off. Power to the rest of the LEDs is left on but as the counters are reset to zero (to decimal count zero or display count '1') all LEDs will be off.

Parts List

Resistors

R1	1M	½W	5%
R2	10k	"	"
R3	1M	"	"
R4-R10	10k	"	"
R11-R14	330 ohms	"	"
R15, 16	10k	"	"
R17-R20	330 ohms	"	"
R21, 22	10k	"	"

Capacitors

C1	10μF 25V electrolytic
C2	4n7 polyester
C3	10μF 25V electrolytic

Semiconductors

D1	1N914 or similar
Q1,2,4,6,8	ZTX500 or BC178
Q3,5,7,9	BC108 or similar
IC1 – 4	4011 (CMOS)
IC5	4518 or 4520
LED.1-14	TIL 209 with clip

Miscellaneous

PB1 Push button SPDT
ETI 241 PC board
14 pc board pins
Front panel
2 battery holders
2 battery clips
4 batteries

wire them in accordance with the component overlay/wiring diagram. With the leads on the LEDs cut this short they may be damaged when soldering if precautions are not taken. To prevent this use a pair of long-nose pliers or similar as a heat sink on the lead of the LED when soldering.

Before wiring the switch check which terminal is common. Usually this is the centre terminal but sometimes, as with the switch we used, it is one of the outside terminals. When the unit is completed a piece of foam plastic should be used between the rear of the LEDs and the PCB so that there is no possibility of shorts ocurring.

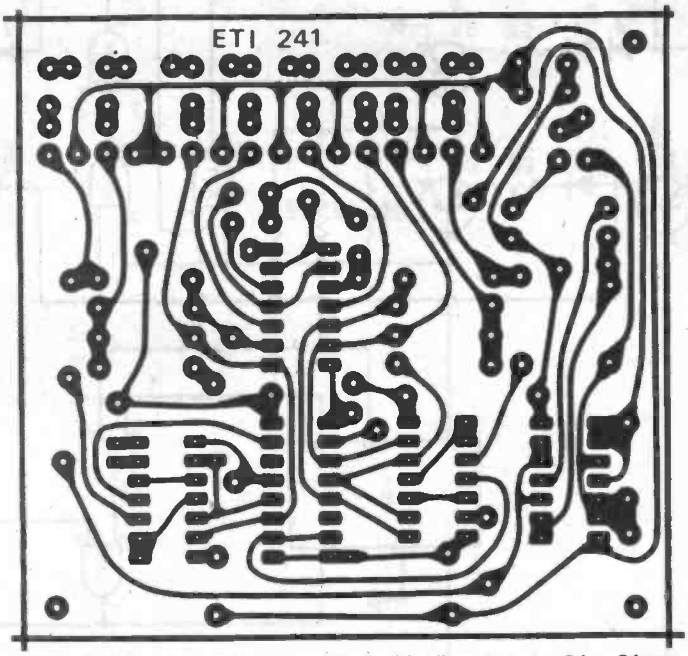
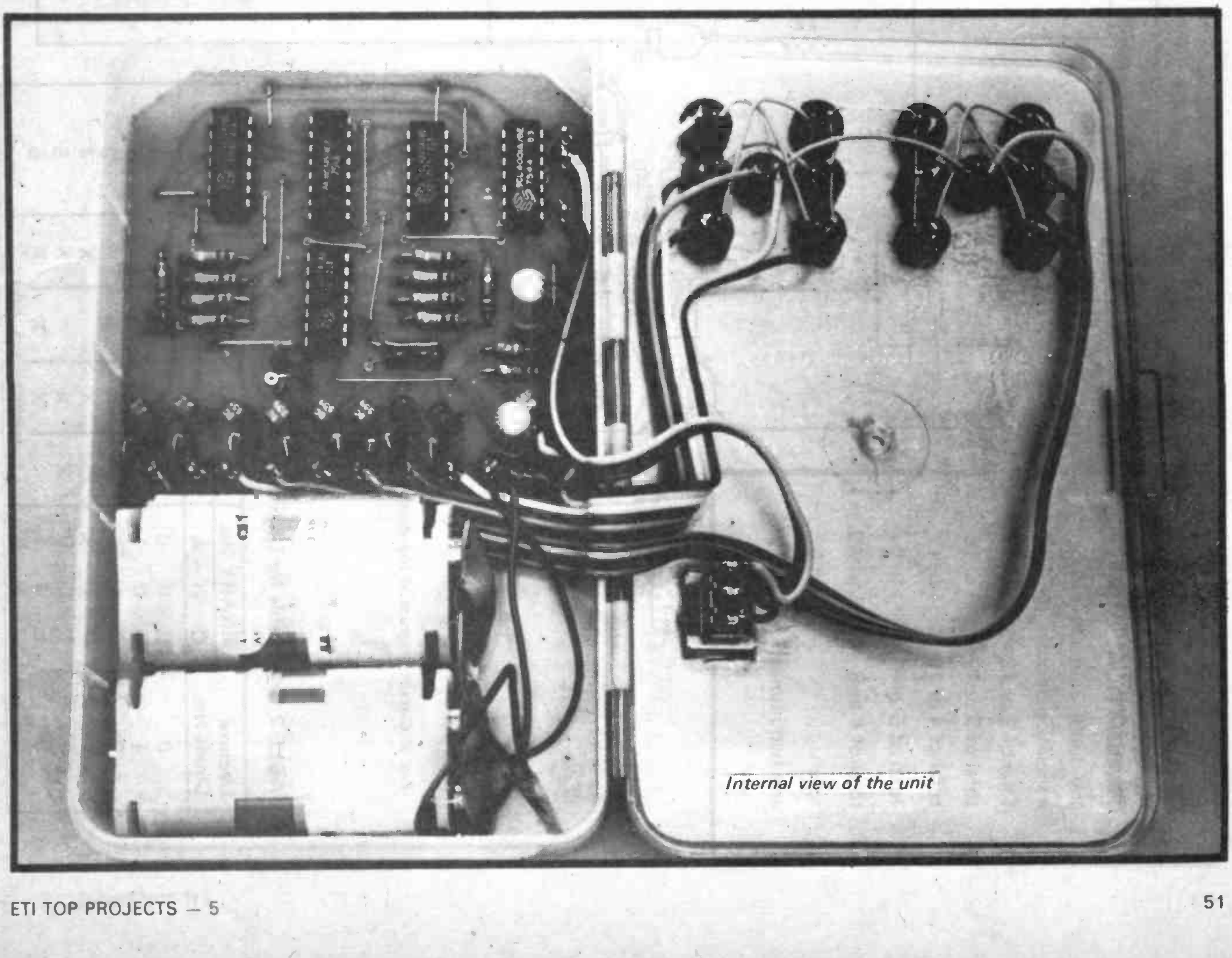


Fig. 1. Printed circuit layout for the double dice. Full size 84 x 81mm.



Internal view of the unit

TABLE 1 Double dice odds.

COMBINATION	ODDS
any double number	1 in 6
a specified double	1 in 36
total of 2 or 12	1 in 36
total of 3 or 11	1 in 18
total of 4 or 10	1 in 12
total of 5 or 9	1 in 9
total of 6 or 8	1 in 7.2
seven	1 in 6
any two numbers	1 in 18

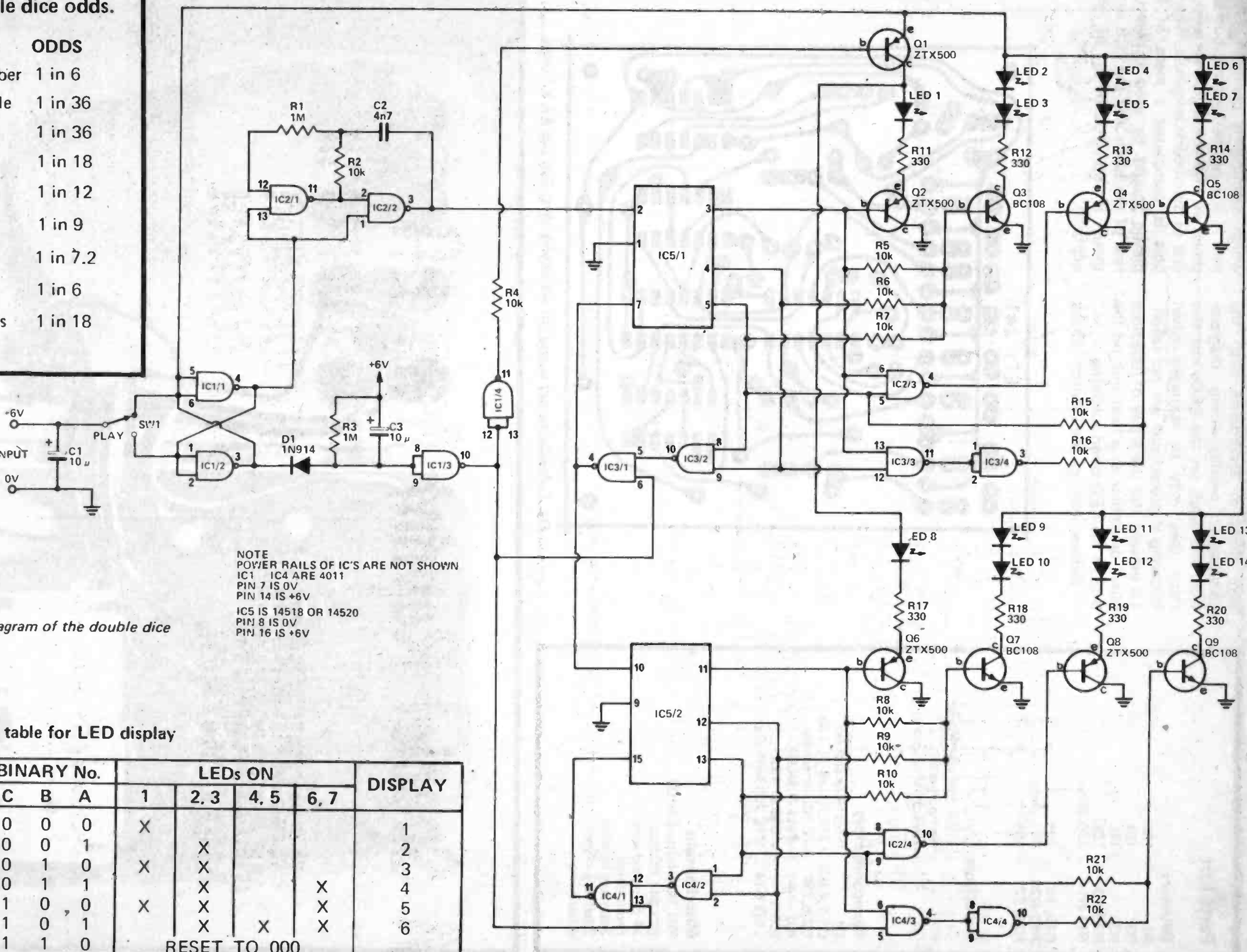


Fig. 2. Circuit diagram of the double dice

TABLE 2 Truth table for LED display

Decimal Count No.	BINARY No. C	B	A	LEDs ON 1	2, 3	4, 5	6, 7	DISPLAY
0	0	0	0	X				1
1	0	0	1		X			2
2	0	1	0	X	X			3
3	0	1	1		X		X	4
4	1	0	0	X	X		X	5
5	1	0	1		X	X	X	6
6	1	1	0	RESET TO 000				

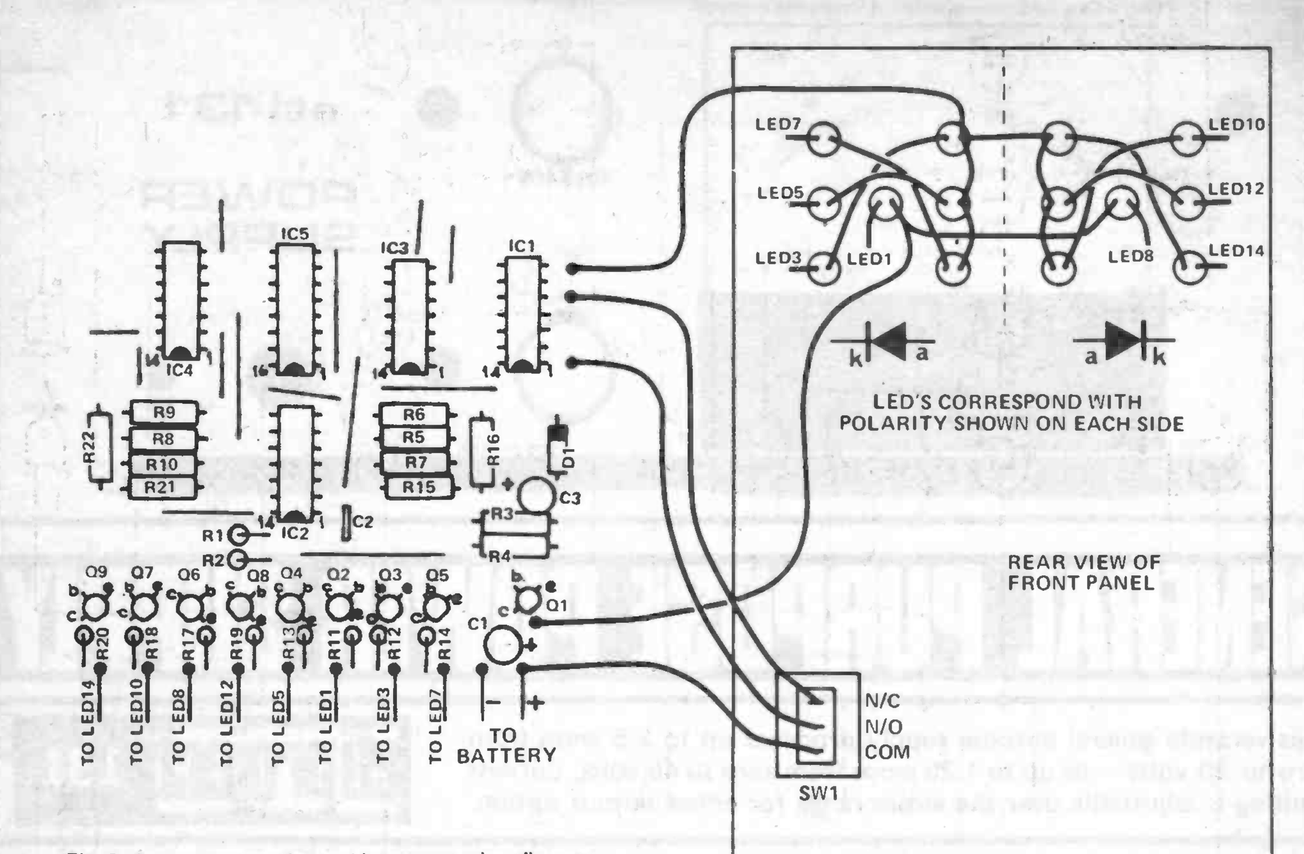
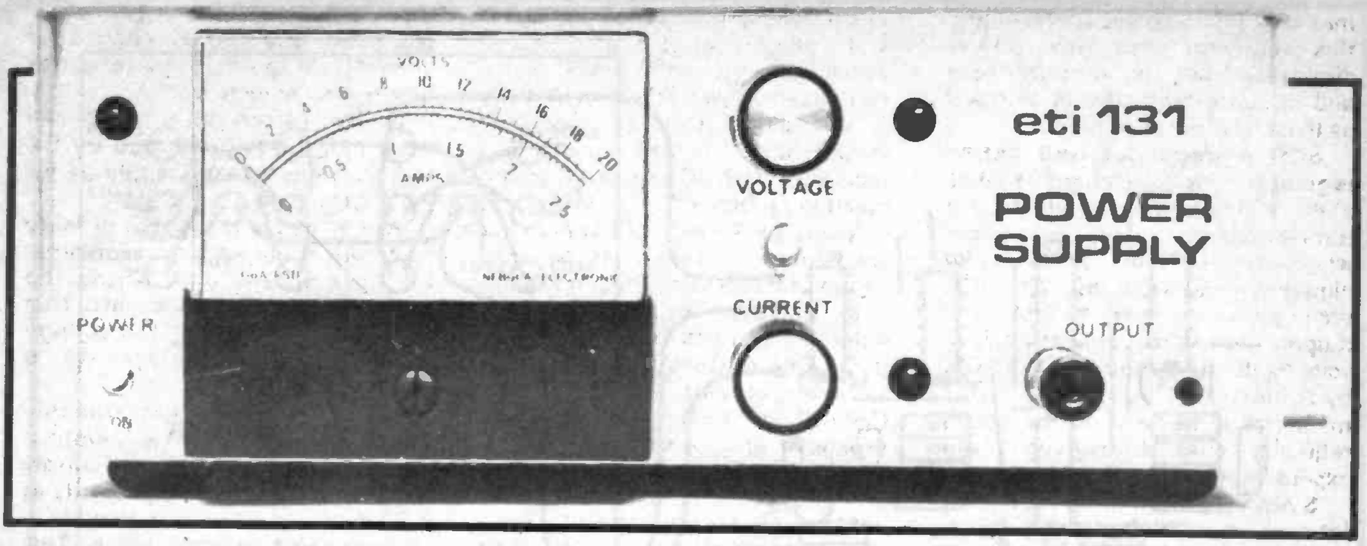


Fig. 3. Component overlay and interconnection diagram.



GENERAL PURPOSE POWER SUPPLY

This versatile general purpose supply produces up to 2.5 amps from zero to 20 volts – or up to 1.25 amps from zero to 40 volts. Current limiting is adjustable over the entire range for either output option.

eti project 131

AN IDEAL POWER SOURCE should supply a voltage which is adjustable over a wide range, and which remains at the set voltage regardless of line voltage or load variations. The supply should also be undamaged by a short circuit across its output and be capable of limiting the load current so that devices are not destroyed by fault conditions.

Two such supplies have previously been described in ETI. The first was a simple supply providing 0 to 15 volts at up to 750 mA. The second was a dual tracking supply providing ± 20 volts at up to one ampere. Both these supplies have been extremely popular, especially the simple one, and are still being built by many people. However there have been many requests for a supply having a greater output current capability than either of these previous designs could provide.

This project describes a supply that will provide 2.5 amperes at up to 18 volts (up to 20 volts at lower currents). Alternately a few simple changes can make the supply provide up to 40 volts at 1.25 amperes. The supply voltage is settable between zero and the maximum available, and current limiting is also adjustable over the full range. The mode of operation of the supply is indicated by two LEDs. The one beside the voltage control knob indicates when the unit is in normal voltage-regulation mode and the one beside the current limit control indicates when the unit is in current limit mode. In addition a large meter indicates the current or voltage output as selected by a switch.

DESIGN FEATURES

During our initial design stages we looked at various types of regulator and the advantages and disadvantages of each in order to choose the one which would give the best cost-effective performance. The respective methods and their characteristics may be summarized as follows.

The shunt regulator. This design is suitable mainly for low-power supplies — up to 10 to 15 watts. It has good regulation and is inherently short-circuit proof but dissipates the full amount of power it is capable of handling under no-load conditions.

The series regulator. This regulator is suitable for medium-power supplies up to about 50 watts. It can and is used for higher power supplies, but heat dissipation can be a problem especially at very high current with low output voltages. Regulation is good, there is little output noise and the cost is relatively low.

SRC regulator. Suitable for

SPECIFICATION – ETI 131

20 VOLT VERSION	
VOLTAGE	
Output	0–20 volts
Regulation	<20 mV (0–2.5A)
Ripple and noise	< 1 mV at 2.5A
CURRENT	
Output	0–2.5A (up to 18 V) 0–2.0A (up to 20 V)
Limit	0–2.5A
Regulation	<10 mA (0–20 V)
40 VOLT VERSION	
VOLTAGE	
Output	0–40 V
Regulation	<20 mV (0–1.25A)
Ripple and noise	<1.5 mV at 1.25A
CURRENT	
Output	0–1.25A
Limit	0–1.25A
Regulation	<10 mA (0–40 V)

In both versions LEDs indicate voltage or current modes and the meter is switchable to read voltage or current.

medium to high power applications, this regulator has low power dissipation, but the output ripple and response time are not as good as those of a series regulator.

SCR preregulator and series regulator. The best characteristics of the SCR and series regulators are combined with this type of supply which is used for medium to high-power applications. An SCR pre-regulator is used to obtain a roughly regulated supply about five volts higher than required, followed by a suitable series regulator. This minimizes power loss in the series regulator. It is however more expensive to build.

Switching regulator. Also used for medium to high-power applications, this method gives reasonable regulation and low power dissipation in the regulator but is expensive to build and has a high frequency ripple on the output.

Switched-mode power supply. The most efficient method of all, this regulator rectifies the mains to run an inverter at 20 kHz or more. To reduce or increase the voltage an inexpensive ferrite transformer is used, the output of which is rectified and filtered to obtain the desired supply. Line regulation is good but it has the disadvantage that it cannot easily be used as a variable supply as it is only adjustable over a very small range.

OUR OWN DESIGN

Our original design concept was for a supply of up to 20 volts at 5 to 10 amps output. However, in the light of the types of regulator available, and the costs, it was decided to limit the current to about 2.5 amps. This allowed us to use a series regulator — the most cost-effective design. Good regulation was required, together with variable-current limit, and it was also specified that the supply would be useable down to virtually zero volts. To obtain the last requirement a negative supply rail or a comparator that will operate with its inputs at zero volts is required.

Rather than use a negative supply rail we chose to use a CA3130 IC operational amplifier as the comparator. The CA3130 requires a single supply (maximum of 15 volts) and, initially, we used a resistor and 12 volt zener to derive a 12 volt supply. The reference voltage was then derived from this zener supply by another resistor and a 5 volt zener. It was felt that this would have given sufficent regulation for the reference voltage but in practice the output from the rectifier was found to vary from 21 to 29 volts and some of the ripple and voltage change that occurred across the 12 volt zener, as a consequence, was reflected into the 5 volt zener reference. For this reason the 12 volt zener was replaced by an IC regulator which cured the problem.

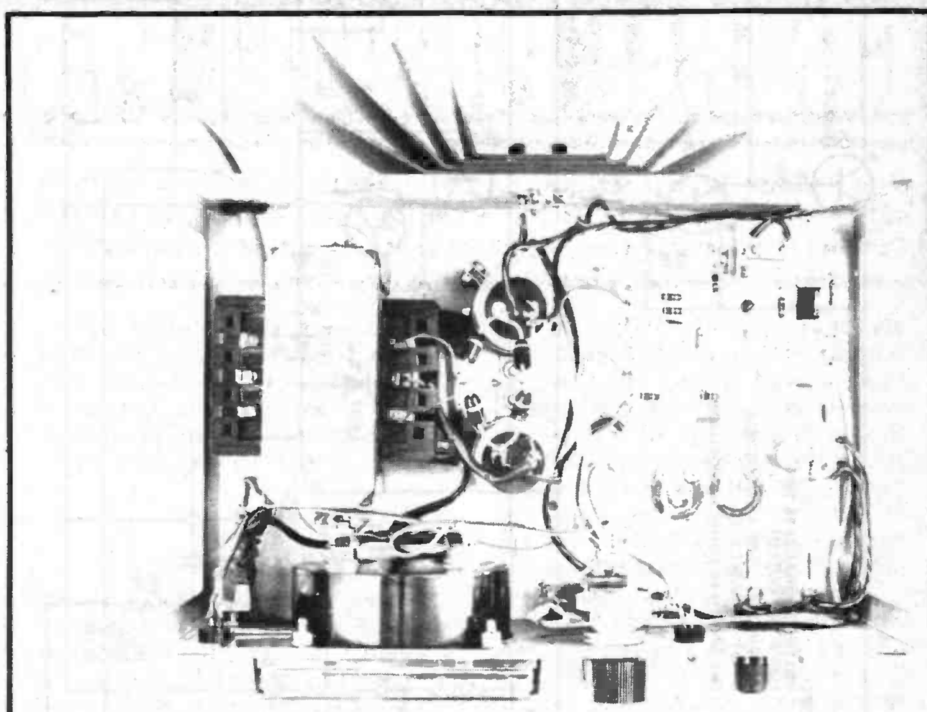
With all series regulators the series-output transistor by the nature of the design, must dissipate a lot of power especially at low output voltage and high current. For this reason an adequate heatsink is an essential part of the design. Commercial heatsinks are very expensive and sometimes difficult to mount. We therefore designed our own heatsink which was not only cheaper but worked better than the commercial version we had been considering — being easier to mount. However at full load the heatsink still runs hot as does the transformer, and under high-current low-voltage conditions the transistor may even be too hot to touch. This is quite normal as the transistor under these conditions is still operating within its specified temperature range.

With any highly regulated supply, stability can be a problem. For this reason in the voltage-regulation mode of operation, capacitors C5 and C7 are incorporated to reduce the loop gain at high frequencies and thus prevent the supply from oscillating. The value of C5 has been chosen for best compromise between stability and response time. If the value of C5 is too low the speed of response is greater — but there is a higher chance of instability. If too high the response time is unduly increased.

In the current-limit mode the same function is performed by C4 and the same remarks apply as for the voltage case.

As the supply is capable of fairly high current output there is inevitably some voltage drop across the wiring to the output terminals. This is overcome by sensing the voltage at the output terminals via a separate pair of leads.

Whilst the supply was primarily designed for 20 volts at 2.5 amps it was suggested that the same supply could be used to supply 40 volts at 1.25 amps and that this would be of more value to some users. This may be done by changing the configuration of the rectifier and by changing a few components. Some thought was given to making the supply switchable but the extra complication and expense were such that it was not considered to be worthwhile. Thus you should simply decide which configuration suits your need and build the supply accordingly.



Inside view of the completed 40 volt power supply. Note how the heatsink is mounted to the rear of the unit.

The maximum regulated voltage available is limited either by the input voltage to the regulator being too low (at over 18 volts and 2.5 amps) or by the ratio of R14/R15 and by the value of the reference voltage.

$$\left(\text{Output} = \frac{R14+R15}{R15}\ V\,\text{ref}\right)$$

General purpose power supply

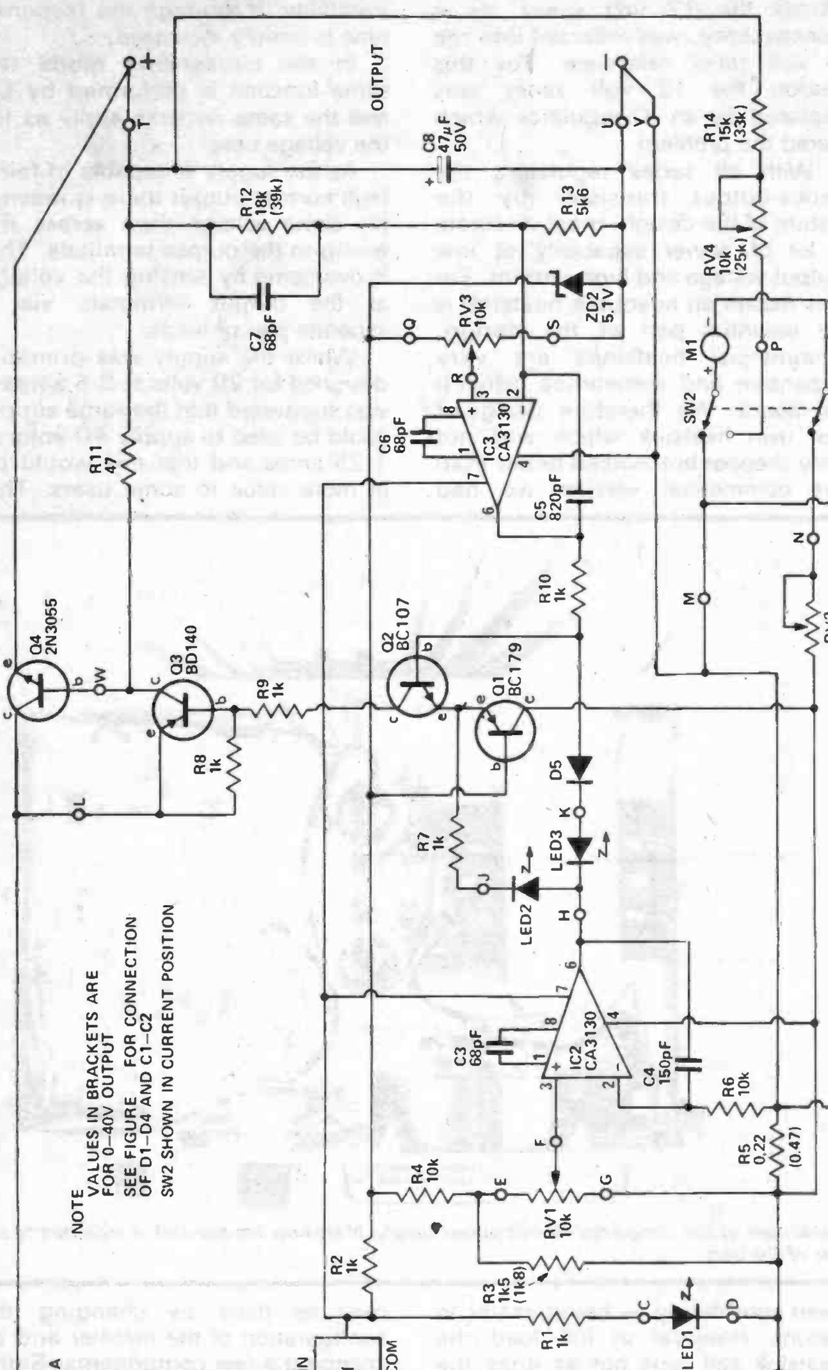


Fig. 1. Circuit diagram of the complete power supply 20 volt 2.5 ampere version.

Due to the tolerance of ZD1 the full 20 volts (or 40 volts) may not be obtainable. If this is found to be the case R14 should be increased to the next preferred value.

Single turn potentiometers have been specified for the voltage and current controls because they are inexpensive. However if precise setability of voltage or current limit is required ten-turn potentiometers should be used instead.

CONSTRUCTION

The recommended printed-circuit board layout should be used as construction is thereby greatly simplified. Printed-circuit board pins should also be used for the 20 wire connections to the board. These should be installed first. The rest of the components may now be assembled onto the board making sure that the polarities of diodes, transistors, ICs and electrolytics are correct. The BD140 (Q3) should be mounted such that the side with the metal surface faces towards IC1. A small heatsink should be bolted onto the transistor as shown in the photograph.

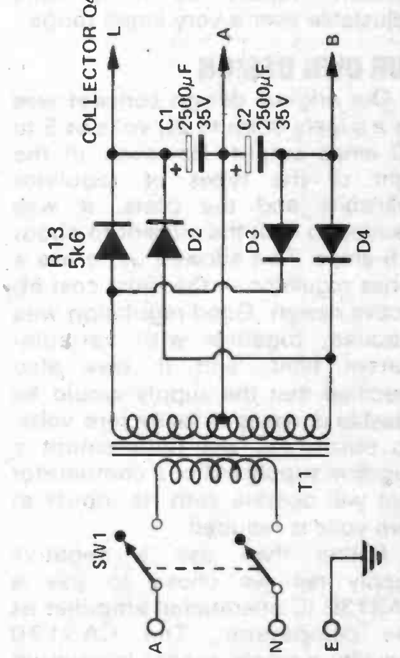


Fig. 2. Alternative rectifier and filter capacitor connections required for 40 volt, 1.25 ampere version.

HOW IT WORKS – ETI 131.

The 240 volt mains is reduced to 40 Vac by the transformer and, depending on which supply is being built, rectified to either 25 or 50 Vdc. This voltage is only nominal as the actual voltage will vary between 29 volts (58 volts) on no-load to 21 volts (42 volts) at full load. The same filter capacitors are used in either case. They are connected in parallel for the 25 volt version (5000 μF) and in series for the 50 volt version (1250μF). In the 50 volt version the centre tap of the transformer is connected to the centre tap of the capacitors thus ensuring correct voltage sharing between the capacitors. This arrangement also provides a 25 volt supply for the regulator IC.

The voltage regulator is basically a series type where the impedance of the series transistor is controlled in such a way that the voltage across the load is maintained constant at the preset value. The transistor Q4 dissipates a lot of power especially at low output voltages and high current and is therefore mounted on the heatsink on the rear of the unit. Transistor Q3 adds current gain to Q4, the combination acting as a high-power, high-gain, PNP transistor.

The 25 volts is reduced to 12 volts by the integrated-circuit regulator IC1. This voltage is used as the supply voltage for the CA3130 ICs and is further reduced to 5.1 volts by zener diode ZD1 for use as the reference voltage. The voltage regulation is performed by IC3 which compares the voltage as selected by RV3 (0 to 5.1 volts) with the output voltage as divided by R14 and R15. The divider gives a division of 4.2 (0 to 21 volts) or eight (0 to 40 volts). However at the high end the available voltage is limited by the fact that the regulator loses control at high current as the voltage across the filter capacitor approaches the output voltage and some 100 Hz ripple will also be present. The output of IC3 controls transistor Q2 which in turn controls the output transistor such that the output voltage remains constant regardless of line and load variations. The 5.1 volt reference is supplied to the emitter of Q2 via Q1. This transistor is in effect a buffer stage to prevent the 5.1 volt line from being loaded.

Current control is performed by IC2 which compares the voltage selected by RV1 (0 to 0.55 volts) with the voltage generated across R7 by the load current. If say 0.25 volts is set on RV1 and the current drawn from the supply is low, the output of IC2 will be near 12 volts.

This causes LED 2 to be illuminated as the emitter of Q1 is at 5.7 volts. This LED therefore indicates that the supply is operating in the voltage-regulator mode. If however the current drawn is increased such that the voltage across R7 is just above 0.25 volts (in our example) the output of IC2 will fall. When the output of IC2 falls below about 4 volts Q2 starts to turn off via LED 3 and D5.

The effect of this is to reduce the output voltage so that the voltage across R7 cannot rise further. When this happens the voltage comparator IC3 tries to correct for the condition and its output rises to 12 volts. IC2 then takes more current to compensate and this current causes LED 3 to light, indicating that the supply is operating in the current-limit mode.

To ensure accurate regulation the voltage sensing leads are taken to the output terminals separately from those carrying the load current.

The meter has a one milliamp movement and measures the output voltage (directly across the output terminals) or current (by measuring the voltage across R7) as selected by the front panel switch SW2.

PARTS LIST – ETI 131A

Resistors

R1	–	1 k	½ W	5%
R2	–	1 k	"	"
R3	–	1 k5	"	"
R4	–	10 k	"	"
R5	–	0.22 ohm 5 W		
R6	–	10 k	½ W	5%
R7	–	1 k	"	"
R8	–	1 k	"	"
R9	–	1 k	"	"
R10	–	1 k	"	"
R11	–	47	"	"
R12	–	18 k	"	"
R13	–	5 k6	"	"
R14	–	15 k	"	"

Potentiometers

RV1	–	10 k lin rotary
RV2	–	1 k trim
RV3	–	10 k lin rotary
RV4	–	10 k trim

Capacitors

C1	–	2500 μF 35V electro
C2	–	2500 μF 35V electro
C3	–	68 pF ceramic
C4	–	150 pF "
C5	–	820 pF "
C6	–	68 pF "
C7	–	68 pF "
C8	–	47 μF 50V electro

Transistors

Q1	–	BC179
Q2	–	BC107
Q3	–	BD140
Q4	–	2N3055 (with insulation kit)

Diodes

D1,2	–	IN5404
D5	–	IN914

Other Semiconductors

ZD1	Zener Diode 5.1V 400 mW
LED 1,2	LED TIL209 or similar
IC1	Integrated Circuit LM341P-12
IC2,3	" " CA3130

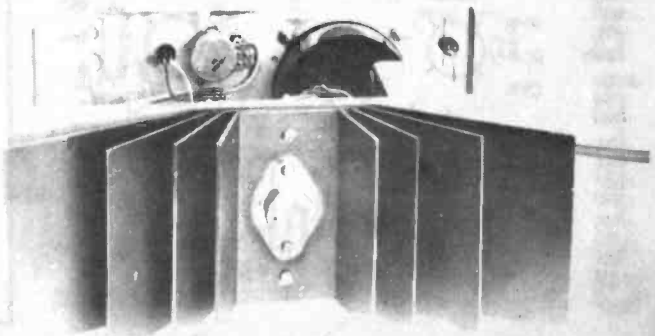
Miscellaneous

PC board ETI 131
Transformer 40V CT 2A
SW1,2 switch DPDT toggle
Meter 1 mA FSD scaled 0-20V, 0-2.5A
Chassis to Fig. 11
Cover to Fig. 13
Heatsink to Fig. 10
Front panel to Fig. 9
Two terminals
Power cord & clamp
Two knobs
Four 10 mm long spacers
20 PC board pins
Four rubber feet
nuts, bolts, washers etc.

PARTS LIST – ETI 131B

All parts for ETI 131A except

Change	R3	to	1 k8
	R5	to	0.47 ohm
	R12	to	39 k
	R14	to	33 k
	RV4	to	25 k



Rear view of the heatsink showing how it and the transistor are mounted.

General purpose power supply

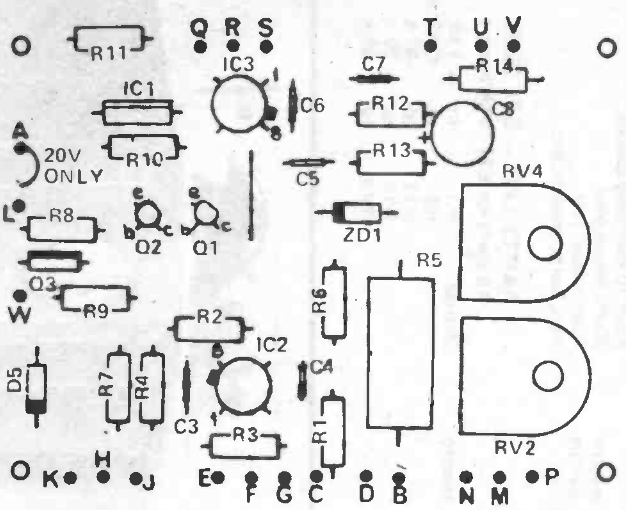


Fig. 3. Component overlay for the printed-circuit board assembly.

If the metalwork as described is used the following assembly order should be used.

a) Mate the front panel to the front of the chassis and secure them together by installing the meter.

b) Fit the output terminals, potentiometers and meter switch on to the front panel.

c) The cathodes of the LEDs (that we used) were marked by a notch in the body which could not be seen when the LEDs were mounted onto the front panel. If this is the case with yours, cut the cathode leads a little shorter to identify them and then mount the LEDs into position.

d) Solder lengths of wire (about 180 mm long) to the 240 volt terminals of the transformer, unsulate the terminals with tape and then mount the transformer into position in the chassis.

f) Install the power cord and the cord retaining clip, wire the power switch, insulate the terminals and then mount the switch onto the front panel.

g) Assemble the heatsink and screw it onto the rear of the chassis via two bolts — then mount the power transistor using insulation washers and silicon grease.

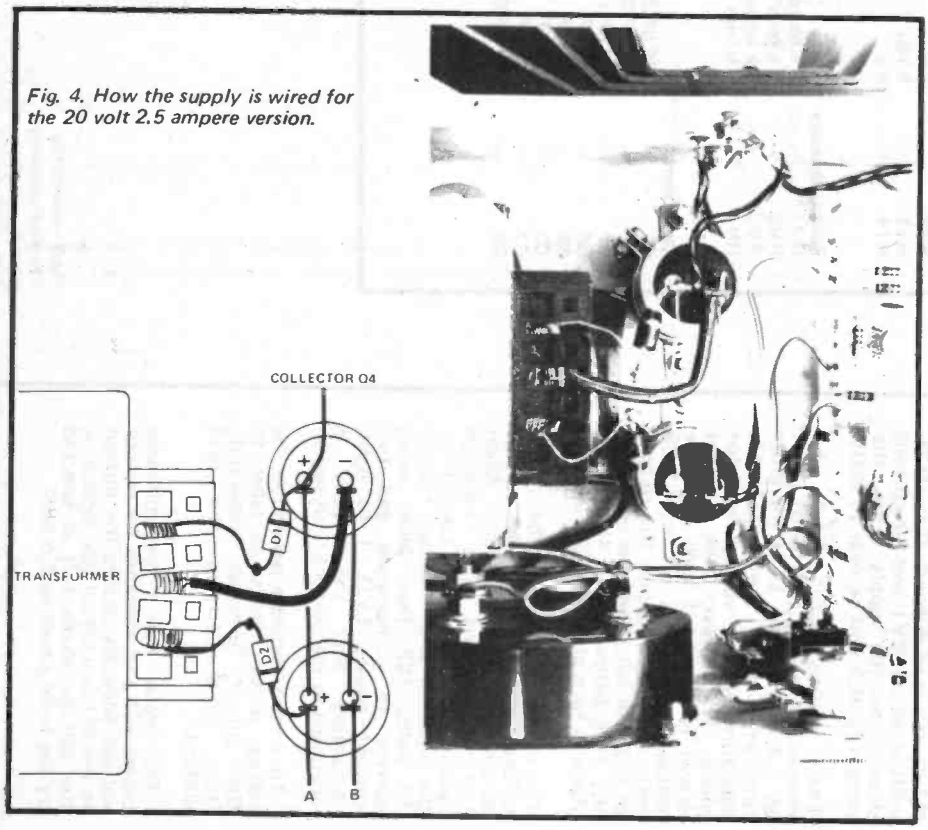
h) Mount the assembled printed-circuit board to the chassis using 10 mm spacers.

i) Wire the transformer secondary, rectifier diodes and filter capacitors. The diode leads are stiff enough not to need any additional support.

j) The wiring between the board and the switches may now be made by connecting points with corresponding letters on the front panel diagram and component overlay diagrams.

The only setting up required is to calibrate the meter. Connect an accurate voltmeter to the output control of the power supply until the external meter reads 15 volts (or 30 volts on the alternate arrangement).

Fig. 4. How the supply is wired for the 20 volt 2.5 ampere version.



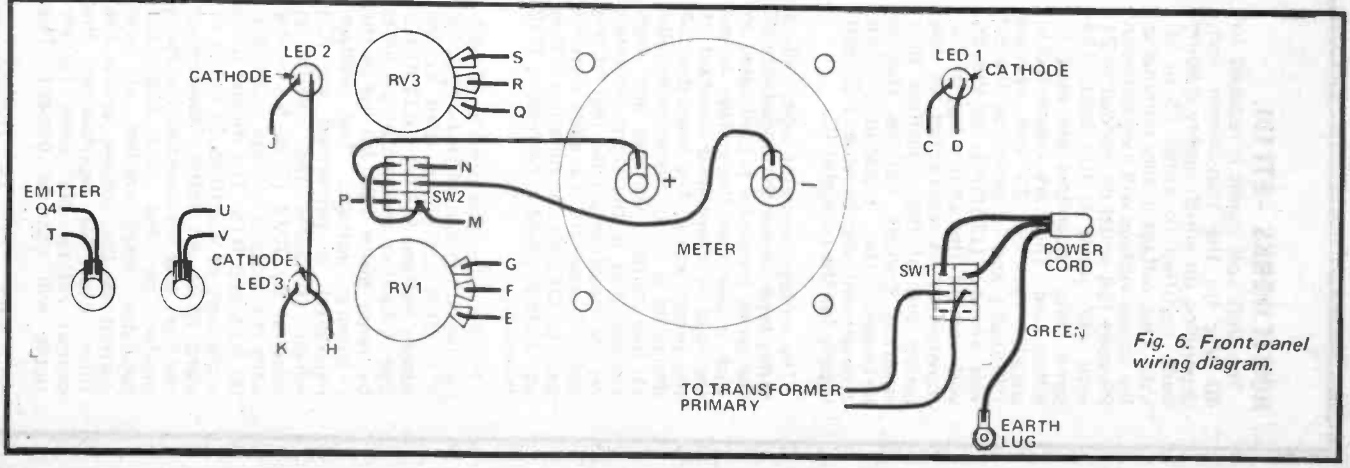


Fig. 6. Front panel wiring diagram.

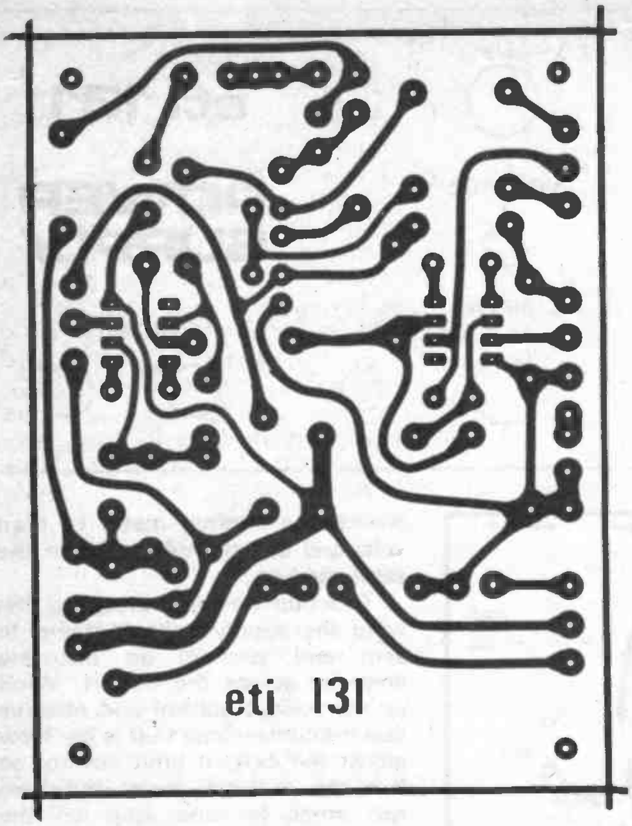


Fig. 7. Printed-circuit board layout for the power supply. Full size 100 x 75 mm.

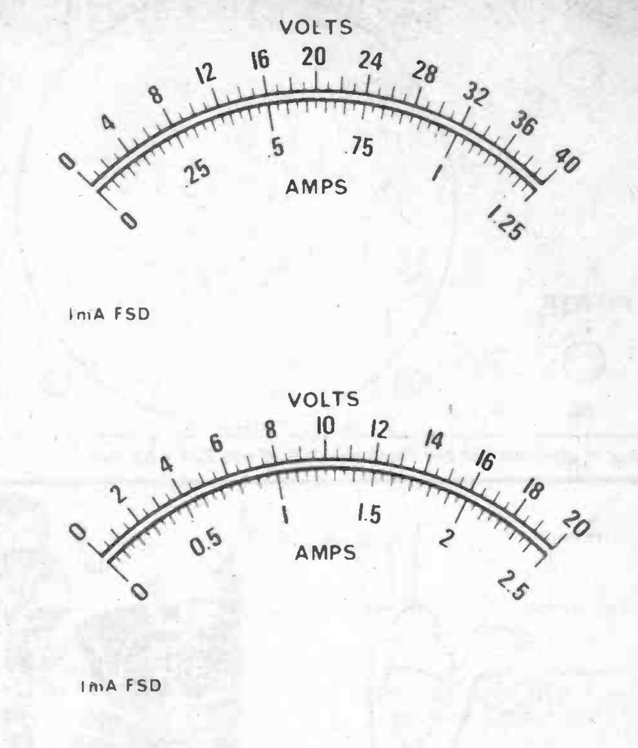
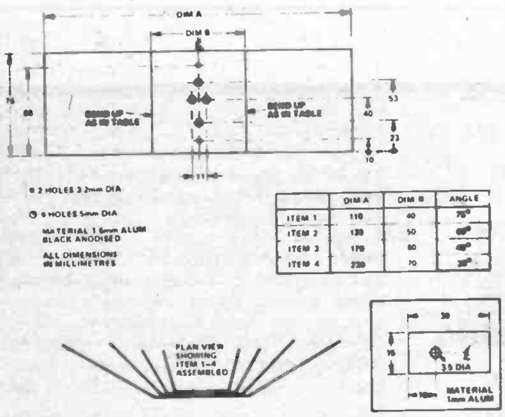
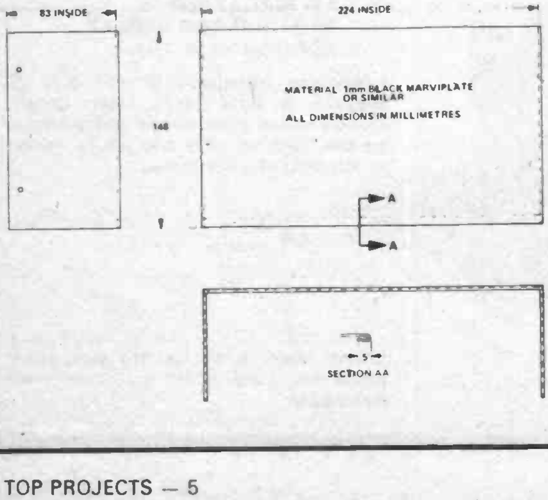


Fig. 8. Scales for the alternative meters for the unit shown full size.



	DIM A	DIM B	ANGLE
ITEM 1	110	40	75°
ITEM 2	130	50	[illegible]
ITEM 3	170	60	[illegible]
ITEM 4	230	70	30°

Fig. 10. Heatsink detail.



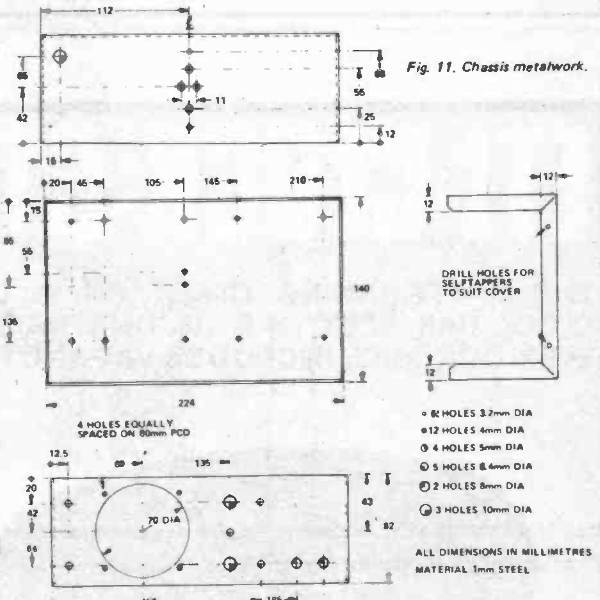


Fig. 11. Chassis metalwork.

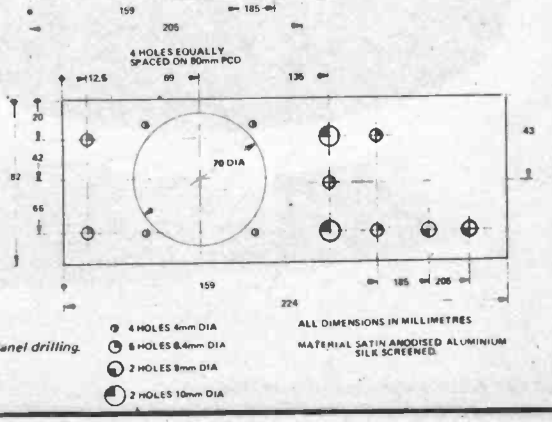


Fig. 12. Front panel drilling.

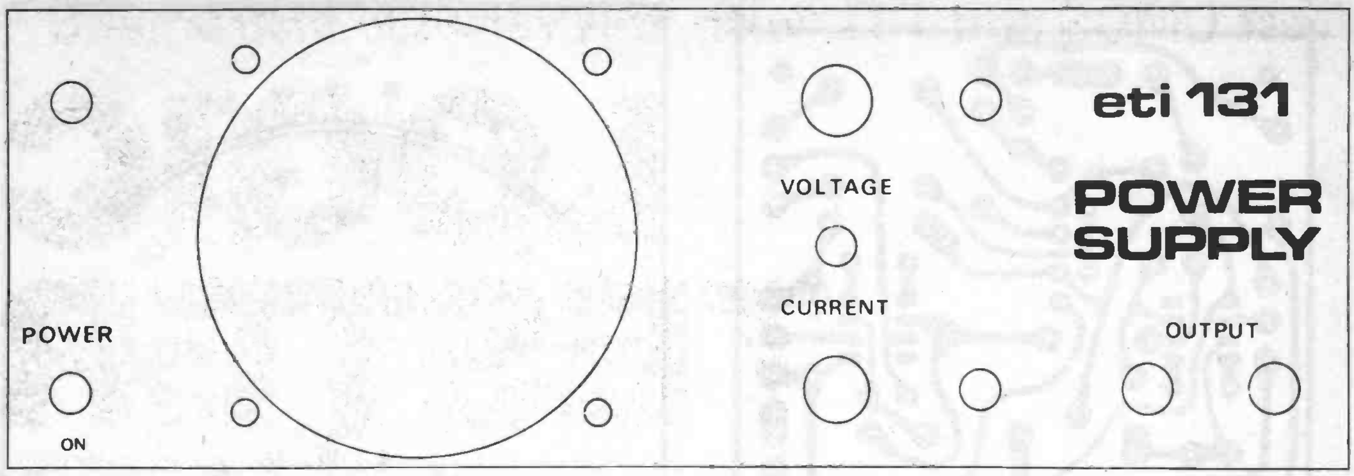


Fig. 9. Artwork for the front panel. Full size 224 x 82 mm.

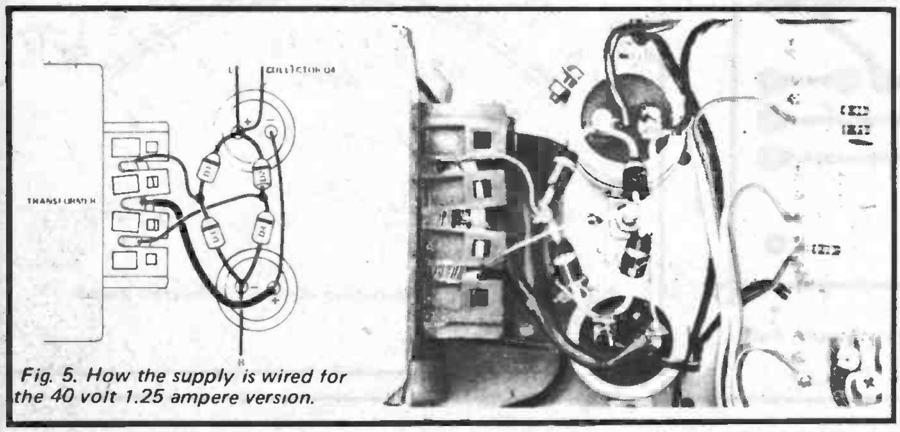


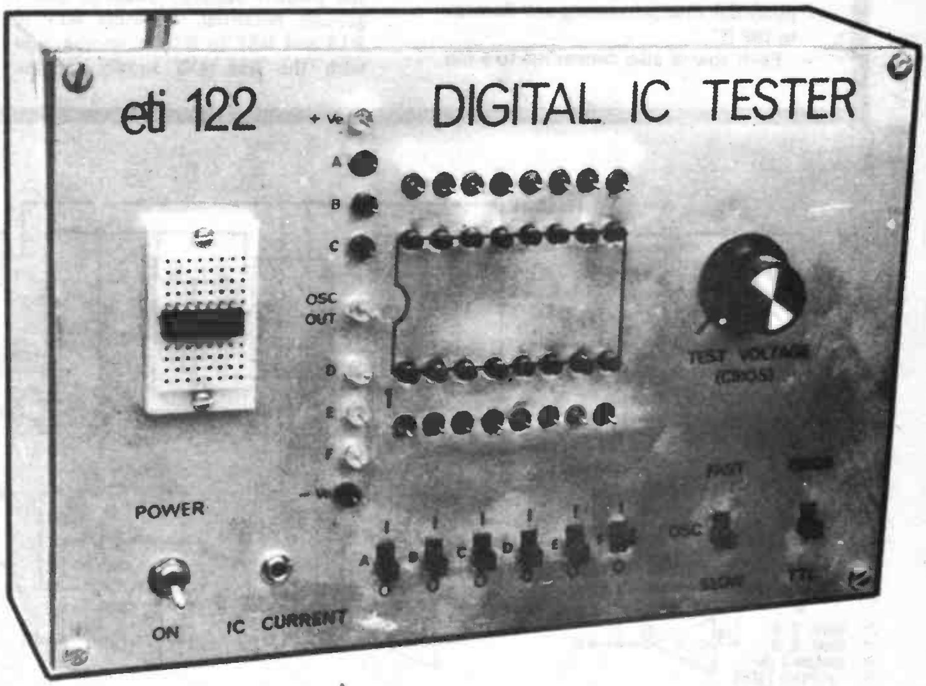
Fig. 5. How the supply is wired for the 40 volt 1.25 ampere version.

Switch the internal meter to read volts and adjust RV4 to obtain the same reading.

To set up the current reading first wind the supply voltage down to zero and connect an accurate ammeter across the output. Wind up the voltage control and observe that the current limit LED is on. Now adjust the current limit control so that the external meter indicates two amps (or one amp on the alternative unit). Now adjust RV2 so that the same reading is obtained on the internal meter when it is switched to the current position. ●

Test CMOS and TTL with this versatile instrument.

LOGIC TESTER



WARNING:

When using the tester, remember that manufacturers recommend that CMOS ICs should not be inserted or removed from a circuit without first switching off the power supply.

etiproject 122

EXPERIMENTERS often damage ICs in the process of developing a new circuit and often try a new IC in a circuit that is not working to eliminate that as a possible cause. The result of this is that one usually finishes up with a box full of ICs which are of dubious value. To sort out these ICs one must use a tester that is capable of testing the wide range of differing ICs that are available in the most commonly used families.

Until recently the most commonly used family has been TTL. But CMOS is rapidly gaining widespread usage and any tester, to be of value these days, must be able to test both these families. The ETI Logic Tester is capable of testing both families, and is also capable of being used to breadboard and test simple circuits based on single ICs.

An LED indicator is associated with each pin of the IC under test and these are arranged around the perimeter of a box representing the IC under test. This allows a small card, which has the schematic of the particular IC drawn on it, to be fitted to the front of the tester as an aid to the interpretation of the LED test indications.

CONSTRUCTION

The most expensive single component in the tester, after the transformer, is the case. For this reason we decided to make a wooden case and a plain aluminium front panel. Some people may however wish to mount the unit in a diecast box and for this reason the printed circuit board has been sized to fit in a standard 222 x 146 x 51 mm die-cast box. The following description is for a wooden box specifically, but applies equally well to the metal box.

The printed-circuit board is mounted to the rear of the front panel, copper side to the panel, such that the LEDs and patch pins, mounted on the printed-circuit board, project through the front panel. This greatly simplifies construction as it saves some 48 leads and solder joints. The switches are secured to the front panel by first glueing two pieces of printed-circuit board to the rear and then soldering the switches to the copper side of the board. This procedure avoids the necessity of a multitude of screws passing through the front panel.

The printed-circuit board should be assembled with the aid of the component overlay by fitting all components with the exception of IC1, 5, 6 and 7, and LEDs 1 through 16, and the patch pins. Check that the ICs are orientated correctly as are also C2, 5, 7, 9 and D1, 2 and 3. Now solder these parts into position using the least amount of heat necessary on ICs 2, 3 and 4.

Position the LEDs and patch pins onto the copper side of the board but do not solder them in place as yet. Now fit the board to the front panel so that the pins and LEDs protrude through the panel evenly. Secure the pins and LEDs in position by using a very small drop of five minute epoxy for each, on the component side of the

HOW IT WORKS.

The tester consists of four basic sections. The socket for the IC under test, the output level-detect logic, oscillators and switches for the inputs, ánd the power supply.

The socket for the IC under test has the pins in each row electrically connected to each other. These rows are the groups of five holes which are perpendicular to the central groove on the socket. Each row (ie, each pin on the IC under test) is connected via a 10 megohm resistor to ground to prevent the build up of static charges. The resistors also hold all unconnected inputs at ground potential thus preventing any damage to the IC.

Each row is also connected to a pin on the front panel. Test connections are made to these pins by patchable links from the oscillator and test switches so that the correct test conditions may be set up.

Resistors R19-26 and R43-R50 connect each row (ie pin) to a logic level detector, ICs 5, 6, and 7. These CMOS hex-inverters buffer each pin and drive an LED to indicate the logic state of the pin. When the logic voltage on a pin is high the LED will be alight. Resistors R19 to R26 and R43 to 50 protect the internal diodes of ICs 5, 6 and 7 against the possibility of a pin being taken above the positive supply voltage or below ground potential. Resistors R11 to R18 and R51 to R58 in conjunction with the five volt supply set the operating currents for the LEDs.

A 555, IC4, is used as an astable oscillator which initially charges C8 via R9 and R10 until the 2/3 supply threshold is reached. C8 is then discharged via R9 and pin 7 of the 555 to the lower threshold of 1/3 supply volts. Switch SW6, when operated, puts a larger value of capacitance into the circuit which gives a frequency of about one hertz. This is slow enough so that the eye can follow each logic state transition. The high speed operation is used for checking very long counters and shift registers and can also be used in conjunction with an oscilloscope. The square wave output of the oscillator is made available at, a

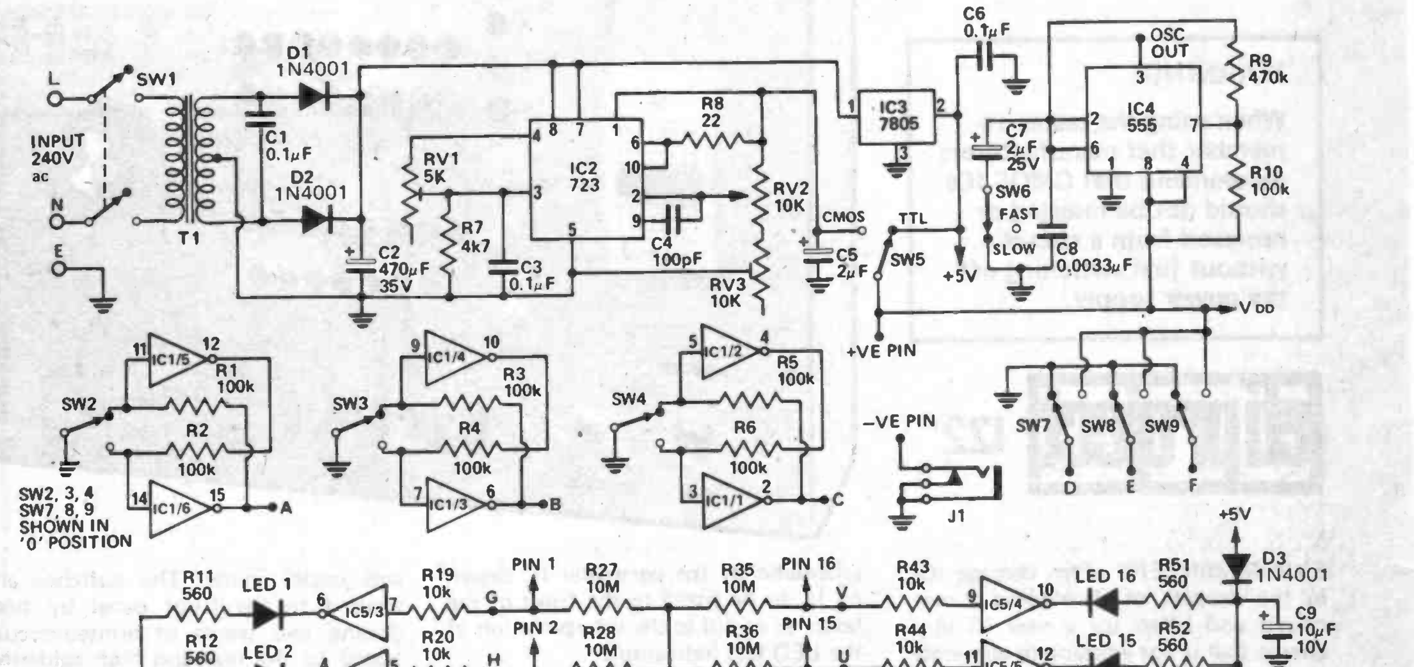


Fig. 1. Circuit diagram of the logic tester.

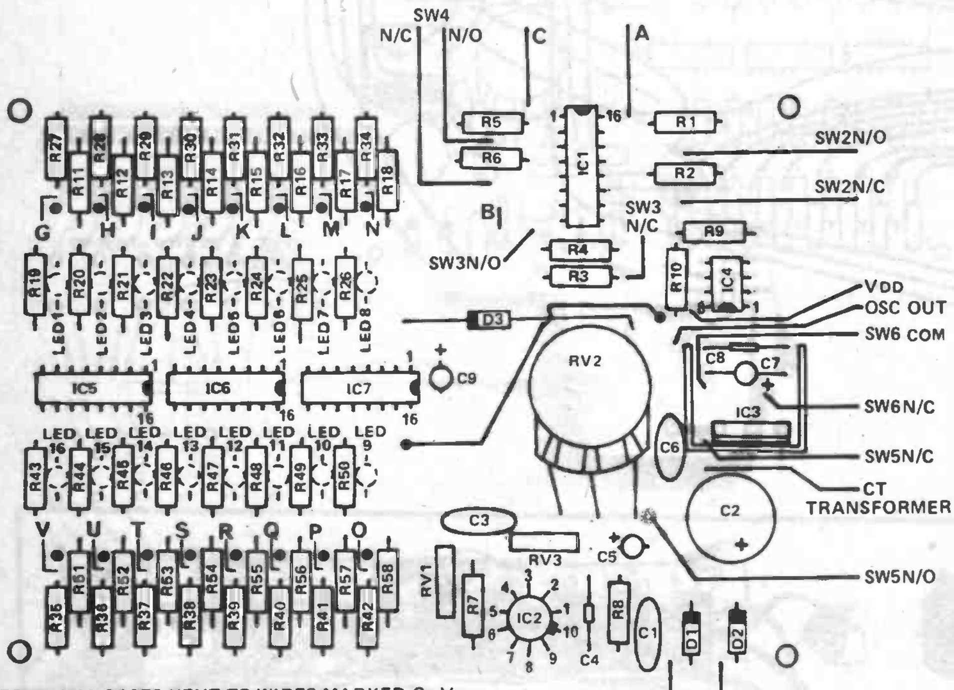
patch-pin on the front panel.

There are six further output pins on the front panel three of which, D, E and F, are set to negative or positive supply by means of toggle switches. As there is no debounce logic associated with these pins they can only be used to set up static conditions and not for clocking counters and shift registers. The remaining three pins are also programmed by switches but these switches are connected to IC1 which contains three RS flip-flops to effectively remove any contact bounce of the switches. This operates as follows. If initially the input of IC 1/5 is earthed by SW2 its output will be high and hence the output of IC 1/6 will be low. When IC 1/6 SW2 is operated again it earths the input of IC 1/6 sending the output of IC 1/6 and input of IC 1/5 high and the output of IC 1/5 low. Since the input of IC 1/6 is connected to the output of IC 1/5 it is held low even if the contacts of SW2 bounce several times when the switch is operated. Thus the output at A is one single transition from high to low (low to high when next the switch is operated). The output of the three debounced switches are labelled on the front panel as A, B, and C.

In the power supply diodes D1 and D2 full-wave rectify the output from the power transformer. The output from the rectifier is smoothed by C2 and regulated to five volts by IC3. The resulting five volt supply is used to drive the LED indicators and to power the TTL device under test. Integrated circuit IC2, a type 723, is a regulator the minimum output of which is set to five volts by RV1 and the maximum of 15 volts by RV3. Front panel control RV2 allows the output voltage to be adjusted between five and 15 volts. The current limit on the output is set to 30 mA by means of R8. SW5 selects the high current five volt supply for testing TTL or the low current variable supply for CMOS. Terminal J1 in the negative supply lead is provided for checking the current drawn by the IC under test. ●

LOGIC TESTER

Fig. 2. How the components are mounted on the pc board.



TERMINAL POSTS NEXT TO WIRES MARKED G–V AND THE LED'S ARE MOUNTED ON COPPER SIDE OF THE PC BOARD

PARTS LIST — ETI 122

R8	Resistor	22	¼W	5%
R11,18	"	560	"	"
R51,58	"	560	"	"
R7	"	4 k7	"	"
R19,26	"	10 k	"	"
R43,50	"	10 k	"	"
R1,6	"	100 k	"	"
R10	"	100 k	"	"
R9	"	470 k	"	"
R27,42	"	10 M	"	"
RV1	Potentiometer	5 k	Trim type	
RV3	"	10 k	"	"
RV2	"	10 k	Linear	
C4	Capacitor	100 pF	Ceramic	
C8	"	0.0033μF	polyester	
C1,3,6	"	0.1μF	"	
C5,7	"	2μF 25V	electro	
C9	"	10μF 10V	"	
C2	"	470μF 35V	"	
D1,2,3	Diode	1N4001 or similar		
LED 1 — LED 16	Light Emitting Diodes			
IC1,5,6,7	Integrated Circuit	4009 (CMOS)		
IC2	"	723 (metal can case)		
IC3	"	7805 (TO-220 case)		
IC4	"	555		
J1	Jack	small earpiece type		
SW1	DPST	toggle 240V rated		
SW2-SW9	miniature	slider switch 2 pole 2 position		

PC BOARD ETI 122

IC Socket
Wooden case see text
Transformer 240 V primary 30 V CT secondary or 2 x 15 V windings

25 patching Pin feed throughs

front panel
3 core flex and plug
heatsink for IC3 (see Fig.6)

boards. Do not glue the LEDs to the front panel. Once the glue has set, carefully remove the board from the front panel and then solder the LEDs and pins into position. Fit 250 mm long leads to the board for later connection to the switches and power transformer and then, using a minimum amount of heat, solder ICs 1, 5, 6 and 7 into position.

Solder the leads to the pins on the IC socket — the front panel must be cut out so that these leads may be passed through. Now affix the socket to the front panel and install the printed circuit board. Mount the transformer into the base of the box and interconnect the board and switches etc.

The wooden box was constructed from 12 mm thick pineboard such that the outside dimensions were 225 x 148 x 70 mm. We finished our box with coloured high-gloss enamel which

LOGIC TESTER

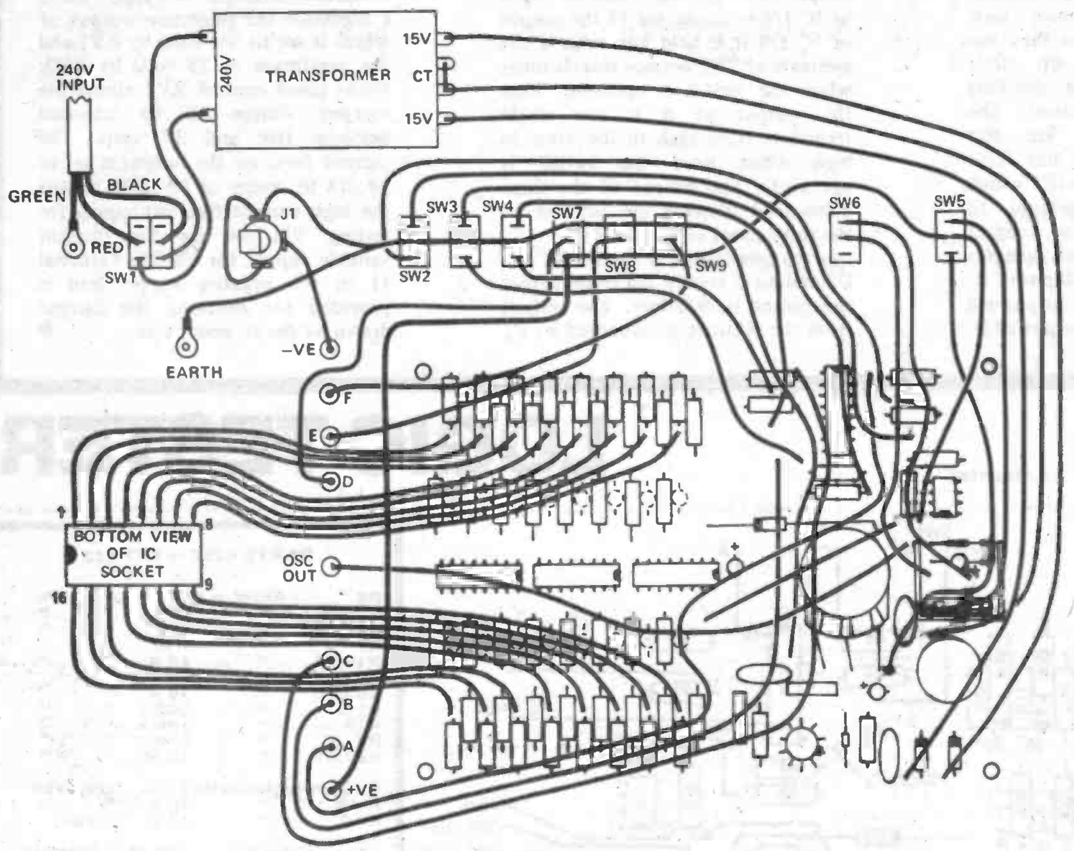
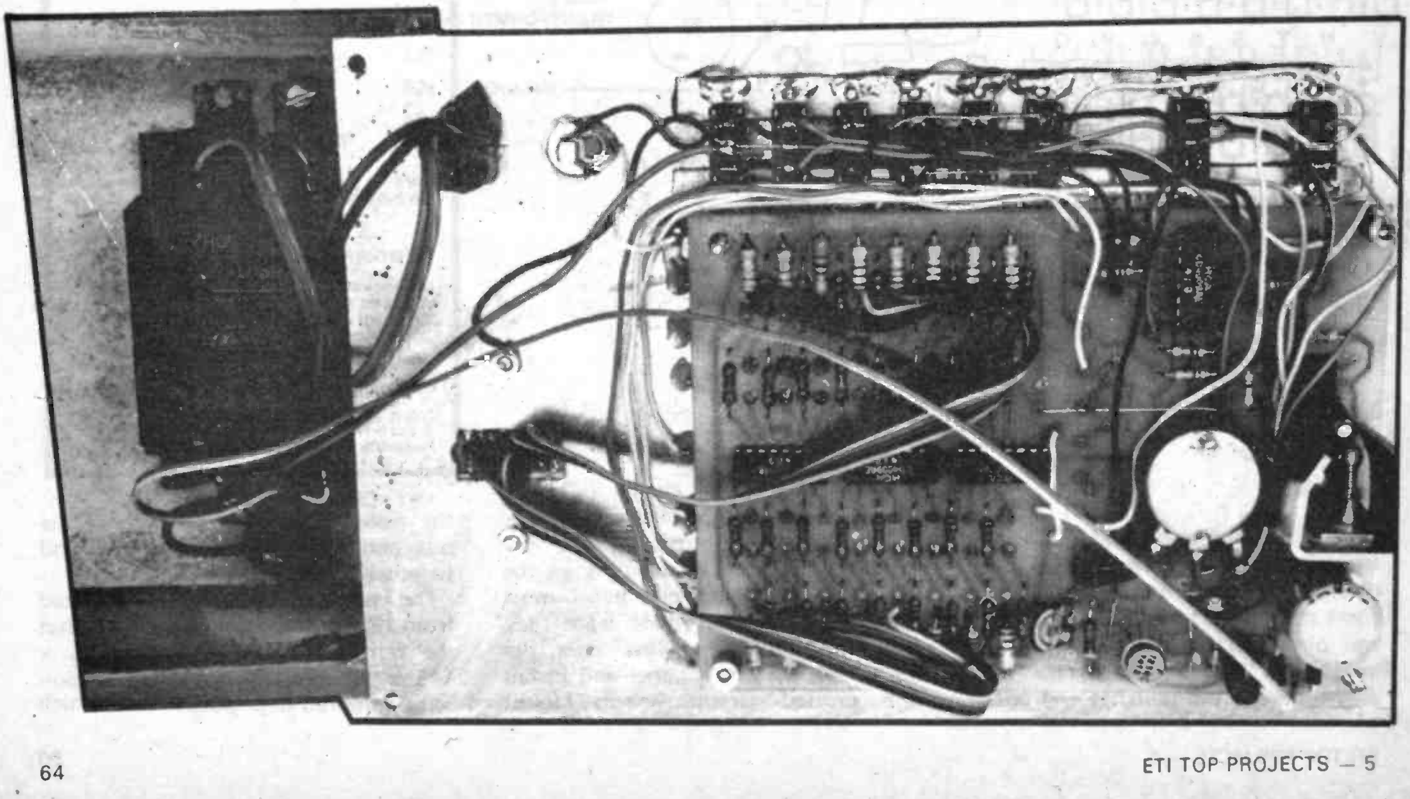


Fig. 3. Wiring diagram of complete unit.



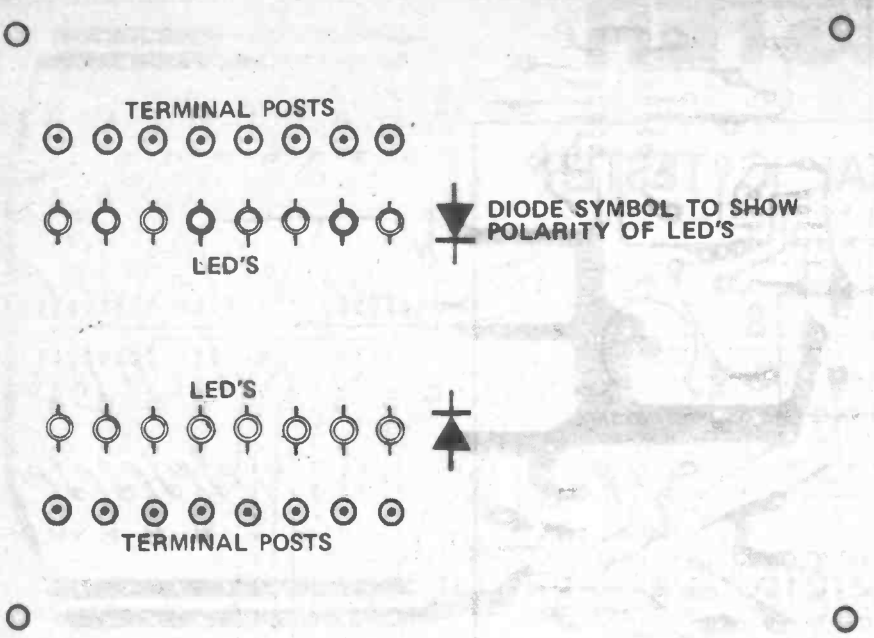


Fig. 4. Positioning of LEDs and terminal posts on the copper side of the printed-circuit board.

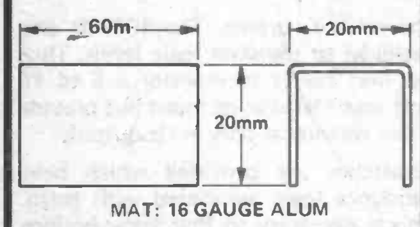


Fig.6. Heatsink for IC3. The IC is mounted (by a screw) through a 3.2 mm hole in the base of the heatsink (see photograph of inside of unit).

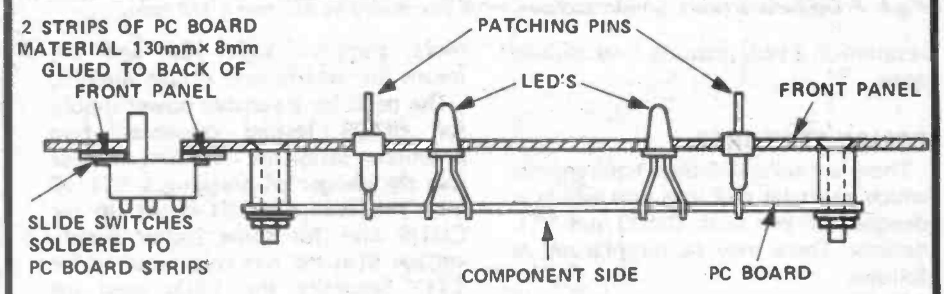


Fig. 5. How the front panel and printed-circuit board are assembled.

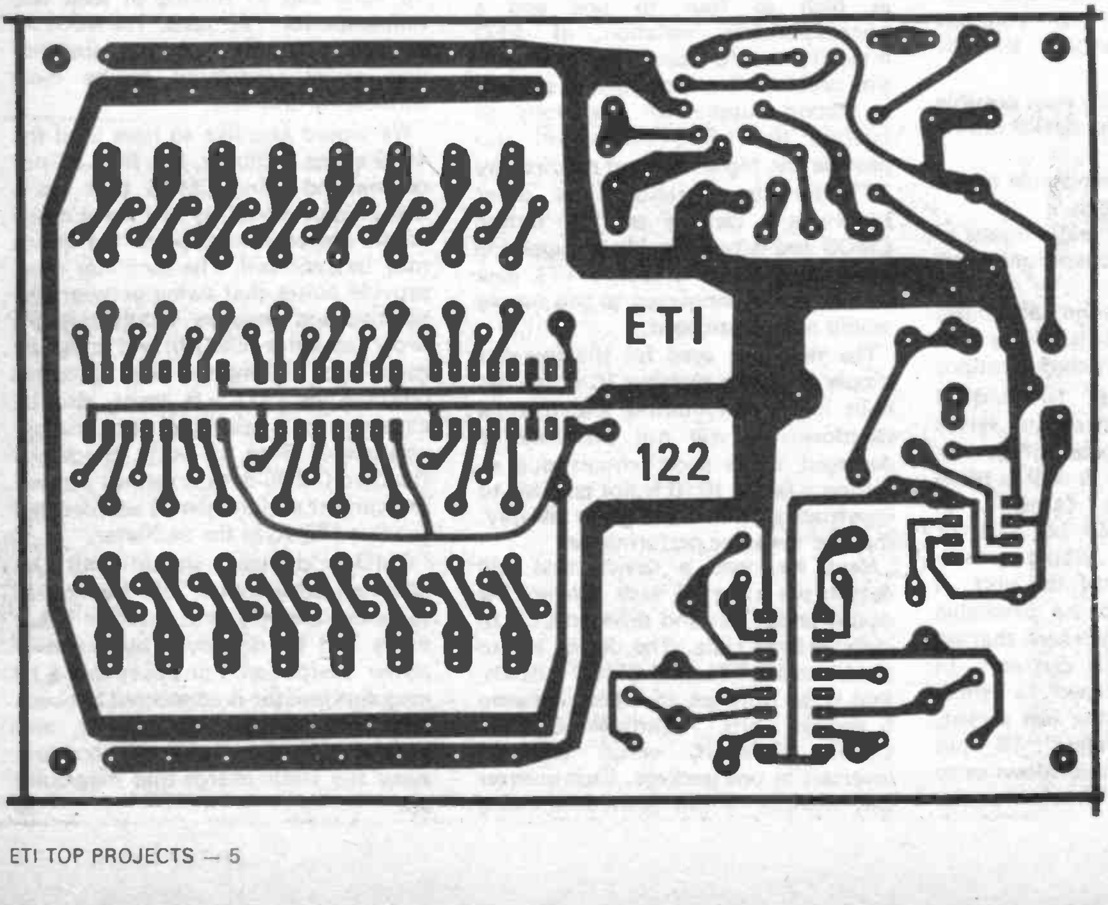


Fig.7. Printed circuit-board artwork. Full size 142 x 104 mm.

LOGIC TESTER

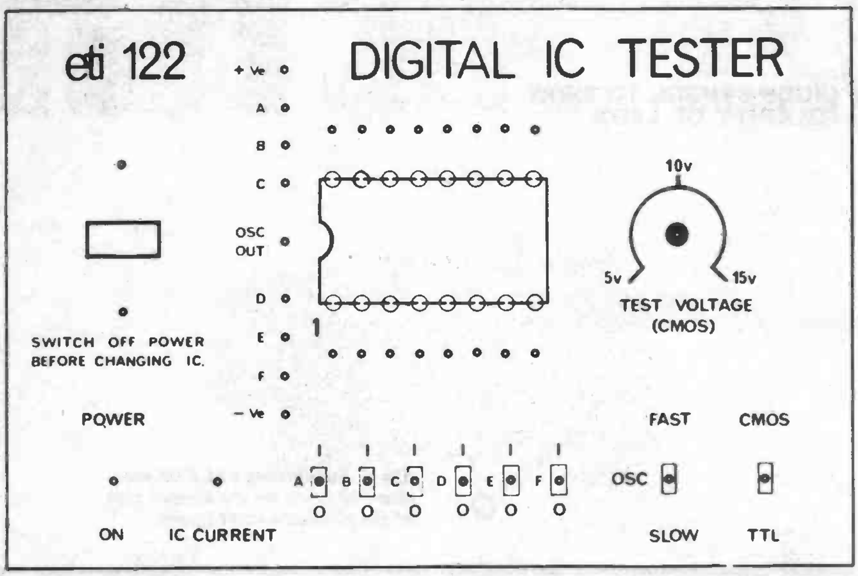


Fig.8. Front panel artwork (shown half-size — full size should be 223 mm x 148 mm).

resulted in a very pleasing final appearance.

DESIGN FEATURES.

There are several design requirements which must be met in a unit which is designed to test both CMOS and TTL devices. These may be summarized as follows.

1) The unit must be capable of correctly testing both types of logic.

2) Simple gate functions should be tested by go/no-go checks and complex functions such as counters and shift registers should also be reliably checked.

3) There should be the least possible chance of damaging the device during testing.

4) CMOS ICs must be testable with a variety of supply voltages.

5) A clock oscillator and a means of setting up the input conditions must be provided.

One of the major design difficulties with a unit such as this is coping with the many different pin configurations of the differing functional requirements (eg a shift register versus a two-input NAND gate) of devices within the one family, as well as those between different families. A multi-way switch could be used for each input pin but would greatly increase the expense of the unit. A good alternative is to use patchable links, and this is the approach that we have chosen to use in our unit. In addition we have used a small breadboard socket as the test socket, rather than a standard 16 pin dual-in-line socket, as this allows us to improvise special test circuits for the more complex logic ICs, and the means to breadboard simple circuits.

The need for a variable power supply for CMOS testing presented two additional problems. The first of these was the danger of plugging a TTL IC into the unit when it is set up for CMOS and for some higher supply voltage than the five volts required for TTL. Secondly the LEDs used for monitoring each pin would draw more current as the supply voltage increased. The current ratio could be as high as four to one and a corresponding variation of LED intensity would occur. To overcome this problem it was decided to provide a second supply of five volts to operate the LEDs which will also provide the higher current required by TTL for its operation. The other supply is a variable one for testing CMOS and is not capable of supplying more than 30 mA. Thus a TTL gate inadvertently connected to this supply would not be damaged.

The regulator used for the five-volt supply is a three terminal IC which has built in current limiting and thermal shutdown. It will not therefore be damaged by a short circuit due to testing a faulty IC. It is not possible to construct a discrete design, as cheaply, that has the same performance.

Next we need a device that will detect the state of each pin on the device under test and drive an LED to indicate that state. The device has to be driven by TTL and CMOS outputs, that is, by voltages anywhere between 5 and 15 volts. A suitable IC is the CMOS 4009 IC which has six inverters in one package. Each inverter will monitor a pin without drawing appreciable current. The 4009 is also designed to translate logic levels. Thus we may use it to monitor a 5 to 15 volt input level at its input but provide a five volt signal only at its output.

Switches are provided which have debounce logic associated with them. This is necessary so that single bounce free rise and fall transitions can be generated for the testing of more complex logic. The debounce logic must be capable of operating on 5 to 15 volts and of sinking at least two milliamps for TTL tests. The 4009 IC with its high output current capability was again considered to be most suitable for this task.

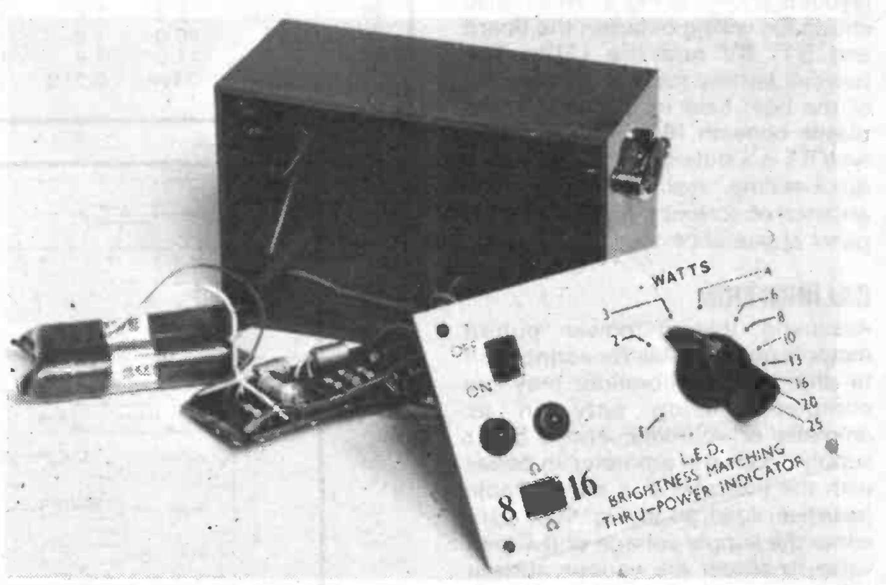
We would also like to have used the 4009 as the oscillator, but RCA do not recommend using CMOS that has a high output capability in a linear mode as the power dissipation of the device may be exceeded. The oscillator must provide pulses that swing between the positive and negative supply rails (in order to drive CMOS) and must be capable of sinking the two milliamps required by TTL. It must also be capable of operating on supply voltages of 5 to 15 volts. Since the standard CMOS devices cannot provide the current requirement it was decided to use a 555 IC as the oscillator.

CMOS devices should not be operated with inputs left floating as some devices may drift into the linear mode and be destroyed by excessive power dissipation. For this reason a 10 megohm resistor is connected between each pin, on the test socket, and ground. These resistors also conduct away any static charge that may build up. ●

POWER METER

BY D. KING

WHEN USING OR TESTING a power amplifier, a very common question is, "What is the power output?" Power might be fed to a loudspeaker or load for very short periods as when a voice is being reproduced, or continuously if using an audio generator to provide a steady tone input. Measurements then involve knowledge of (i) the load resistance R and (ii) the current into or the voltage across the load so that the equation $P = V.I$ or V^2/R or $I^2.R$ watts may be completed. The formula assumes that a sinusoidal test signal is used, the instrument giving an rms voltage or current reading (usually) and the true power is thus calculated. However if a non-sinusoidal waveform were used, the 'hang' or inertia of the pointer would give an incorrect reading 50% or more low and the calculations would be wasted.



Considering these points, a 'measuring' instrument was decided against in favour of an instantaneous indicator of power using an LED and connected in series with the load or loudspeaker so that speech, music or steady tone in excess of a preset power level is indicated by flashes of the LED. Accuracy of indication is adequate, bearing in mind the fact that normal hearing only realises that there is a change of power (or volume) for a 1:2 change in power level. A bonus is that the completed and boxed indicator has a cost comparable with that of a moving-coil movement alone, not including its housing and associated electronics.

CONSTRUCTION

The indicator is contained in a small plastic box about 110 × 70 mm, sockets for input and output being

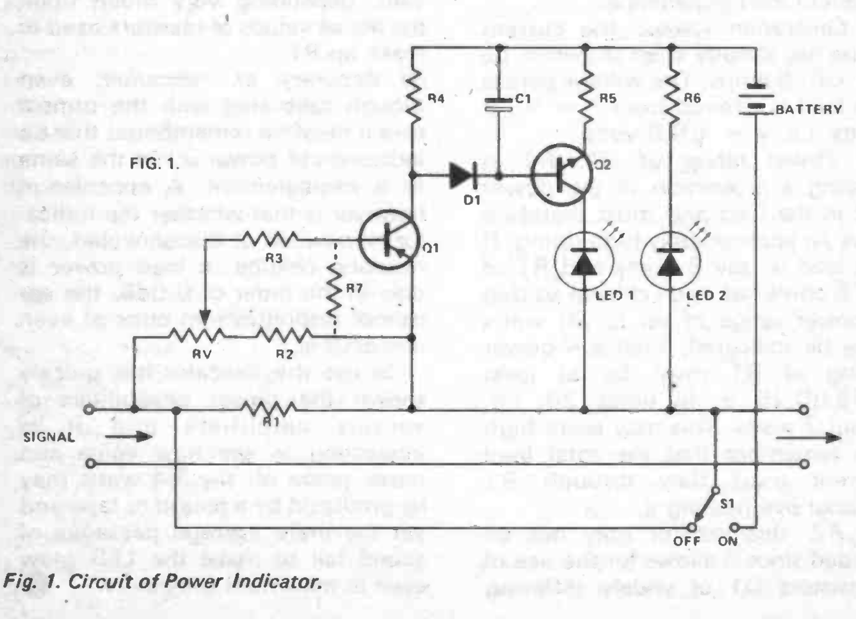


Fig. 1. Circuit of Power Indicator.

HOW IT WORKS

This indicator monitors the current to the load rather than the voltage across the load. Voltage (peaks) of the correct polarity developed across the current-sampling resistor R1 in Fig 1 turns on Q1 (pnp), RV1 setting the sensitivity and R3 acting as base-current limiter. Via D1, the positive-going voltage at Q1 collector charges C1 and turns on Q2 (npn) which thus illuminates LED1. D1 stops C1 from discharging via R4, the charge on C1 only being used to supply a diminishing current to Q2 base.

The value of C1 determines the length of time for which LED1 remains illuminated; increasing C1 to 100uF or more results in long flashes of light that tend to average over different peaks of sound. Decreasing C1 below about 5uF results in very fast indication but equally fast decay of LED flashes, which may make the indication too brief and not easily seen in a well-lit room.

R6 and LED2 are included to show that the internal battery of two 1.5V cells is in fact working and also to allow a direct comparison of brightness; without LED2 there may be some uncertainty about when LED1 is the correct brightness for a particular setting of RV against its power scale. When switched off, S1 short-circuits R1 so that the apparatus may be left in series with the load and yet dissipate no power. For high powers S1 needs to be of ample current rating.

R2 determines the maximum power indication when using a particular value of R1. With the suggested 100 lhm RV and R2 of 27 ohms, a range of one to twenty watts is obtained. If R2 is increased in value, the power range is reduced, so the value of R2 may be chosen by the constructor to suit his needs.

POWER METER

fitted at either end. The front panel is fitted with S1, RV, the control knob for RV and the power scale calibrations. The circuit is constructed on Veroboard which is then located in slots within a Doram Module Case (but of course the individual layout and housing may be easily varied). The Veroboard layout is shown in Fig 3, which also shows the wiring between the board and S1, RV and the LEDs. The two-cell battery rests in the bottom of the box, held in place by Foam plastic beneath RV1. In the prototype S1 is a slide-switch fixed with a quick-setting resin adhesive; the absence of screws maintains a neat panel appearance.

CALIBRATION

Assuming that a power output meter is not available for connection to the load, valibration may be completed using only an ac ammeter or voltmeter and a 50Hz supply. With the ammeter in series with the indicator and any suitable (resistive) load as in Fig 4(a), vary either the supply voltage or the load value to obtain the various current values shown in Table 1 and mark the dial or scale of the indicator at the point where adjustment of RV1 gives a brightness of LED1 matching that of LED2. In fact LED1 will start glowing at lower current (and hence power) values, but 'full glow' should be reached at one particular setting of RV1 and then any increase in current (or power) or RV1 sensitivity should give virtually no further increase in glow. If an ammeter is not available, a voltmeter across the correct value load resistor may be used as in Fig 4(b). The supply voltage must now be varied to obtain the wanted power levels in the load as shown in Table 1.

TABLE ONE

Load Power	4Ω Current	4Ω Voltage	8Ω Current	8Ω Voltage	16Ω Current	16Ω Voltage	32Ω Current	32Ω Voltage
1W	0.5A	2.0V	0.35A	2.8V	0.25A	4.0V	0.18A	5.7V
2	0.71	2.8	0.5	4.0	0.35	5.7	0.25	8.0
3	0.87	3.5	0.61	4.9	0.43	6.9	0.31	9.8
4	1.0	4.0	0.71	5.7	0.50	8.0	0.35	11.3
6	1.2	4.9	0.87	6.9	0.61	9.8	0.43	[illegible]
8	1.4	5.7	1.0	8.0	0.71	11.3	0.50	16.0
10	[illegible]	6.3	1.1	8.9	0.79	12.6	0.56	[illegible]
13	1.8	[illegible]	[illegible]	10.2	0.90	14.4	0.66	20.4
16	2.0	8.0	1.4	11.3	1.0	16.0	0.71	22.6
20	2.2	8.9	1.6	12.6	1.1	17.9	0.79	25.3
25	2.5	10.0	1.8	14.1	1.3	20.0	0.88	28.3
30	2.7	11.0	1.9	15.5	1.4	21.9	0.97	31.0
R1 for 20W	0.5Ω	25W	0.71Ω	1.8W	1Ω	1.3W	1.4Ω	0.9W

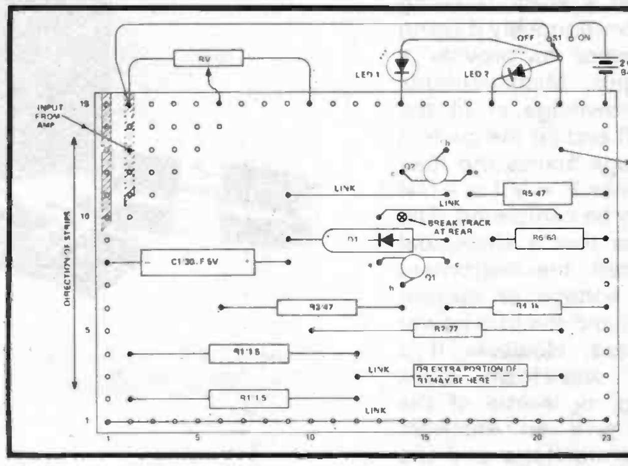


Fig. 3. Veroboard layout to fit Doram module case. Top (non-stripe) side.

MODIFICATIONS AND CALCULATIONS

(i) R1; using a germanium Q1, the 'turn-on' base-emitter voltage is about 0.25V. The gain of Q1 then determining the rate-of-charge of C1. Now if the load value is R, the power in R is I^2.R watts. Hence for a maximum sensitivity of indication for P watts, the current flowing through R1 is given by $I = \sqrt{P/R}$ amps. The value of R1 needed to produce about 0.25V for this current is thus given by R1 = V/I = $0.25/\sqrt{P/R}$ ohms. For a 1W maximum sensitivity then R1 = $0.25/\sqrt{1R} = 0.25 \times \sqrt{R}$ ohms.

The value of R1 needs to be increased if the value of the load R is increased. Either separate resistors may be switched (or plugged) into circuit or R1 may be made of two or more resistors in series with those not in use being short-circuited by a 'load impedance' switch. Such a circuit is shown in Fig 2 to allow for two different load impedances.

(ii) Calibration values; the current value has already been shown to be $I = \sqrt{R}/R$ amps. The voltage across the load is derived from $P = V^2/R$ watts, i.e. $V = \sqrt{R}.R$ volts.

(iii) Power rating of R1; R1 is sharing a proportion of the power fed to the load and must therefore have an appropriately high rating. If the load is, say 8 ohms and R1 of 0.75 ohms has been chosen so that a power range of up to 20 watts may be indicated, then the power rating of R1 must be at least 0.75/(0.75 + 8) times 20, i.e. about 2 watts. This may seem high but remember that the total load current must flow through R1 without overheating it.

(iv) R7; this resistor may not be needed since it allows for the use of transistors Q1 of widely differing gain characteristics. With RV set fully clockwise to the minimum sensitivity position (i.e. 20W in prototype), R7 was found during calibration to be 75 ohms for one particular transistor and yet was not required when using a different, lower gain transistor. Without R7 it is likely that the maximum sensitivity will be from about 0.5 to one watt, depending very much upon the actual values of resistors used to make up R1.

(v) Accuracy of indication; even though calibrated with the utmost care it must be remembered that an indication of power is not the same as a measurement. A consolation however is that whether the indicator is in circuit or disconnected, the resulting change in load power is only in the order of 0.5dB; the ear cannot distinguish an error of even one decibel.

In use the indicator has quickly shown the power capabilities of various amplifiers and it is interesting to see how voice and music peaks of, say 3-4 watts may be produced by a record or tape and yet the more average passages of sound fail to make the LED glow even at maximum sensitivity. ●

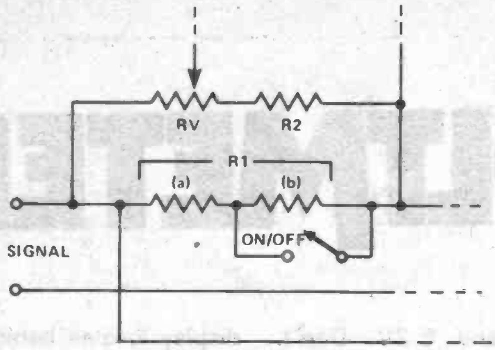


Fig. 2. Circuit modification allowing for two differing load impedances.

Parts List

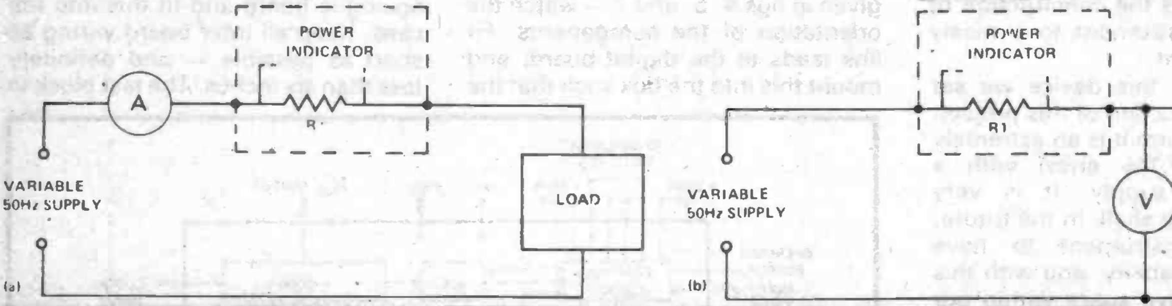
Resistors
R1 See text and table 1
R2 27R see text
R3, 5 47R
R4 1k
R6 68R
R7 See text
RV1 100R wirewound

Capacitor
C1 30uF 3v.

Semiconductors
Q1 OC71
Q2 AC127
D1 IN4148
LEDI, 2 Til 209

Miscellaneous
Two 1.5v cells
S1 SPDT see text
Input and output sockets
Case, nuts and bolts etc.

Fig. 4. Calibration arrangements.



DIGITAL VOLTMETER

EVERY NOW AND THEN AN IC drops into the public eye, which, on removal, proves to be a new-quick-answer to an old problem. Such a useful mote is the ZNA 116E from Ferranti. This is a DVM chip, which simplifies the construction of a 3½ digit instrument to a nicely ridiculous extent.

Armed with this device we set about the production of this project. In its present form it is an extremely accurate (< 0.1% error) with a 5V stabilised supply. It is very possible that we shall, in the future, extend the instrument to have multimeter capability, and with this in mind we leave space within our recommended case to accommodate this modification.

CONSTRUCTION COMMENCED

Although the circuit diagrams depict a complex device, construction is really very simple. The first thing to do is build the power supply as shown in fig. 9. Assemble the components onto the board as per fig 8. The regulator is mounted onto the rear of the case — no insulator is required, but be careful that the legs do not contact the case. Check the output of this — it should lie between 4.7V and 5.2V. Don't proceed if it doesn't! Wire up the mains switch and neon.

Once the supply is operational and mounted in the case, assemble the main PCB's. Follow the overlays given in figs 4, 5, and 7 — watch the orientation of the components. Fit link leads to the digital board, and mount this into the box such that the display locates behind the perspex panel you fitted there when you did the metalwork. (You did leave a hole for the displays — didn't you? . . . Oh.)

Next connect up the links to the analogue board and fit this into the case. Keep all inter board wiring as short as possible — and definitely less than six inches. The last block to

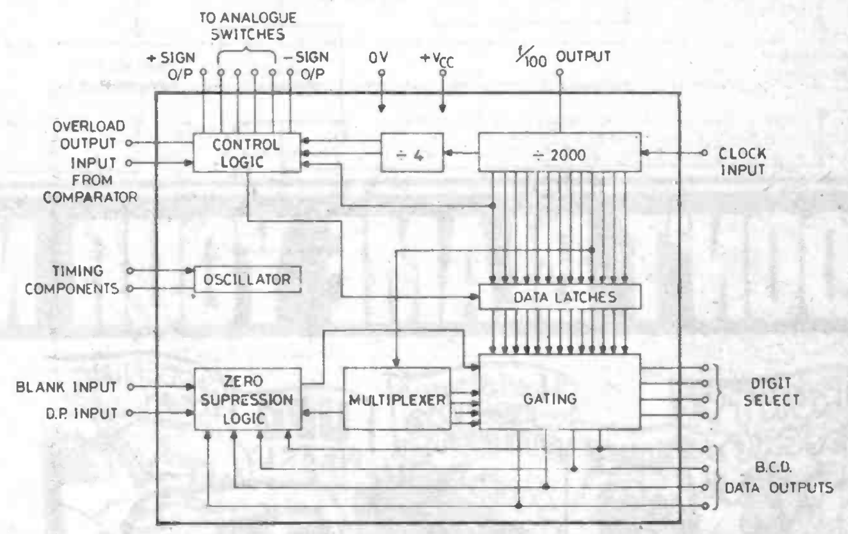
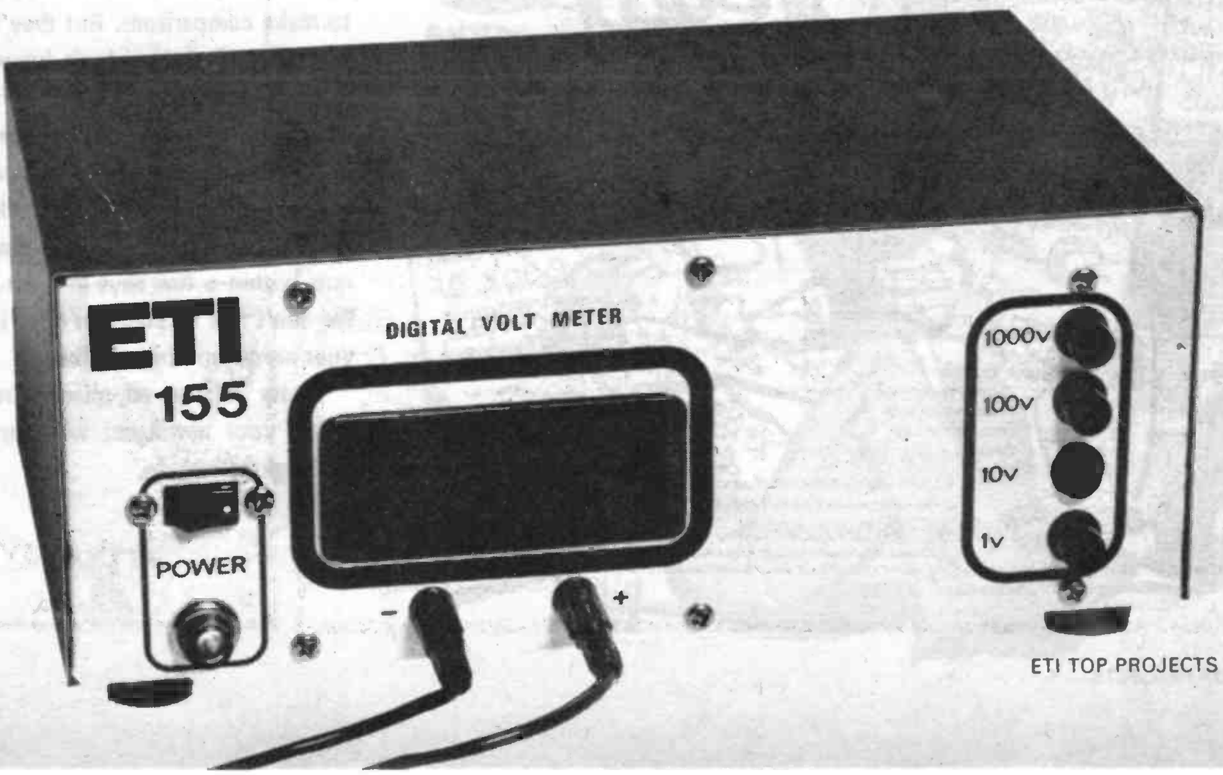


Fig. 1: Block Diagram of the ZNA116E.



How it works

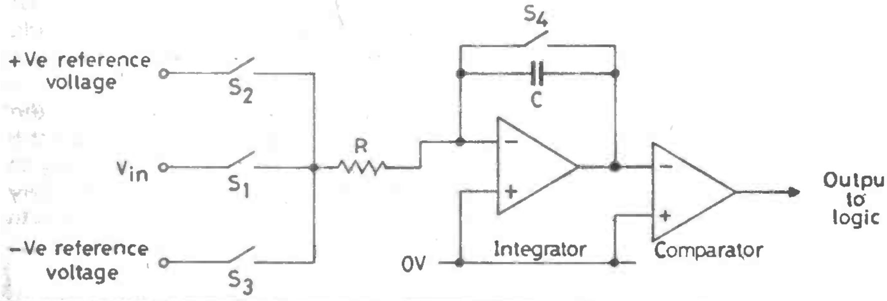
The method of A→D conversion used in the system is dual slope integration. Referring to the drawing below this operates thus:

At time T, S4 S3 and S4 are open, and S1 closes to apply the input voltage to the integrator. The integrator capacitor C will charge up linearly until time T_2(4000 clock pulses later). The voltage at the integrator is proportional to Vin.

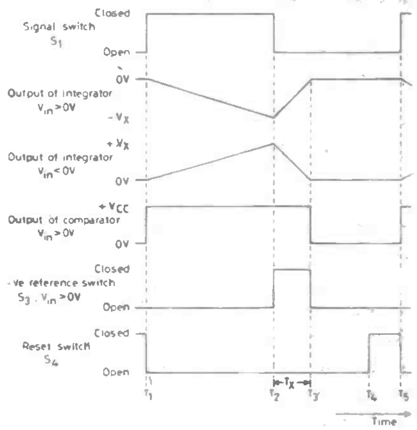
After time T_2 S1 opens and either S2 or S3 closes, applying a reference voltage (of opposite polarity to Vin) to the integrator. C now discharges at a constant rate, and at time T_3 the output of the integrator is again zero. This is detected by the comparator, and the ref. is switched off, and the number of clock pulses corresponding to Tx transferred to latches. This number is directly proportional to Vx, hence to Vin. If Tx is greater than 2000 clock pulses, an overload condition exists, and the display is flashed.

S1 is made to be closed for a time which is an exact multiple of 20msec, the period of the mains, and hence any ripple superimposed on Vin will be integrated to zero. Very convenient.

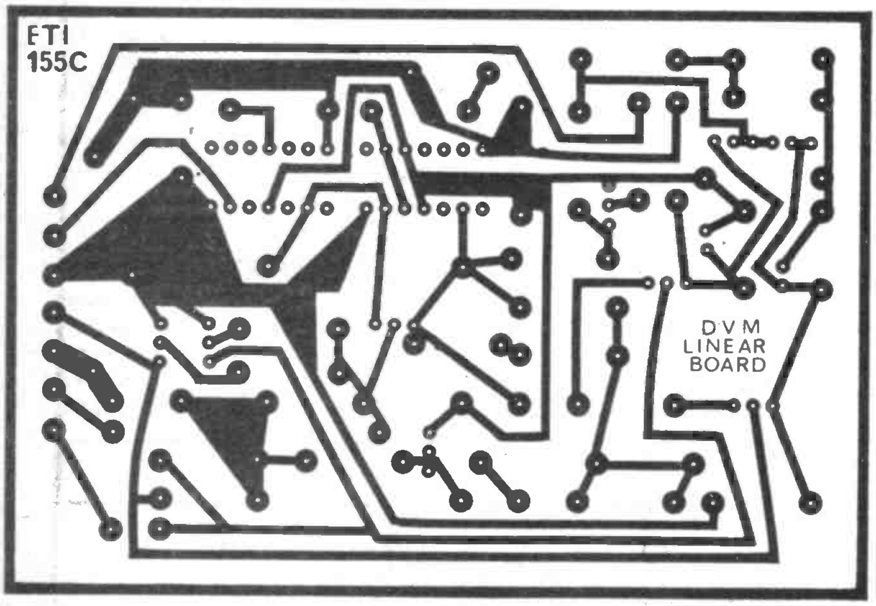
Using the dual slope technique means that neither the capacitor C nor the oscillator (clock) has to possess high stability.

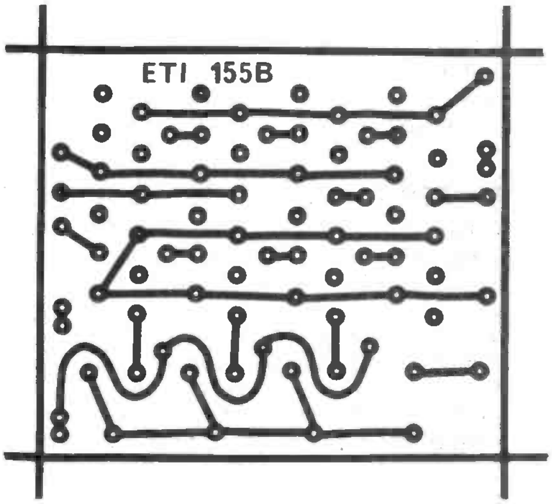


Referring our discussion to this circuit, IC4 forms the integrator, IC3 the comparator, IC1, the ZNA 116E is the control logic which

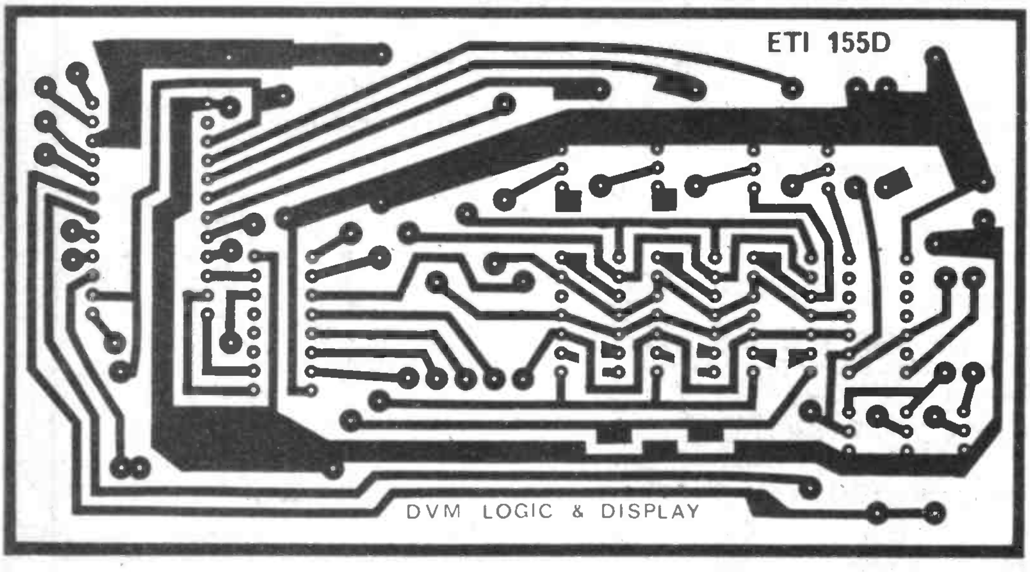


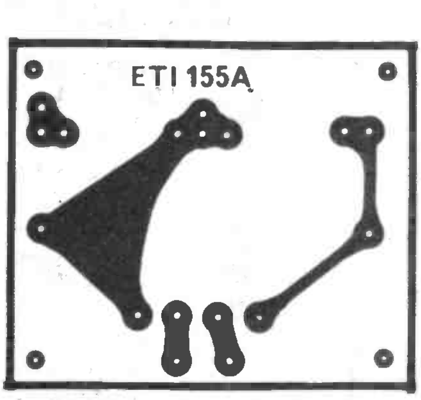
performs the transfer and timing for the system. A block diagram of this chip is given in fig. 1.





Our thanks to Ferranti who designed boards 155C and 155D for this project





Parts List

Resistors
R1 16k*
R2, 33 68k*
R3-9 150R
R10, 11, 12 1k5
R13, 18, 19, 20 3k3
R14 33k
R15, 26 15k
R16, 17 680R
R21 100R
R22, 23 100k
R24, 25, 31, 34* 10k
R27 27k
R28 1M*
R29, 30, 36 51k*
R32 470R
R35 560R
R37 240k*
R38 180R
R39 180k*
R40 2M*
R41, 42 10M*
R43 22k*
(All Resistors 5% Ex * = 2% type.)

Potentiometers
RV1 100k Bourns 3009P
RV2, 3 5k Bourns 3009P
RV4, 5, 6 4k7 Min Hor. Trim.

NOTE!!
R1-R38 inc, RV1-RV3 inc
obtainable as pack from
Doram (997-134)
RV1-RV3 inc

Capacitor
C1 2n2
C2, 4 33n
C3, 5 68μ 10V electrolytic
C6, 10, 11, 12 100n
C7 2μ2
C8 10n
C9 470p
C13 2,200μ 16v electrolytic
C14, 15 220n
NOTE!!
C1-C12 inc Obtainable as pack from Doram (997-140)

Semiconductors
IC1 ZNA 116E
IC2 ZN 7447A
IC3, 4 ZN 424E
TRI, 2, 3, 4 ZTX 4403
TRI-11, 13-16 ZTX 108
TRI 12 ZTX 23
D1, 2 ZN 423
D3 1N 914 (see text)
BR.1 200V 1.6A Bridge Rectifier
REG 1 5V 600mA regulator TO3*.
Display 1, DL701
Displays 2, 3, 4/DL707L
* with insulating kit

NOTE!!

IC1, D1, 2, TRI-4, TR12
Obtainable as pack
from Doram (997-112)

IC2, 3, 4, TR-11, 13-16
Displays 1, 2, 3, 4
Obtainable as pack
from Doram (997-128)

Switches
S1,2,3,4 4 blank assembly, 4 pole 2 way push button with cancelling action
Doram
4 x 338 — 636
4 x 338 — 563
1 x 338 — 254
S5 Off/On rocker

Transformer
T1 240V — 9V 1A type
Case
Samos S7 (Doram — 984-497)
Boards
The 2 main boards, Analogue and Digital, are available as pack from Doram (997-156)

Miscellaneous
Fuse holder, fuse, mains neon, 2mm red and black sockets, P.C.B. pillars, flex, 3 core mains flex, nuts and bolts etc., red perspex.

be positioned will be the switching bank and input attenuators. Wire this to the other boards once in place.

Before connecting *anything* to the PSU check over the boards again. Note the 'overload' diode D3, is mounted on the foil side of the digital PCB. Check the number of links. There are five on the analogue board, and twelve on the digital.

CALIBRATING AND ATTENUATING

Unfortunately there is no other way of calibrating such an instrument other than applying a known voltage. Before you do that put the range switch to 'one volt' position, and set RVI until the polarity indicator just flickers from '+' to '—'. (Carry this out with the input shorted).

Connect your known (accurate!) voltage preferably positive, to the DVM and adjust RV3 until the instrument shows this value. Reverse the terminals, and set RV2 so that the display is again correct. The basic accuracy is now achieved.

Each range of the attenuator is independent of the others, so each can be set individually.

Calibration is now complete.

USING THE METER

When the input voltage exceeds the maximum reading the display will flash and no further measurements can be taken — switch up a range. Decimal point is automatical-

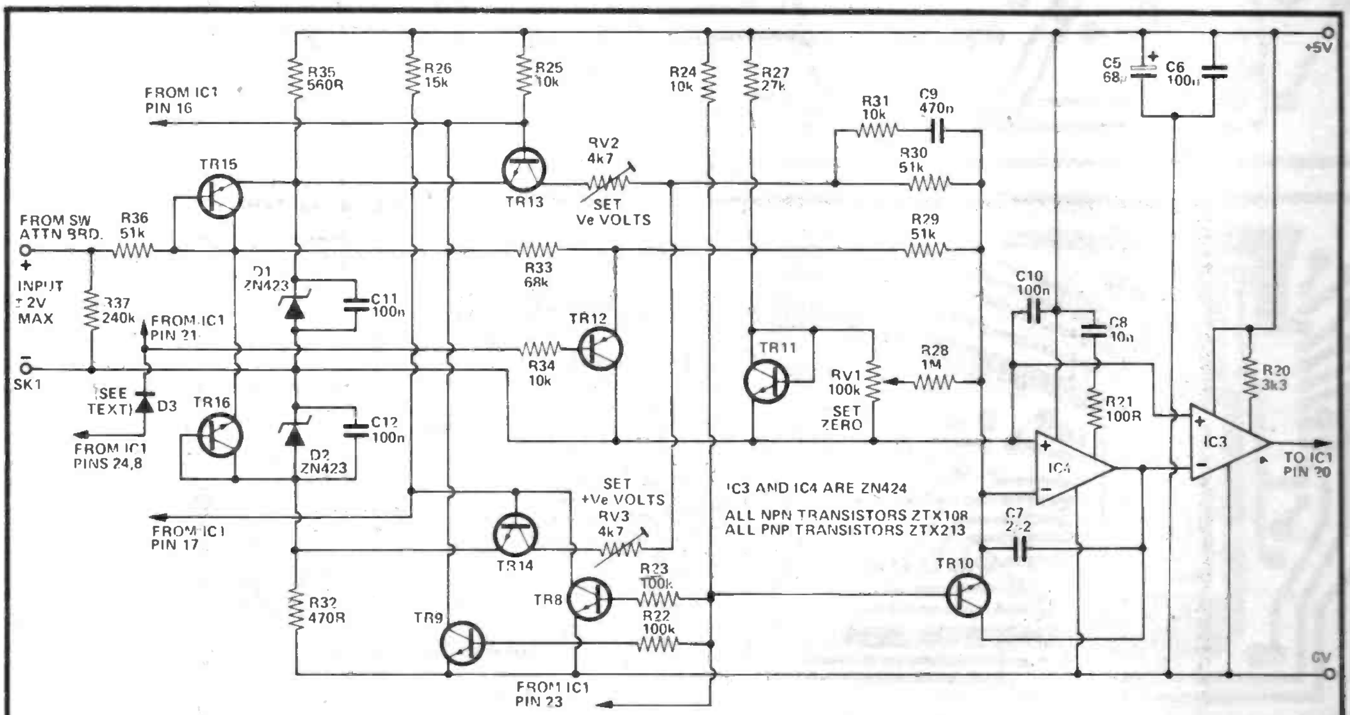


Fig 2: Circuit Diagram — Analogue Board

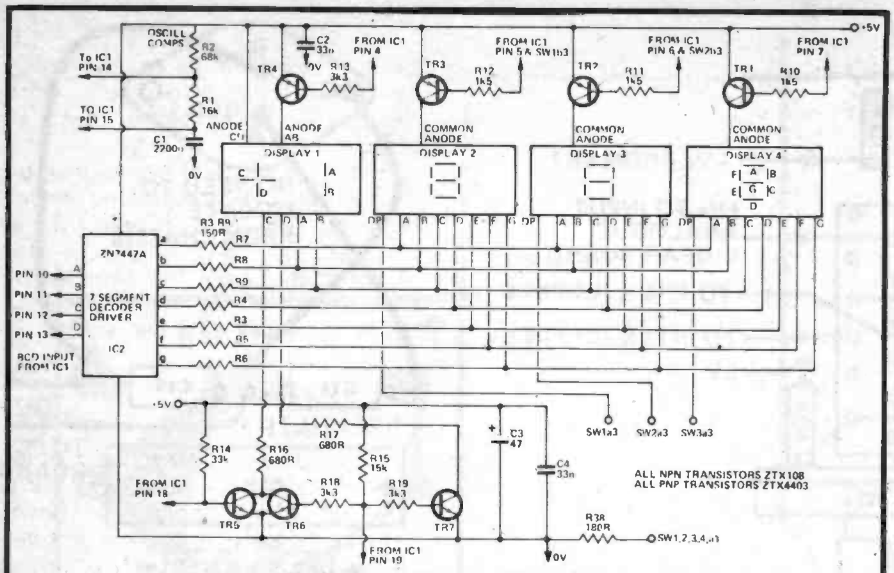


Fig 3: Circuit Diagram: Digital Board

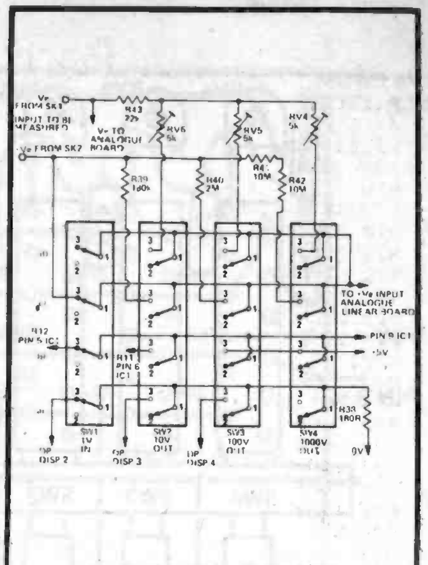


Fig 6: Circuit — Switching

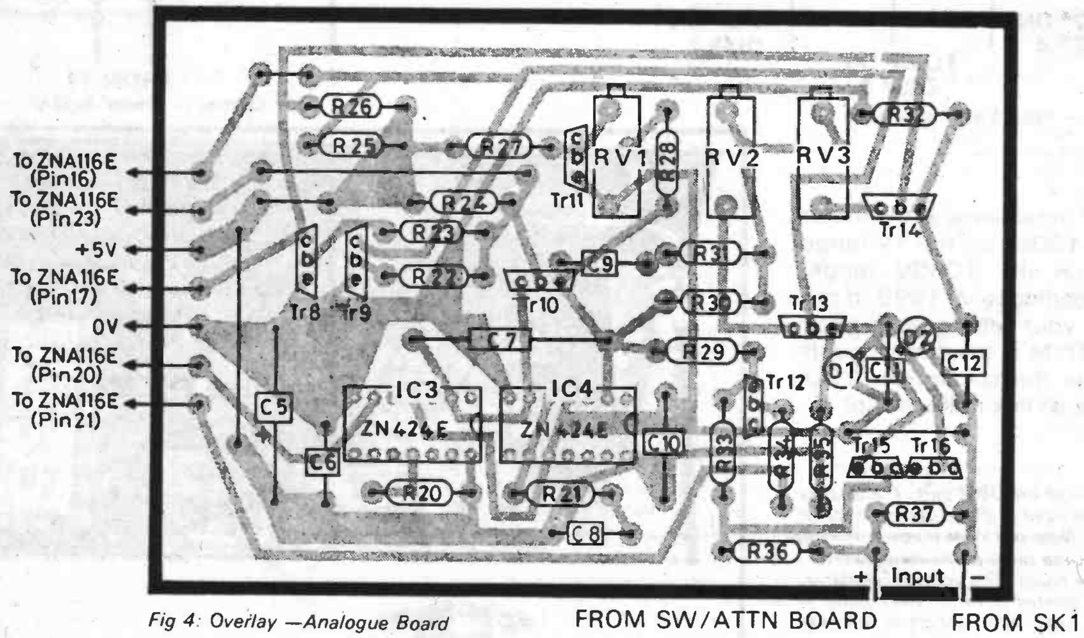
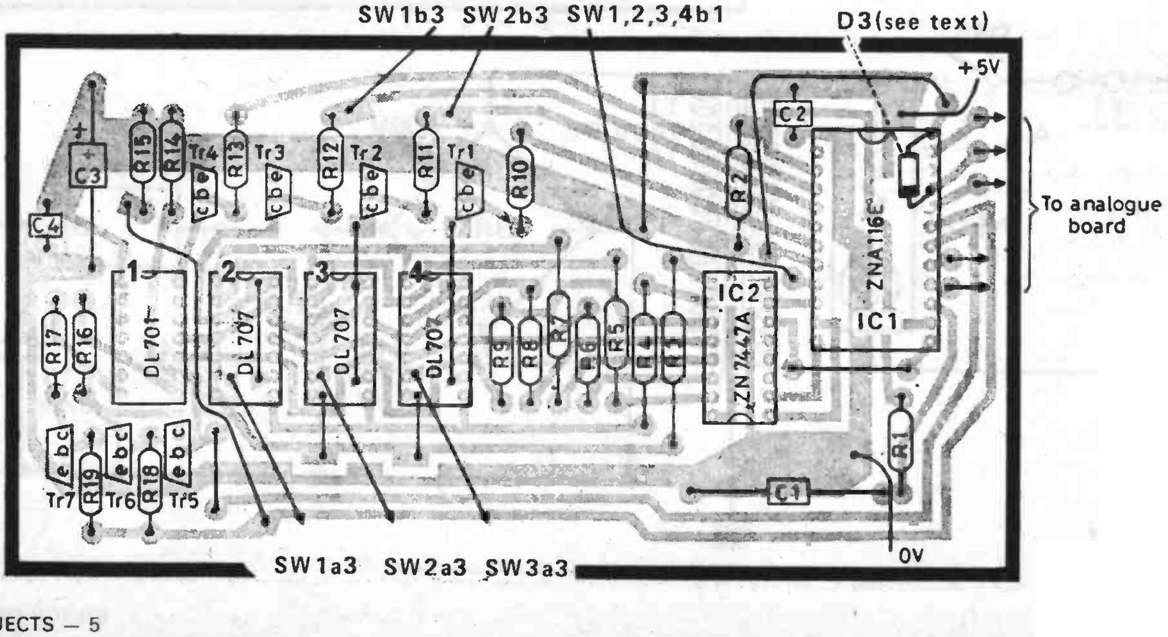


Fig 4: Overlay —Analogue Board

Fig 5: Overlay — Digital Board



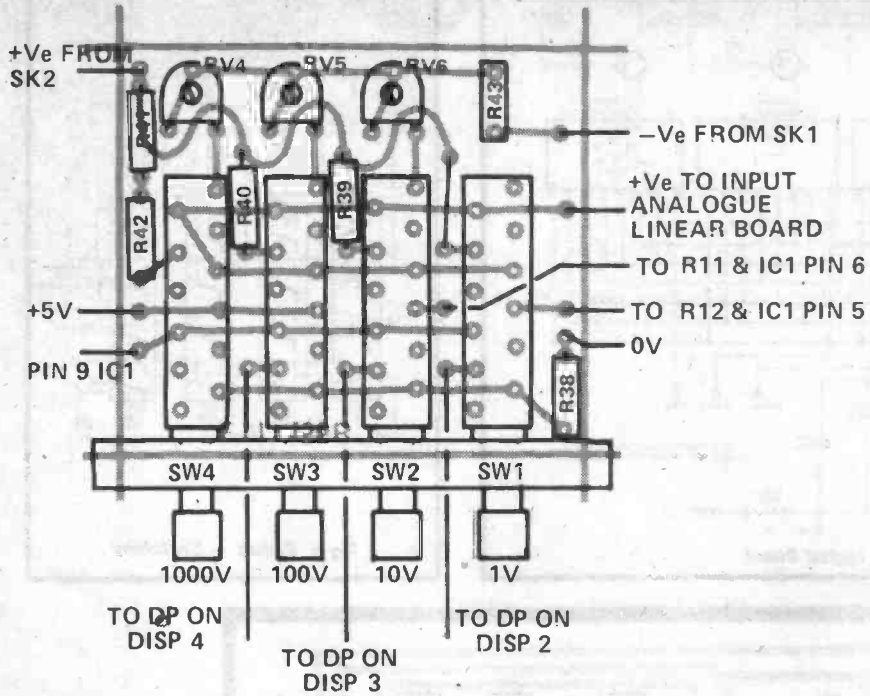


Fig 7: Overlay — Input Switching Board

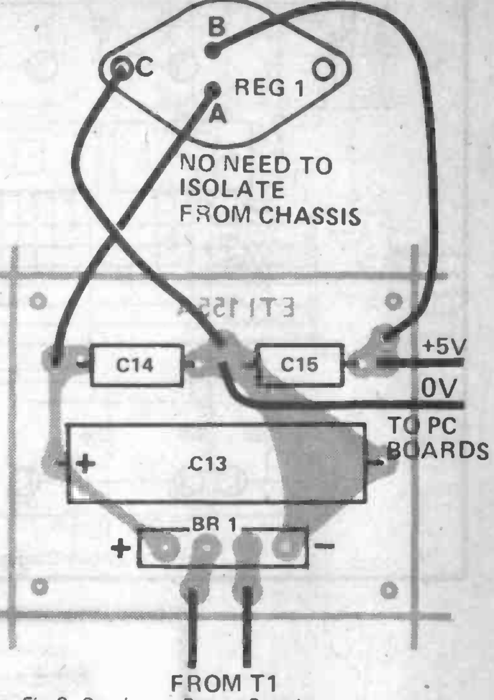
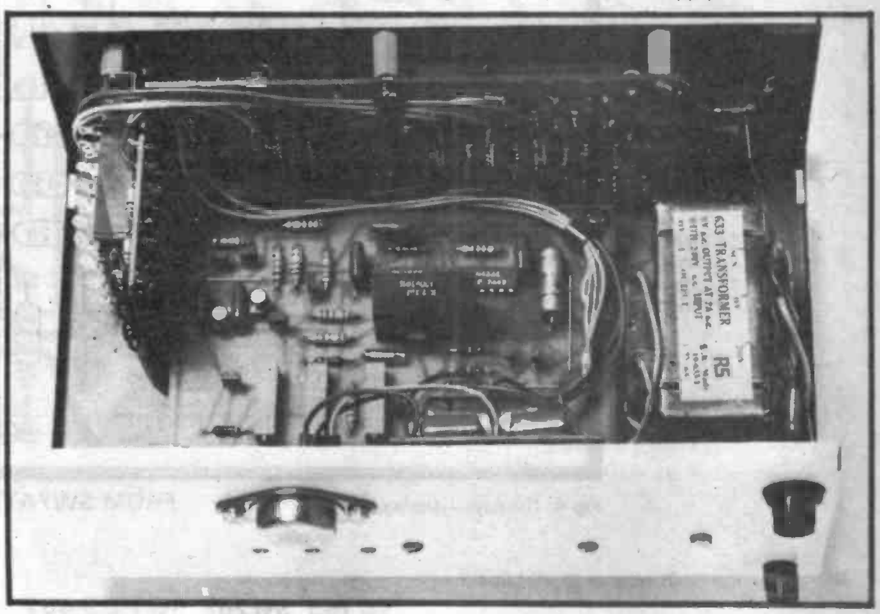


Fig 8: Overlay — Power Supply

ly set. Input impedance of the meter varies from 100kΩ on the 1V range to 20MΩ on the 1000V range. Maximum reading is ± 1999. If the accuracy of your setting-up is good — so is the DVM's! Insulting though it sounds, as the constructor YOU are the weakest link in the chain!



An internal view of the DVM unit. The display board is shown fixed in place upright against the front panel. Note the three holes in the back panel to adjust the three multi-turn presets on the analogue board. The voltage regulator need not be insulated from the back panel — but ensure the 'legs' do not short to the case.

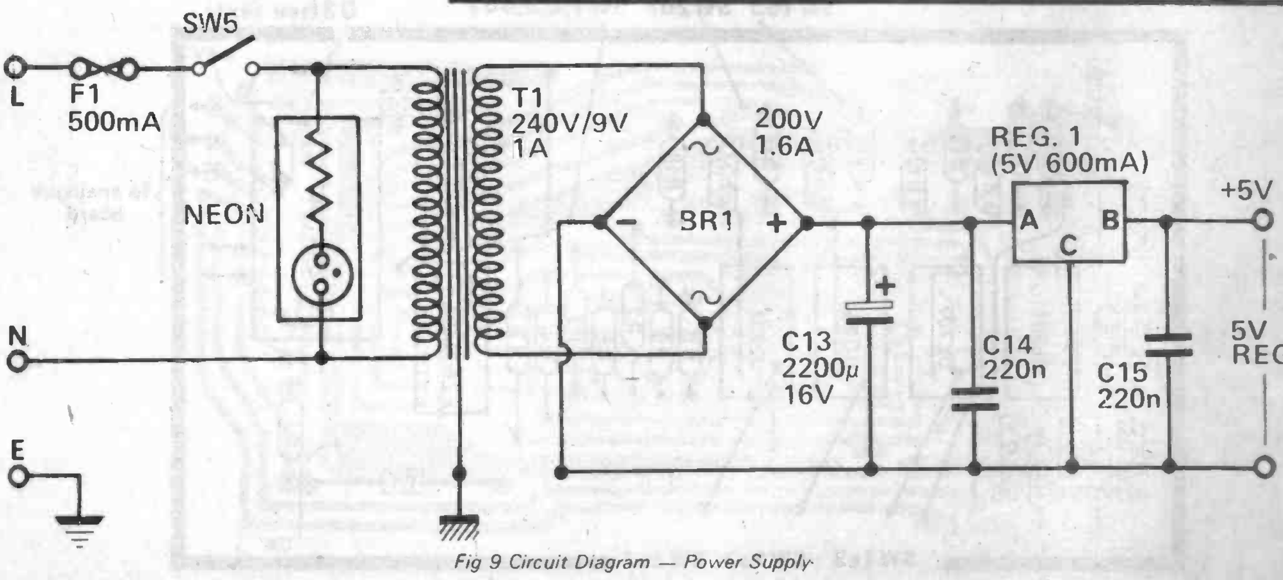
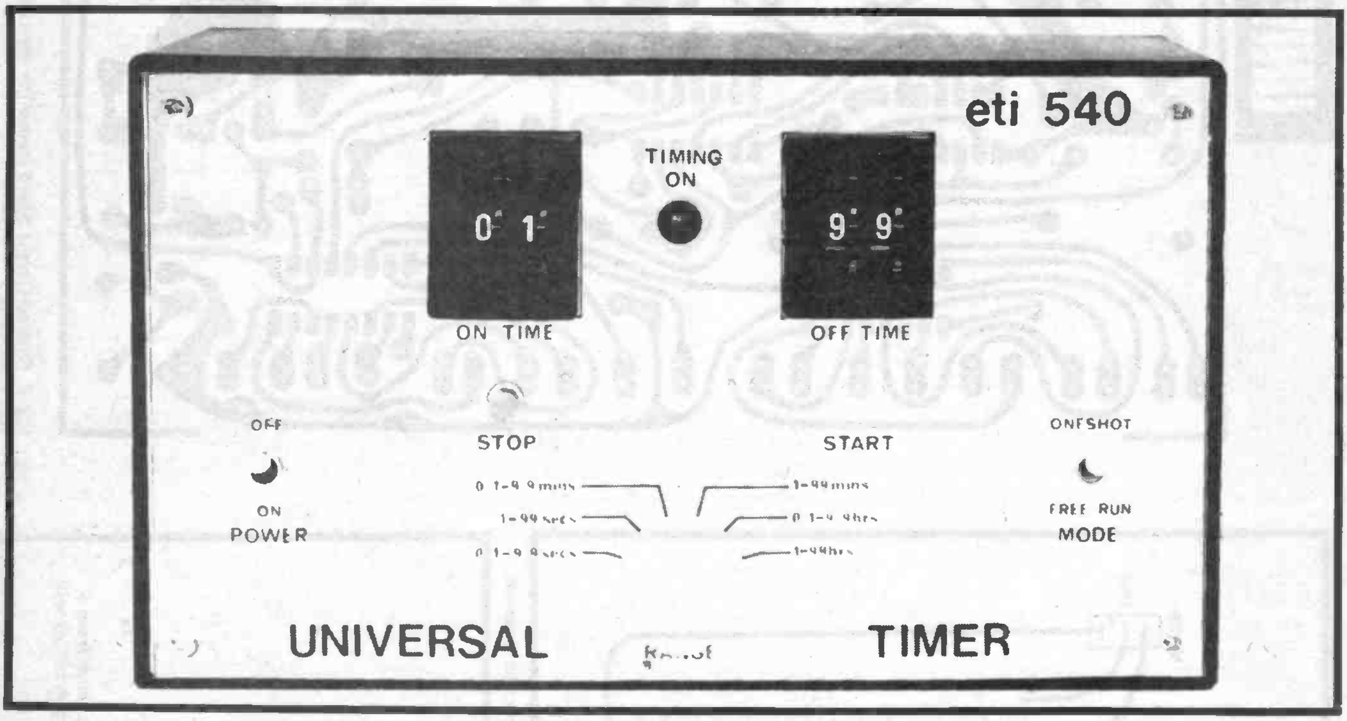


Fig 9 Circuit Diagram — Power Supply

UNIVERSAL TIMER



One tenth of a second to 99 hours. Both on and off times programmable. Manual or automatic operation, resettable at any time.

ETI project 540

THE TIMING OF EVENTS and processes is becoming an ever-increasing necessity particularly in applications involving automation.

Unfortunately most timers are either specifically made for a particular application — and difficult to adapt to others — or have restricted timing range, accuracy and facilities.

The ETI Universal Timer described in this project is free of most such constraints. It is extremely flexible, accurate and versatile. Its timing range is from 0.1 seconds to 99 hours. Both 'on' and 'off' times can be programmed (for example 12 hours on and 47 hours off). It can be manually started, stopped, or reset at any time, can be set for automatic cycling or for single cycle operation. It may be triggered by an external source (light, sound or pressure transducer, etc). Finally, as the unit is digital — the 50 Hz mains is used as the reference — timing accuracy is very high indeed, and a manual reset facility enables the timer to be synchronized with local time if so desired.

Clearly not all users will need all the facilities provided — so if the unit is required for a specific permanent use it is a simple matter just to leave out those ICs not required — several variations are described at the end of this project.

CONSTRUCTION

We strongly recommend that this unit be assembled using the printed circuit board shown.

Begin by fitting the links to the board as shown on the component overlay. Note that there are two points labelled 'a' and two points labelled 'b'. Link 'a' to 'a' and 'b' to 'b' using insulated hook-up wire routed on the copper side of the board.

Mount the resistors to the board followed by the diodes, transistors, capacitors and finally the ICs. Take particular care to ensure that all the polarized components are orientated correctly — especially the integrated circuits.

Wires should now be attached to the board for later connection to the front panel switches. We used rainbow cable for the connections to the thumb-wheel switches as this makes the wiring easier and also helps to keep the wiring tidy. Mount the printed-circuit board into the case and mount the power outlet socket. Assemble the switches to the front panel and then interconnect the printed-circuit board, front panel and power socket in accordance with the interconnection diagram.

Finally after wiring the 240 Vac

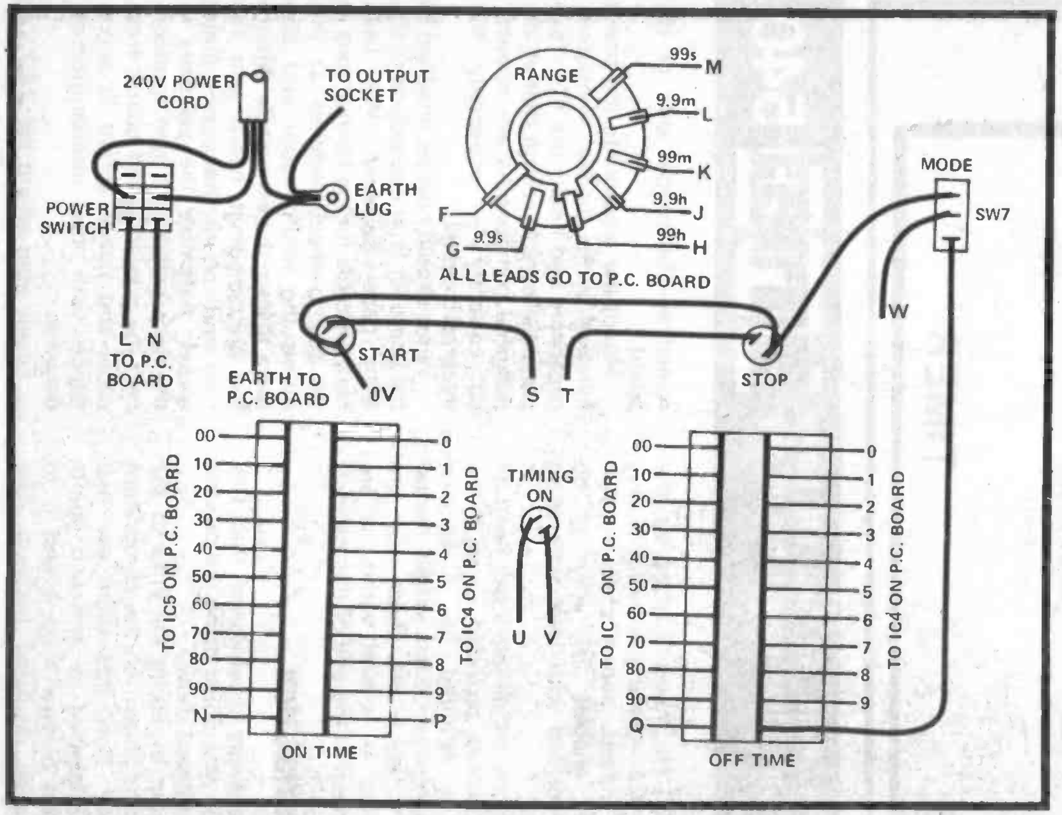


Fig. 3. Interconnection diagram.

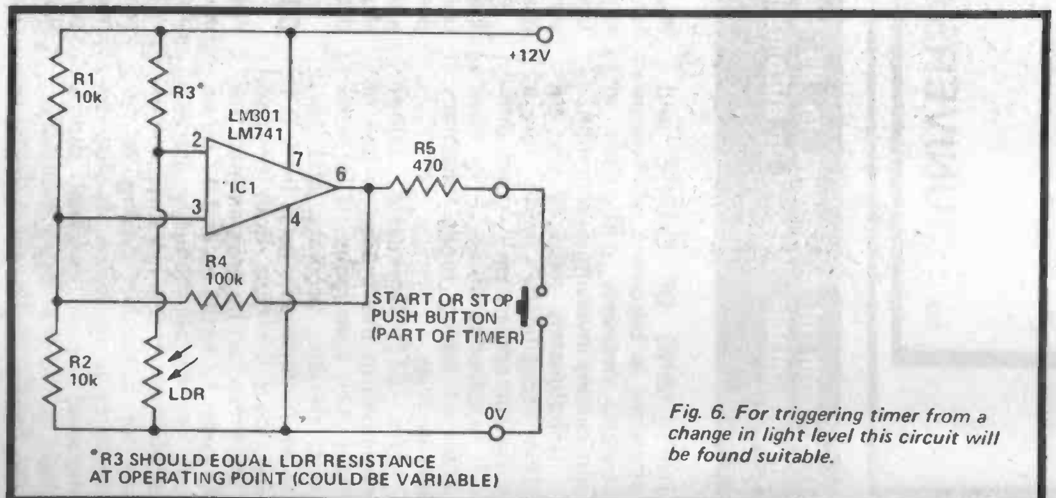


Fig. 6. For triggering timer from a change in light level this circuit will be found suitable.

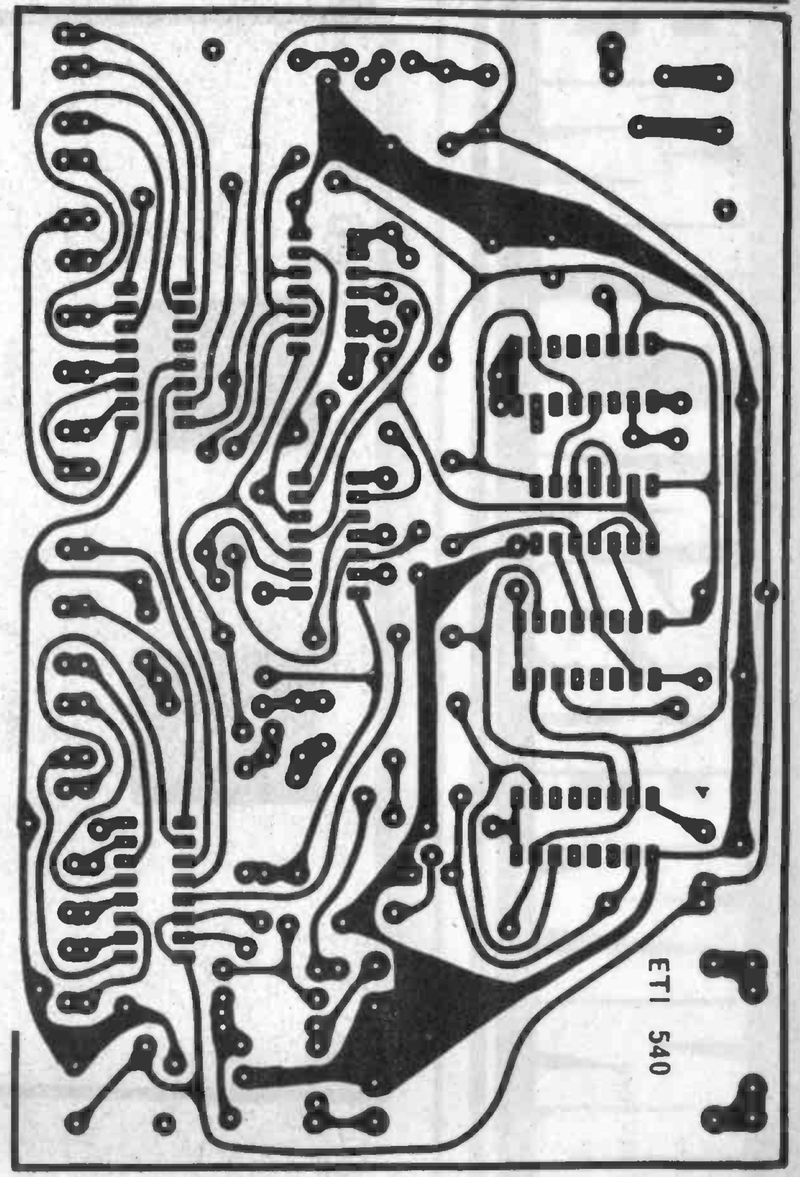


Fig. 4. Printed-Circuit board layout for the timer. Full size 153 x 100 mm.

power circuitry insulate all 240 V terminals with tape to ensure that there is no risk of personal contact when fault finding is required at any later date.

CUSTOMIZING

The unit need not necessarily be built in its complete form and many different modifications are possible to lessen the cost of the unit when it is to be used for one particular application only. The modifications required for a number of specific applications are described.

Specific fixed time — delete selector switches SW3 to SW6, and replace by wiring links from the appropriate outputs of IC4 and IC5 to the inputs of IC6/1 and IC6/2 respectively. The range switch may also be omitted by installing a link between the appropriate output of IC1 to IC3 and pin 13 of IC4.

Single shot operation — connect both inputs of IC6/2 to ground and omit switches SW5 and SW6.

Timing 99 hours or less — omit IC3 and connect inputs of IC7/3 and IC7/4 to ground.

Timing 99 seconds or less — omit IC2, IC3 and IC7.

External triggering — simplest way is a relay contact in parallel with start or stop button.

The main consideration when making any changes is that the logic is CMOS and any unused inputs must be connected to ground or to +12 volts to prevent damage to the IC (which may overheat with unconnected inputs).

SPECIFICATION ETI 540

MODES

Freerun
On/off (note 1)
One shot
Manual override (note 2)

TIMING RANGE

0.1 seconds to 99 hours (note 3)

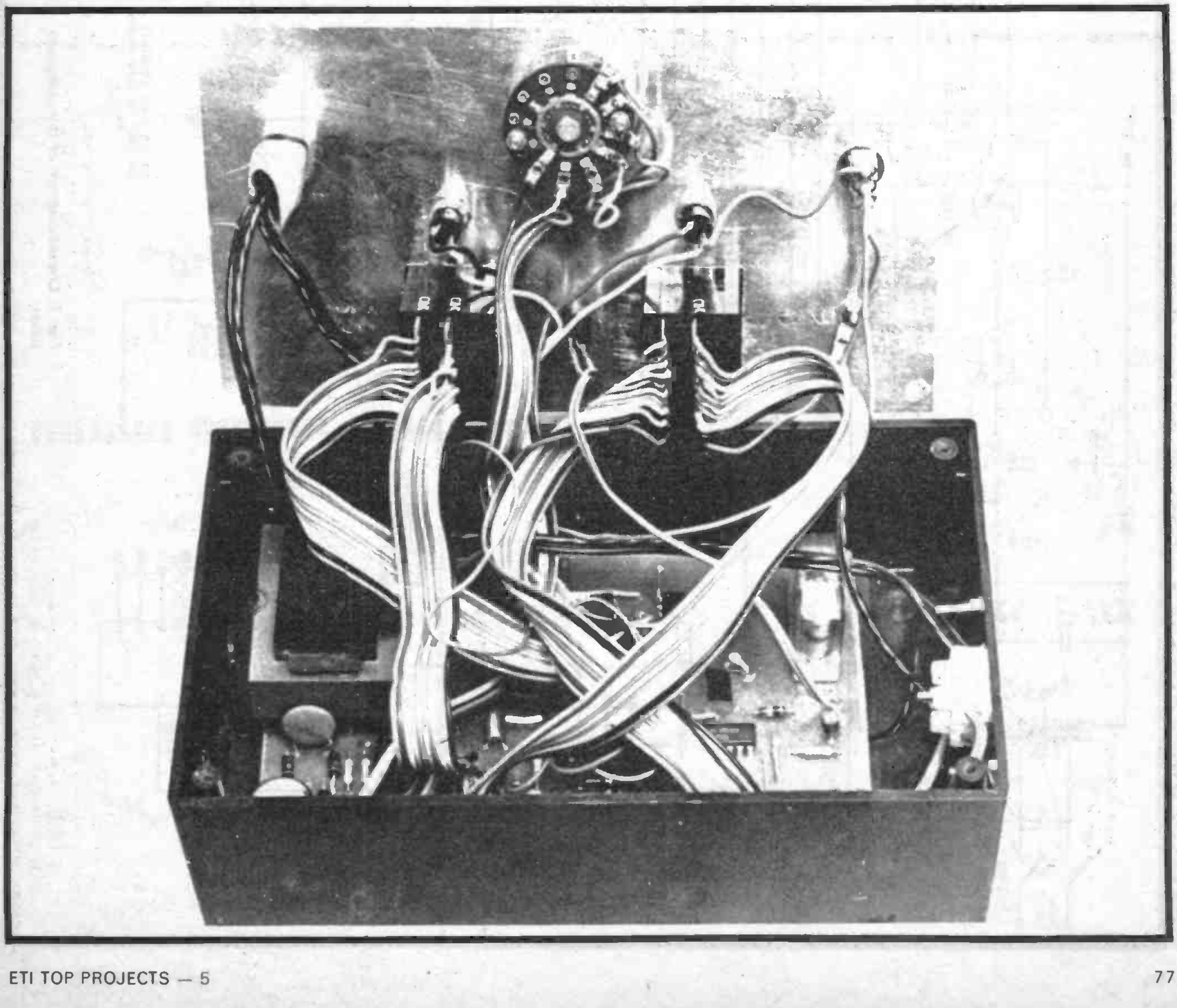
ACCURACY

Mains synchronized

OUTPUT

240 volts ac relay switched

Note 1. Both on and off times are variable independently.
Note 2. Unit may be stopped or started at any time. If the appropriate button is pressed whilst in the same mode the timing is recommenced.
Note 3. Timing is adjustable by a common coarse control which gives ranges having a full scale of 9.9 seconds, 9.9 minutes, 99 minutes, 9.9 hours and 99 hours. Each range is adjustable from 1 to 99 that is one second on and 99 seconds off is possible whereas one second on and two minutes off is not (different coarse range is required).



UNIVERSAL TIMER

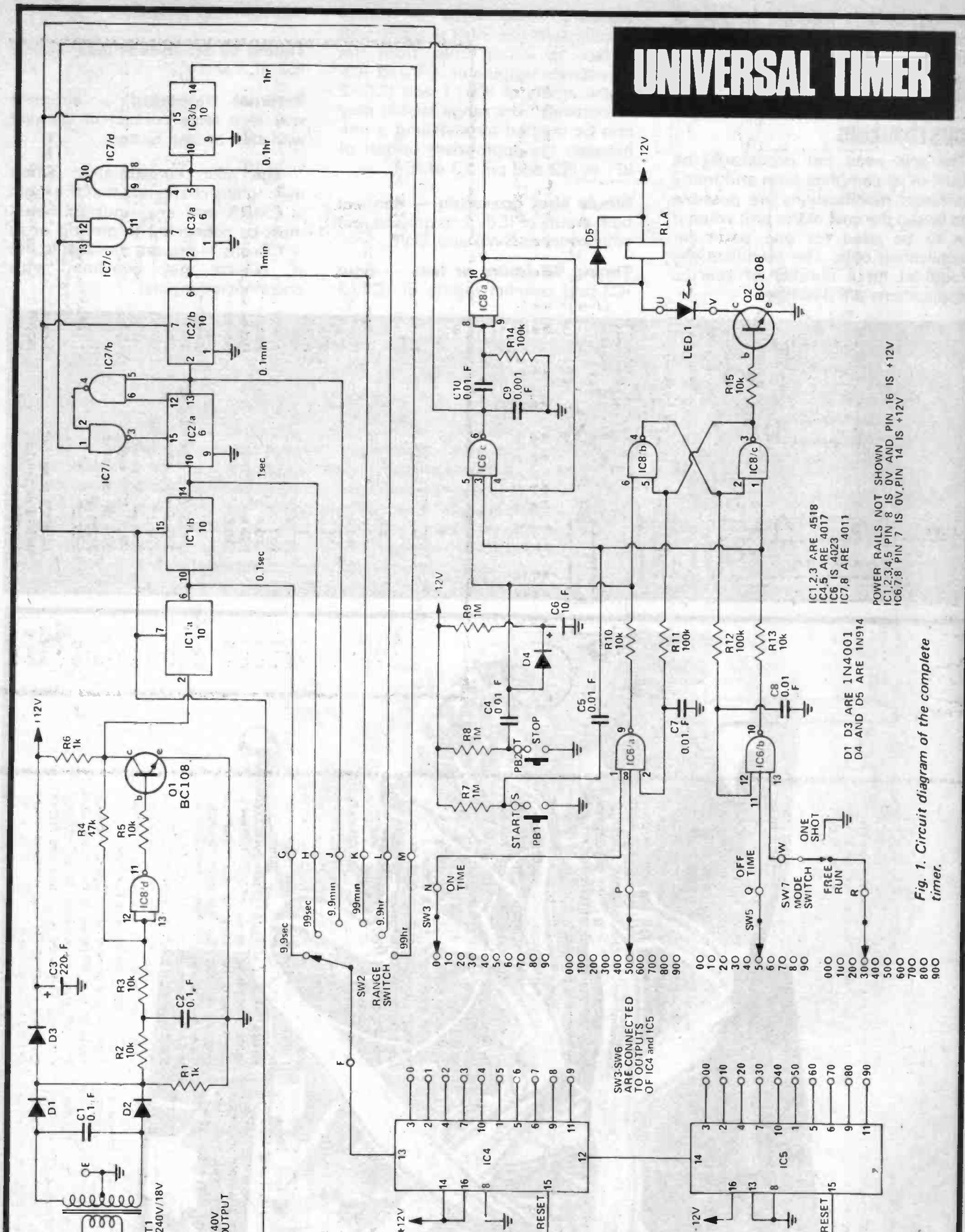


Fig. 1. Circuit diagram of the complete timer.

HOW IT WORKS — ETI 540

The 240 Vac is reduced to 12 Vdc by transformer T1 and diodes D1 to D3. Diode D3 isolates the smoothing capacitor C3 from the rectifiers and therefore 100 Hz ripple appears across R1. This waveform is used for the basic timing reference for the timer. To operate the counting ICs reliably a very fast rise-time waveform is required at the clock input. This is obtained by feeding the 100 Hz to a Schmitt formed by IC8/1 and Q1. Capacitor C2 is included to prevent the control tones superimposed on the mains for the control of hot-water services from upsetting the timing accuracy.

The 100 Hz from the Schmitt trigger is divided by 10 by IC1/1 to give a 10 Hz or 0.1 second output — the first required. Note that due to the low frequencies involved from now on the outputs will be referred to as time periods not as frequencies. A second divide by ten stage is used to give a one second output. A division by six is then performed by IC2/1 with IC7/1 and IC7/2 being used to decode the six count and reset the counter. This gives the one minute (or sixty second) period required. Further divisions of 10,6 and 10 are used to provide the six outputs required to select periods from 0.1 seconds to one hour.

One of these six outputs is selected by the range switch SW2 and is fed to a 4017 IC — the first of a pair of decade counters which have ten decoded outputs. The ten outputs of each IC go high in turn for one clock period each. As the two 4017 ICs are in series, a total division of 100 is obtainable. We have labelled the outputs of IC4 and IC5 as 0 to 9 and 00 to 90 respectively. IC4 is triggered by the clock enable as negative edge triggering is required. The second IC is clocked normally by the carry output from IC4.

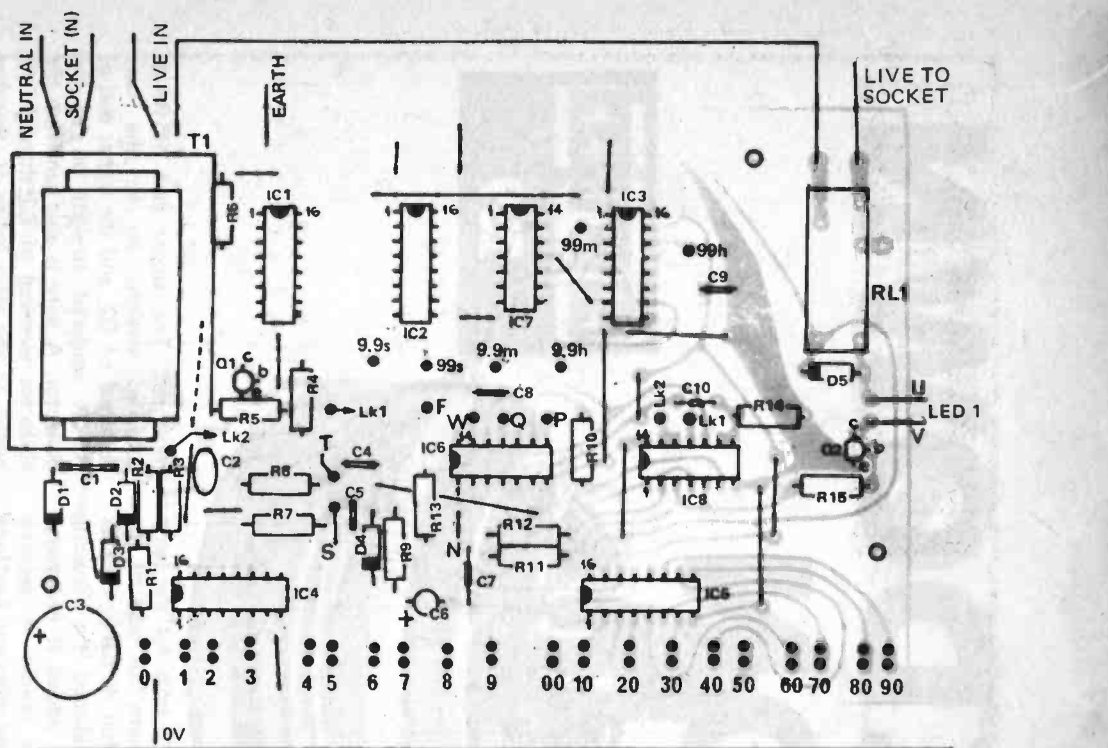
We pause at this point to go straight to the control output which is via a relay RL1, this in turn being controlled by the flip-flop made up of IC8/2 and IC8/3. This flip-flop can be controlled either manually by PB1 (manual on) and PB2 (manual off) or automatically by IC6/1 and IC6/2. To toggle the flip-flop automatically the output of either IC6/1 or IC6/2 must be low and for the output to be low the three inputs must all be high. This occurs only when the number selected by SW3 and SW4 (for IC6/1) and SW5 and SW6 (for IC6/2) is held by the counters IC4 and IC5 and the third input from the flip-flop is used to ensure that the off-time of the relay is controlled only by the off-time selector switches. A small time delay is incorporated in the signal back from the flip-flop to avoid the ambiguity that could arise with equal times.

If the output of either IC6/1 or IC6/2 goes low the monostable formed by IC6/3 and IC6/4 is triggered and its resultant output is used to reset all the counters to zero. This reset also occurs if either of the manual push buttons is pressed. The push buttons are coupled into the logic by capacitors so that only the initial part of the press actuates the logic and there is therefore no dependency on the length of time for which the button is pressed.

The sequence of events is as follows assuming that initially the switches are set for 25 seconds on and 14 seconds off.

On first switch-on C6 ensures that the flip-flop is toggled into the off state and also that the counters are all reset to zero. The control inputs from the flip-flop to IC6/1 and IC6/2 are low and high respectively. Therefore until the flip-flop changes state only IC6/2 can have the three high inputs necessary to provide a low at the output. Meanwhile the counters IC4 and IC5 are counting up at the rate of one count per second. After 14 seconds all three inputs to IC6/2 are high and the output goes low toggling the flip-flop. The monostable is then triggered and all counters are reset to zero. This removes the three high inputs to IC6/2 and the output goes high again. The pulse output of IC6/2 is very narrow and is about a microsecond long. As the flip-flop has now changed state the relay has been closed and IC6/1 has been enabled (control input to pin 2 now high). After 25 seconds all the inputs to IC6/1 are high and the same procedure as before resets the counters and changes the state of the flip-flop.

In the one-shot mode of operation one input of the off timer is grounded and the off time procedure is effectively disabled. The only way that the timer can now start is for the manual start button to be pressed.



PARTS LIST — ETI 540

Resistors

R1	—	1 k	½ W	5%
R2,3	—	10 k	"	"
R4	—	47 k	"	"
R5	—	10 k	"	"
R6	—	1 k	"	"
R7-R9	—	1 M	"	"
R10	—	10 k	"	"
R11.12	—	100 k	"	"
R13	—	10 k	"	"
R14	—	100 k	"	"
R15	—	10 k	"	"

Capacitors

C1	—	0.1 μF 50 V disc ceramic
C2	—	0.1 μF polyester
C3	—	220 μF 16 V electro
C4,5	—	0.01 μF polyester
C6	—	10 μF 16 V electro
C7,8	—	0.01 μF polyester
C9	—	0.001 μF "
C10	—	0.01 μF "

Diodes

D1-D3	—	1N4001 or similar
D4, 5	—	IN914 or similar
LED 1	—	TIL209 or similar

Transistors

Q1,Q2	—	BC108 or similar

Integrated Circuits

IC1-IC3	—	4518
IC4,5	—	4017
IC6	—	4023
IC7,8	—	4011

Transformer 240 V/18 V CT PL18/5 VA
pc Board ETI 540
Relay, single pole 280 Ω coil 240 V 5A contact

Switches

SW1	double pole toggle switch
SW2	single pole 6 position rotary
SW3-6	single pole 10 position *
SW7	single pole toggle
PB1,2	single pole "make" push buttons

* Thumbwheel switches — Doram 338—175

Case plastic 196 x 113 x 60 mm
power cord, plug and clamp
3 pin power outlet socket

BREAKDOWN BEACON

ETI PROJECT 239

AN ESSENTIAL DEVICE FOR ANY CAR OWNER............

THE BREAKDOWN BEACON IS A dual purpose device. It can be used atop a disabled motor vehicle as a flashing warning to other traffic — a highly desirable safety device. Alternatively it can be used as a non-flashing trouble light for finding and fixing faults at night. Its three rubber-sucker feet will hold it to the roof of a car, to the underside of a bonnet, or to any other convenient flat surface.

The circuit operates from the vehicle's battery and, as all electrical parts are isolated from the metal case, the same circuit can be used for cars with either negative or positive earth wiring systems. The beacon is fed from a plug pushed into the cigarette lighter socket — however as this plug is polarised, a beacon with a plug for negative earth cannot be used in a car with opposite polarity unless the plug connections are reversed. Alternatively it could be powered from the car battery.

CONSTRUCTION

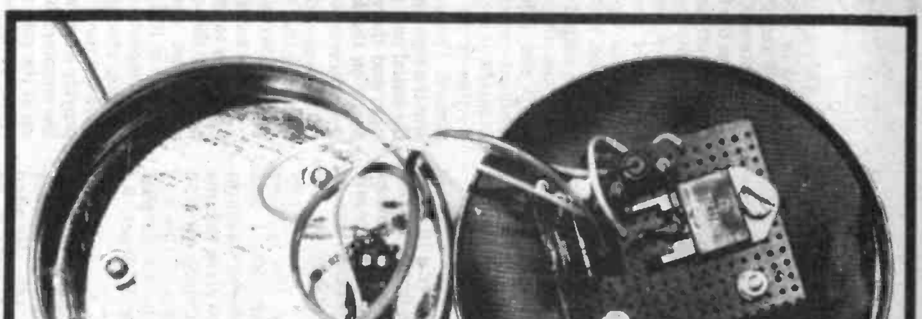
The nicest thing about the construction of this project is that first you have to eat half a pound of jam, in order to get the empty glass jar for the lamp housing. Other, jars about 70mm dia. and 70mm high with a twist off cap would do. You'll need also a round tobacco tin about 75–80mm dia. and 30mm high with a twist off cap. These two parts make up the case.

First solder the lids of the jar and the tin together, concentrically — outside to outside. Then before fitting the batten lamp holder fit the lamp to it and check that it will fit inside the jar when the jar is screwed into its lid. If it will, then mount the lamp holder by three bolts through both lids. Two of these bolts should be longer than the third as they will carry a piece of Veroboard. If the jar is slightly too short to accept the lamp holder and lamp — as was the case in the prototype — then cut a hole for the lamp holder through both lids, and fit the lamp holder so that its flange finishes up inside the tabacco tin. Spacing washers may be added if necessary. Again the lamp holder is secured to the lids with one short and two long bolts.

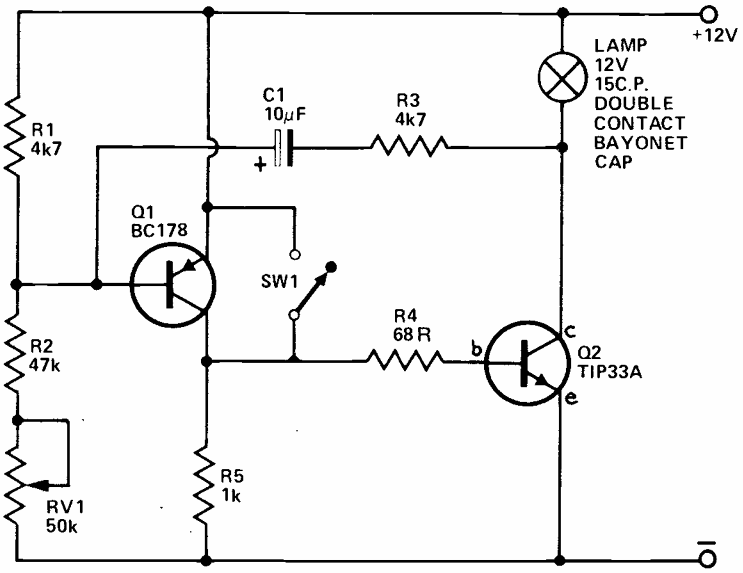
The electronic part of the beacon is constructed on 0.1 inch matrix Veroboard 45mm x 36mm. Only one break needs to be cut in the copper strips — between the two leads of capacitor C. Only the outer legs of RV1, are passed through the Veroboard. The centre leg is connected to either outer leg above the board and the excess cut off. Note that all resistors except R5 are vertically mounted. The upper end of R4 is soldered straight on to the base terminal of Q2, and the upper end of R3 is soldered straight on to the collector. A wire is also run from the collector terminal of Q2 through the board to the strip below it. Another wire is run from the emitter terminal of Q2 to the negative rail which is the copper strip just below.

The Veroboard is mounted into the case below the lamp holder, using two of the lamp holder mounting bolts.

The switch SW1 is mounted on the bottom of the tobacco tin where it is out of the weather. The switch must be positioned such that it does not clash with the components on the Veroboard when the tobacco tin is screwed



Inside view of the completed unit. Note the plastic disc used to replace the normal airtight seal of the jar.



Circuit diagram of the Breakdown Beacon.

PARTS LIST – ETI 239

R1	Resistor	4k7	¼ watt
R2	"	47k	"
R3	"	4k7	"
R4	"	68R	"
R5	"	1k	"
RV1	Preset pot	50k	
C	Electrolytic capacitor 10 μF at least 15 volts		
Q1	Transistor PNP BC 178 or similar		
Q2	Transistor NPN TI P33A or similar		
SW1	small on/off slider switch, single pole		

Lamp 12 volt automotive lamp 15 candlepower double contact cap.
Lampholder – to suit lamp, batten mounting, double contact bayonet catch type. (This is an electricians line not an automotive line. They are used for pilot lamps).
Tobacco tin, jam jar, or similar. Nuts and bolts, hook up wire.
Lead to battery – 7 m speaker extension lead.
Cigarette-lighter plug.

HOW IT WORKS

The circuit is an oscillator of a not very common type. It is ***not*** a multivibrator as both transistors conduct at the same time rather than alternately as in a multivibrator. Most 'explanations' of this type of circuit state that the circuit oscillates by a regenerative action from Q2 to Q1. This doesn't really explain how it works, so perhaps the following is a little clearer.

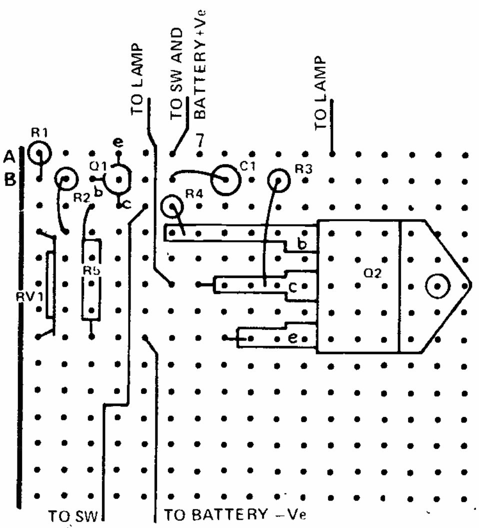
The setting of the pot RV1 is such that when power is first applied Q1 is turned on slightly. By varying RV1 the circuit can be made to 'lock' with the lamp on or off. In between these extremes the circuit oscillates. The setting of RV1 is not critical.

As said above, when power is applied Q1 turns on slightly. Current through Q1 feeds into the base of Q2 and turns it on. Capacitor C charges through R1, R3 and Q2. This increases the current through R1 and so lowers the voltage at the base of Q1 thus turning it on harder – hard enough to turn Q2 full on and light the lamp.

As C charges, the voltage at the base of Q1 rises and so tends to turn Q1 off, thus reducing the base current in Q2 and hence the current through the lamp. This increases the voltage across Q2 quite rapidly. As the voltage across the capacitor cannot be changed rapidly, the increase of voltage across Q2, i.e. the voltage change at the collector of Q2, is transferred through the capacitor to the base of Q1 – so turning it off. This turns Q2 hard off. The voltage at the collector of Q2 then rises rapidly to 12 volts, so the voltage at the base of Q1 is forced up through capacitor C, turning Q1 hard off.

Capacitor C then discharges round R1, the lamp, and R3 until, when fully discharged, Q1 turns on slightly and the cycle is repeated.

The switch SW1 (connected across Q1) is used to disable Q1 and so give a steady light when SW1 is closed.



Veroboard layout for the beacon circuit. The copper strips run from left to right across the board. Only one break is required and this is at B7

together.

The long twin-lead to the battery is run through the bottom of the tin (to prevent moisture entering) and connected to a cigarette-lighter plug taking care to wire with a polarity to suit the car system (positive or negative earth). Speaker extension lead is good for this purpose as it has polarity marking.

It is likely tha the operation of soldering the two lids together will have destroyed the air-tight seals in the jar and tin; they should be replaced with a disc in the tin and a ring in the jar cut from fairly heavy plastic sheeting.

TESTING

Before connecting up make sure that switch SW1 is open – otherwise the unit will not flash.

Connect the unit to the battery by inserting the plug into the cigarette lighter socket. It may now be found that RV1 needs some adjustment to make the circuit operate correctly, so don't be disappointed if the lamp does not light at first or alternatively, stays on all the time. The flashing rate may be altered by changing either C or R3 if thought necessary. About 70 to 100 flashes per minute is right.

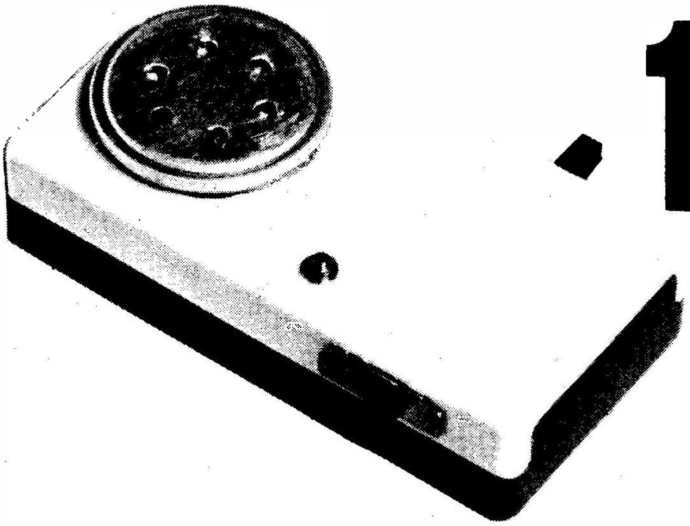
The value of R4 shown in the circuit was selected to suit the transistor Q2 used in our prototype. If the lamp lights at less than full brilliance then R4 may be reduced until Q2 saturates and the lamp is turned on fully.

USE

The illustration shows the prototype with a clear glass 'lens'. This is ideal when the beacon is used as a trouble light – turned permanently on. However, if it is thought desirable to have a amber or red colour when the beacon is flashing, then it is a simple matter to make a sleeve of suitable coloured material to be dropped inside the jar. ●

A PROJECT TO AVOID BURNT CAKES AND SMILING WARDENS

1-2 HOUR TIMER



eti project 252

THE DESIGN CRITERIA to be satisfied by this timer are that it is simple to operate, reliable, pocket sized, has an audio output and is cheap to run.

IN PRACTISE

As figure 1 shows, the circuit consists of two parts: a precision digital timer and an audio oscillator. After the preset delay period, the timer circuit energises the audio oscillator. There are two operating controls.

Switch S1 is first set for the required period; switch S2, the on/off switch, then initiates the delay. At the end of the period, a rapid series of pips is heard from the speaker. The time period is simply reset by switching it on again. THe LED D1 is used to indicate that timing is in progress and goes out when the alarm sounds at the end of the delay period. The general appearance of the prototype timer is shown in Fig. 2.

Accurate timing is set by shunting VR1 and VR2 with a 2k2 resistor to obtain a time delay of 40 seconds.

IN THEORY

Firstly, the timer circuit based on IC1. This integrated circuit is a precision timer device, (Ferranti ZN1034E), in a 14 lead DIL package. The frequency of an 'on chip' oscillator is determined by an externally-connected capacitor and resistor. Pulses from this oscillator are fed through a 12 stage binary divider which switches the output stage after 4095 counts. During the count-out period the drain current is a low 5mA or so, and the oscillator frequency is independent of supply voltage in the range 5V to 450 V (an on-chip voltage regulator is used).

Capacitor C1 has a fixed value of 4.7µF and the resistors R1 and R2 are selected empirically to provide time intervals of 1 hour and 2 hours, respectively. Values of approximately 270 kΩ and 540 kΩ are required. Of course, great precision in the time intervals required is not necessary for the application in mind for the timer, but the great advantage of using this timer chip instead of the ubiquitous '555' IC is that large-value resistors and capacitors are not required for delays of an hour or so. For connections shown in the figure, the time delay in seconds is given by

$$T = 2736 C1 R1$$

At the end of the delay period, output pin 2 goes positive and output pin 3 goes negative. Thus, during the timing period, the positive voltage on pin 3 drives on the LED and the negative voltage on pin 2 keeps off transistor Tr1. When the timer counts out the positive voltage rise at pin 2 switches on Tr1 which provides current for the oscillator based on the integrated circuit IC2.

IC2 is the well known dual timer device, the '556' consisting of two '555' timers in the same chip. Each timer is wired as an astable multibrator which are cross-coupled by resistor R10. The low frequency oscillator based on R6, R7 and C3 modulates the high frequency audio oscillator based on R8, R9 and C4 to give a rapid series of 'pips' from the speaker LS. The values of these

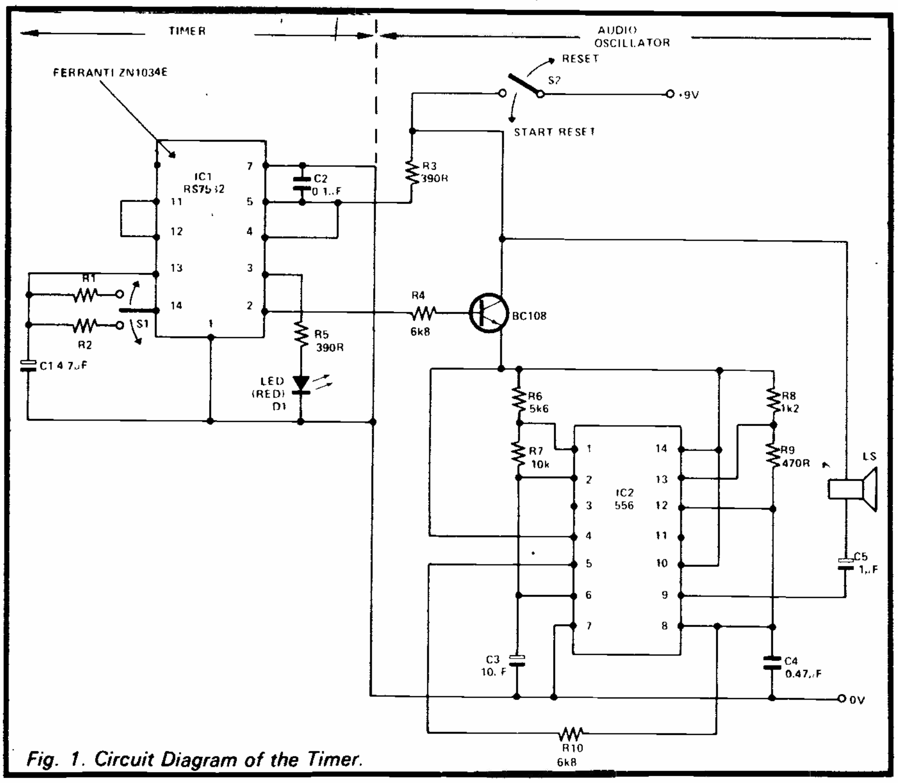
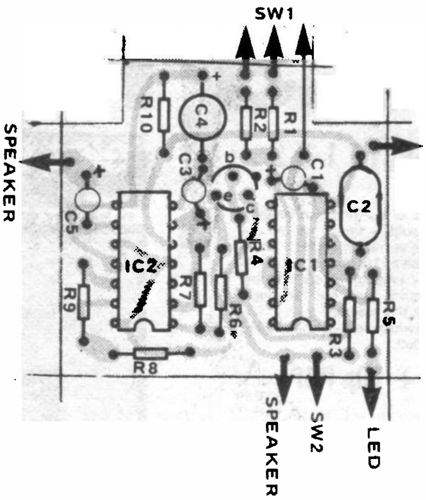
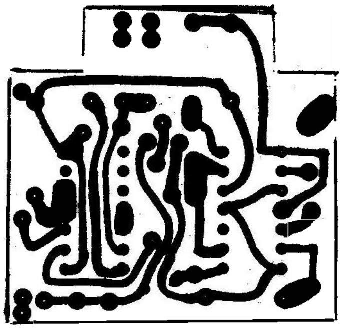


Fig. 1. Circuit Diagram of the Timer.

frequency determining resistors and capacitors, and the value of R10, can be experimented with to obtain the audio signal required. For instance, if the value of R10 is raised from 2.2 kΩ to 6.8 kΩ the audio note changes from a succession of pips to a two-tone alarm.

If it is intended to use this device as a parking timer, it might be best to set the period just short of 1/2 hours, say by 10 minutes or so, to give yourself time to get back and redeem the situation, before the dreaded piece of paper descends on your windscreen.





PARTS LIST ETI 252	
R1	270k (adjust to give 1hr)
R2	540k (adjust to give 2hr)
R3	390R
R4	6k8
R5	390R
R6	5k6
R7	10k
R8	1k2
R9	470R
R10	6k8
	All 5% ¼ watt metal oxide
C1	4.7µf 12v.w.
C2	0.1µf
C3	10µf 12v.w.
C4	0.47µf
C5	1µf 12v.w.
TR1	BC108 or similar
IC1	ZN 1034E (Doram—RS 7532)
IC2	556
D1	TIL 209 or similar
LS	Telephone insert
Verobox to suit, battery (PP3) and clips	

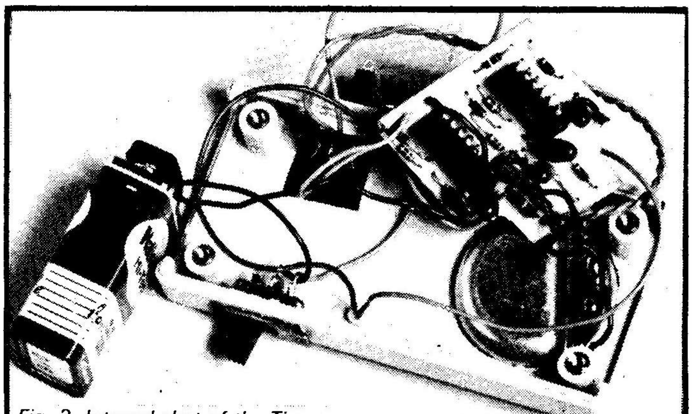
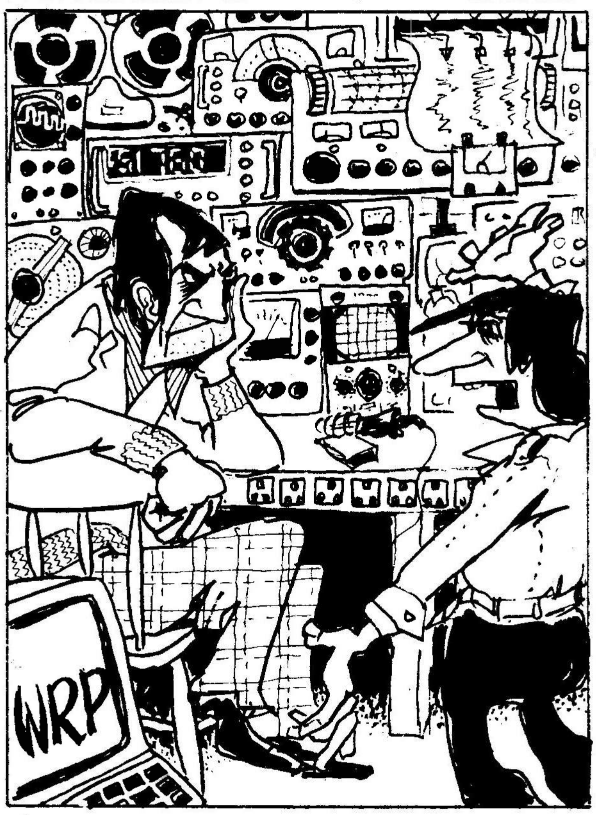


Fig. 2. Internal shot of the Timer.



Well, if you stopped reading those comics and took a sub to ETI you might find something worth building for a change!

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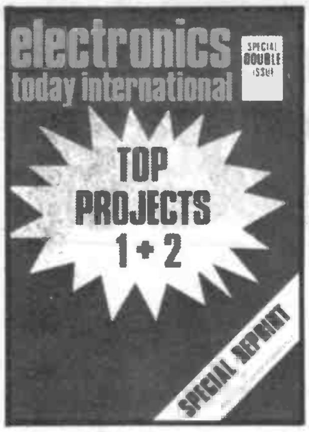

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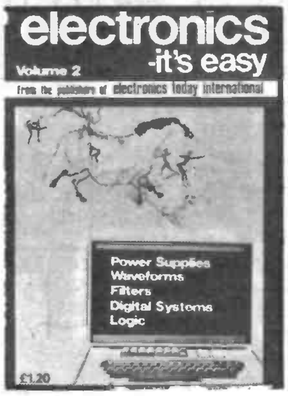

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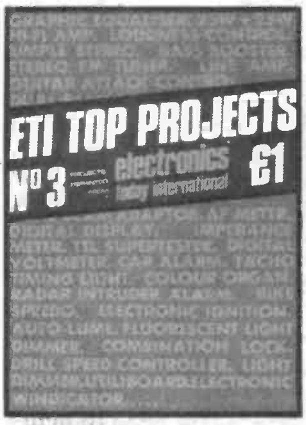

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Originally published in March 1976, Top Projects No. 3 contains 27 constructional projects including Graphic Equaliser, International 25W Stereo Amp, Simple Stereo, New Sound for your Guitar, Bass Booster, Line Amplifier, Loudness Control, Electronic Ignition, Tacho Timing Light, Car Alarm, Dual-Beam Adaptor, AF Meter, Impedance Meter, Digital Display, Digital Voltmeter, TTL Supertester, Fluorescent Light Dimmer, Radar Intruder Alarm, Light Dimmer, FM Tuner, Colour Organ, Drill Speed Controller plus many more.

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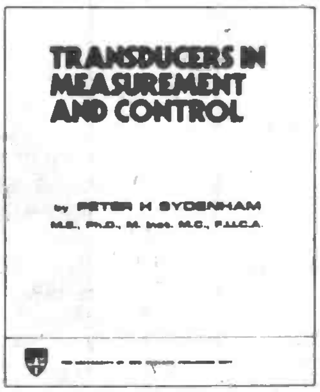

TRANSDUCERS IN MEASUREMENT AND CONTROL

This book is rather an unusual reprint from the pages of ETI. The series appeared a couple of years ago in the magazine, and was so highly thought of by the University of New England that they have re-published the series splendidly for use as a standard textbook. Written by Peter Sydenham, M.E., Ph.D., M.Inst.M.C., F.I.I.C.A., this publication covers practically every type of transducer and deals with equipment and techniques not covered in any other book. Enquiries from educational authorities, universities and colleges for bulk supply of this publication are welcomed. These should be addressed to H. W. Moorshead, Editor.

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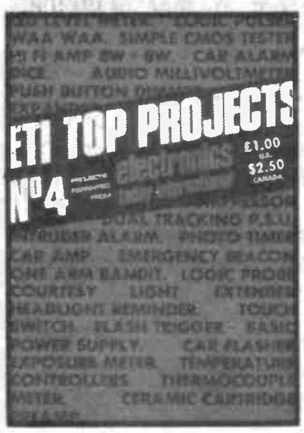

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Available at your newsagents or from ETI direct. Published October 1976. This includes Sweet-Sixteen Stereo Amp, Waa-Waa, Audio Level Meter, Expander-Compressor, Car Anti-Theft Alarm, Head-light Reminder, Dual-Tracking Power Supply, Audio Millivoltmeter, Thermocouple Meter, Intruder Alarm, Touch Switch, Push-Button Dimmer, Exposure Meter, Photo Timer, Electronic Dice, High Power Beacon, Temperature Controller, Electronic One-Armed Bandit plus many more.

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A complete reprint of our superb synthesiser design, published with Maplin Electronics (who also supply the parts). This reprint will also be of interest to those not specifically wanting to build the unit as the circuitry is highly original and is in fact patented by ETI!

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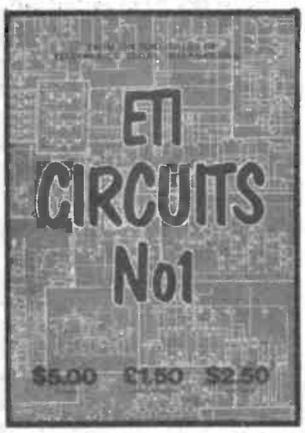

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Just published and available from your newsagent as well as from us direct is this new concept in Specials. ETI Circuits No. 1 contains over 200 circuits, largely based on the Tech-Tips section and Data Sheet but great care has been taken to index each circuit carefully to enable rapid selection. This publication is likely to be regarded as a bible by the experimenter for not only does it contain complete circuits but also ideas and circuit sub-assemblies.

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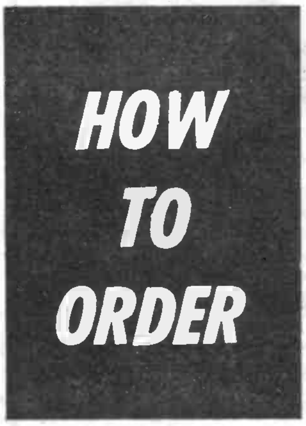

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HEART-RATE MONITOR

An invaluable tool for the bio-feedback experimenter or for the assessment of athletes.

THERE ARE MANY METHODS of measuring heart rate ranging from feeling the pulse, to chart recordings via an electrocardiograph. Other methods include monitoring the electrical potential which triggers each heart best; resistance changes due to changes in blood flow; and change in the volume of blood in blood vessels with each beat.

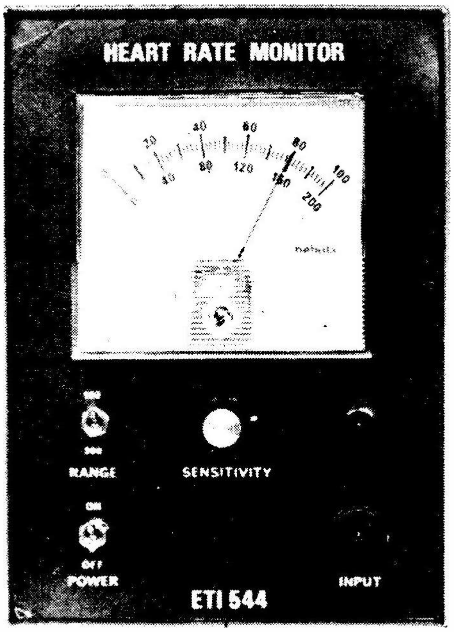
The detection of electrical signals associated with heart action is the best and most reliable method especially if the subject is exercising. However good connection must be made to the body by special electrodes and conductive paste to ensure very low contact resistance. The method is messy and requires skill in attaching the electrodes.

Similar electrodes are required to measure changes in body impedance and in addition the measurement is usually made by passing an electrical current through the body. This poses a considerable safety hazard as any fault in the insulation of mains-operated equipment can cause lethal currents to pass through the body. For this reason we did not use the method and we strongly recommend that experimenters do not either! With very well attached electrodes even small voltages can produce lethal currents.

LIGHTING UP TIME

This leaves us with the light-beam method, two variations of which are in common use. One is to pass light through flesh to a bone where it is reflected to a photo sensitive device adjacent to the lamp. This has the advantage that the sensor may be taped to any convenient part of the body, eg, the forehead, but the signal generated is very low. A second method still uses a light source and photo-sensor but the light is passed to the sensor through some thin section of flesh — the fleshy part of a finger or the ear lobe work very well. As there are no electrical contacts with the body this type of sensor is very safe to use and was therefore chosen for use in the ETI meter.

Specific Circuitry: While the detection and amplification of the signal due to heart action can be done with normal linear amplifiers the frequencies involved are very low. Measures must be taken to reject frequencies other than those of interest and to overcome dc offset problems due to differences in the path lengths depending on where the probe is attached.



Thought must also be given to the type of readout to be used. Were a digital readout to be used, counting of the rate would have to be performed for a full minute in order to obtain a one beat resolution and a new reading could only be taken at one minute intervals if normal frequency measurements are used. However, this problem may be overcome by measuring the period between the pulses and converting this to a frequency which can then be measured using digital logic to obtain a reading on every beat. This is quite valuable in a machine used for diagnostic work where information on the variations in regularity of the interval between adjacent beats can be quite meaningful. However, the method is complex, and expensive and requires some other type of sensor than the light beam type to obtain the accuracy required. As our meter is not intended for diagnosis the digital technique was rejected in favour of a simple analogue meter display.

CHOICE INTEGRATION

Even with an analogue readout we still have a choice of operating methods. We can measure the period between beats as previously discussed or we can use it as an integrating frequency meter. The latter method requires about 25 seconds for the reading to stabilise initially but thereafter it will follow variations in heart rate quite faithfully. The measurement of period between each beat is more rapid in its response but requires more

HEART-RATE MONITOR

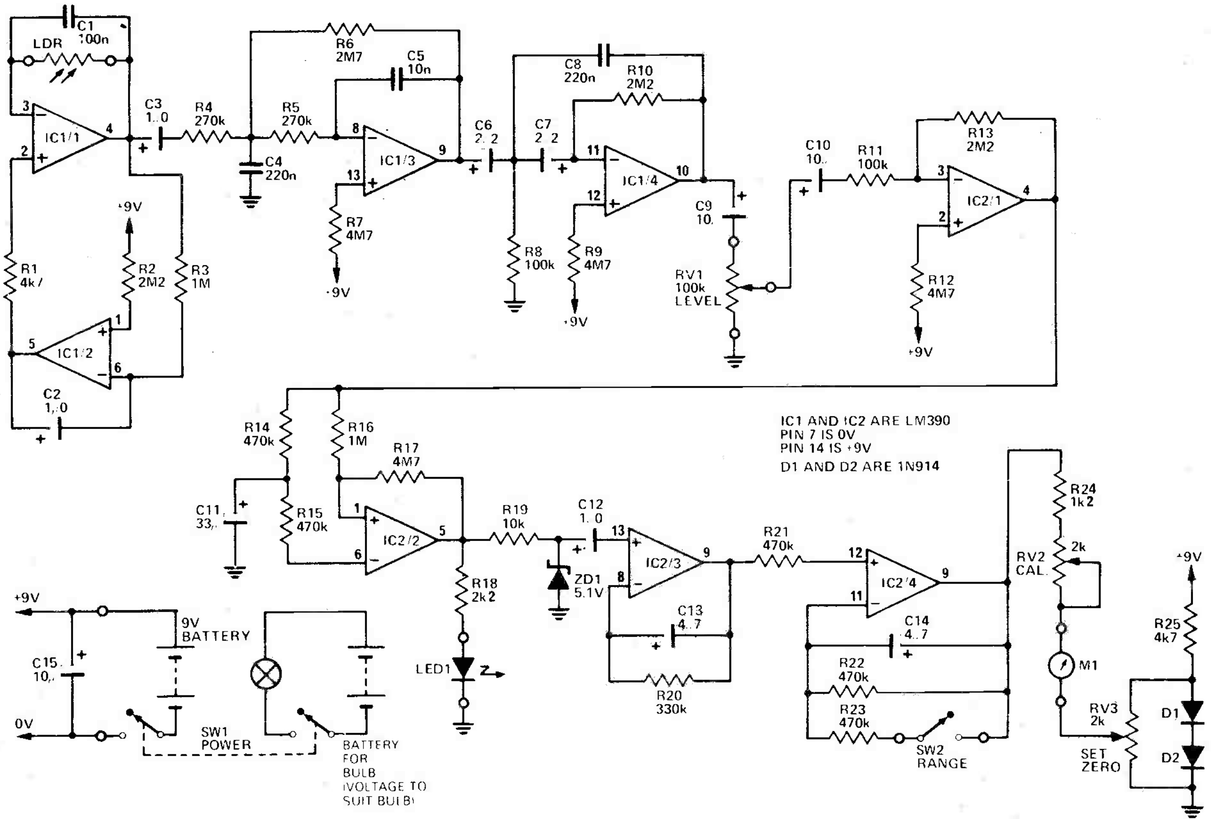


Fig. 1 Circuit diagram for heart-rate monitor.

How it works

The sensor consists of a light bulb and a light-dependant resistor mounted in a clothes peg in such a way that they may be positioned on opposite sides of a small section of flesh such as the ear lobe or a finger. As the heart beats it pumps blood through all the blood vessels of the body which swell. The density of the body therefore changes giving rise to a change in light transmission through the section of flesh to which the sensor is clipped. The LDR which is subject to this change of illumination therefore changes its resistance, and it is this change in resistance which eventually drives the meter. As the actual amount of light transmitted varies greatly from person to person and according to the thickness of flesh between the sensors, some method of stabilising the working base line is required.

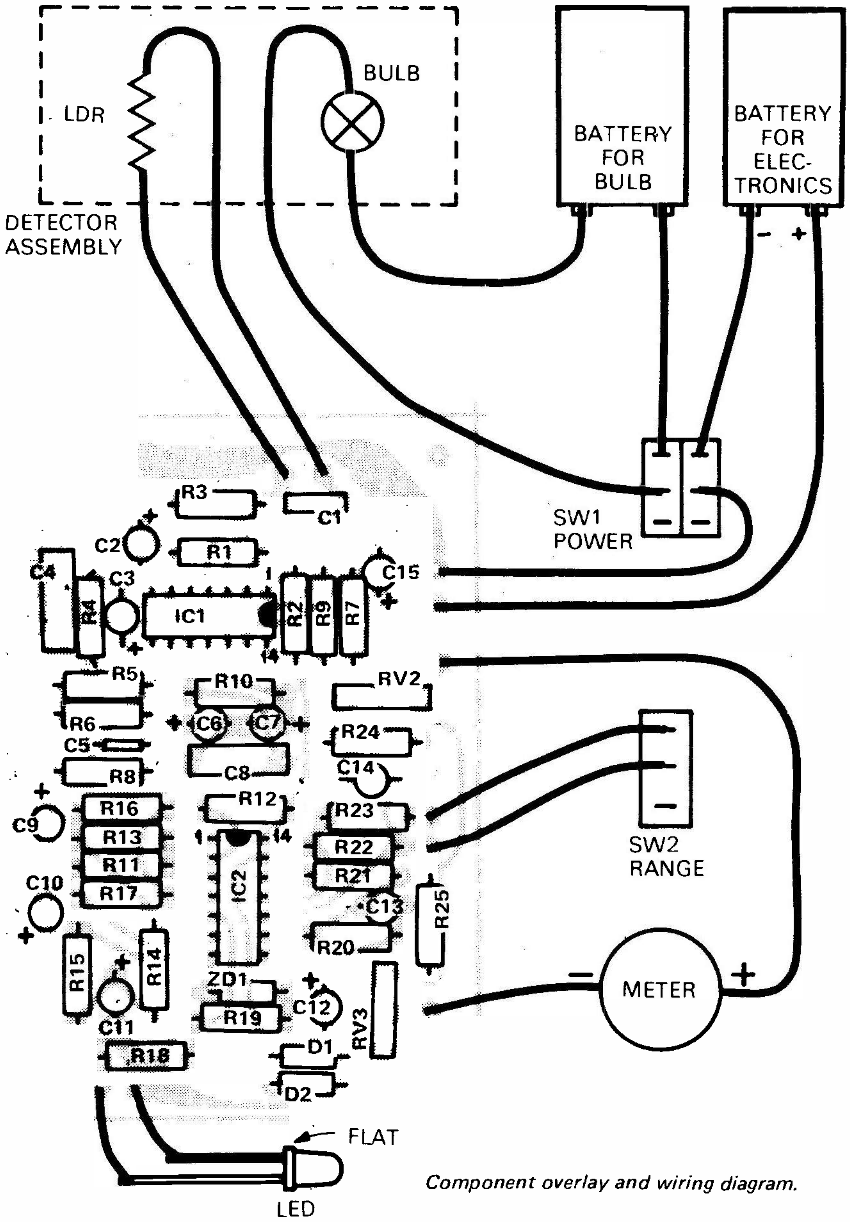
The stabilising function is performed by IC1/1 and IC1/2. Due to the operating mode of IC1/1 the current through the LDR is always equal to the current through R1. The current in R1 is automatically adjusted by IC1/2 such that the output of IC1/1 sits at about four volts (as the current in R2 must equal the current in R3). Capacitor C2 prevents the current in R1 from changing quickly and hence, relatively fast changes due to heart-beat (which cause changes in LDR resistance) are detected.

As the output of IC1/1 is at a very low level this signal must be amplified by IC1/3 and IC1/4 by about 40 dB. A low-pass filter which limits the rate, which can be detected to about 250 beats per minute, is also formed by IC3/3; and a low-pass filter which cuts off all frequencies below 30 beats per minute is formed by IC1/4. These filters eliminate 50 Hz pickup and any other signals generated by slow movement of the body which could also interfere with the measurement. As the actual signal can vary over a range of 20 dB with different people a level control is incorporated, after IC1/4, and the output from this control is amplified by 26 dB in IC2/1.

The output of IC2/1 has now to be squared up before it can be used. This is performed by a Schmitt trigger formed by IC2/2 where the necessary positive feedback is supplied by R17. Both inputs are biased from the output of IC2/1 but the ac signal is prevented from reaching the negative input by capacitor C11. An LED driven by the output of IC2/1 is incorporated to give a visual indication that heart beat is actually being detected.

It is now necessary to convert the square wave from the output of IC2/2 into a voltage proportional to heart rate and this is the purpose of IC2/3. Each time the output of IC2/2 goes high, capacitor C12 is charged up via R19 and the positive input from IC2/3. By the nature of the IC this current has to be balanced by a corresponding current in the negative input. This current can only be supplied by the output going high and supplying current via C13. This charges C13 up a little. On the negative edge of the output from IC2/2 the capacitor is discharged via the protection diodes on the input of IC2/3. If R20 was not present C13 would continue to charge up on each input pulse, however R20 bleeds a little current from C13 and the charging stops when it reaches a voltage where the amounts of charge and discharge become equal. The voltage reached will of course now be proportional to the heart rate. The amount of ripple on this voltage is determined by the time constant of R20 and C13 and this is selected as a compromise between response time and ripple. The zener diode is used to stabilise the output of IC2/2 against any changes in supply voltage.

The last section of IC2 is used as a buffer amplifier which provides the two ranges required along with an extra stage of filtering. The output of IC2/4 is metered to give a direct readout of heart rate. A resistor and trimpot in series with the meter allow the instrument to be calibrated and the potentiometer RV3 provides a zero correction (as the output of IC2/4 is not at zero volts but at about 0.8 volts). Diodes D1 and D2 stabilise this against supply variations.



Component overlay and wiring diagram.

complex circuitry and is very responsive to noise 'glitches' or to phenomena other than heart beat. Furthermore the scale for such an instrument is non-linear and wrong reading. That is high readings are at the left of the scale and vice versa. For these reasons the integrating frequency meter was chosen as the cheapest and most effective method for our particular application.

PROTOTYPE PROBLEMS

Our original prototype was built with 741 type operational amplifiers but in the final version we used the LM3900 which contains four Norton type operational amplifiers in the one package. This is a very economical solution as although the circuit is quite complex in concept, the whole device only uses two inexpensive ICs.

In the development of the circuit for this instrument a laboratory power supply was used. However, when the completed board was mounted into its case and run from batteries it worked alright until the batteries had been used for a while and then problems were encountered. The unit would just not count correctly. After much experimentation it was discovered that when the Schmitt trigger operated the power rail changed by about 10 millivolts or so and this modulated the bulb thus generating a spurious pulse.

Having located the problem it was a simple matter to cure it — just run the bulb from a separate battery.

Parts List

Resistors all ½w 5%

R1	4 k7
R2	2 M2
R3	1 M
R4,5	270 k
R6	2 M7
R7	4 M7
R8	100 k
R9	4 M7
R10	2 M2
R11	100 k
R12	4 M7
R13	2 M2
R14,15	470 k
R16	1 M
R17	4 M7
R18	2 k2
R19	10 k
R20	330 k
R21-R23	470 k
R24	1 k2
R25	4 k7

Potentiometers

RV1 100 k log rotary
RV2 2 k Trim.
RV3 2 k Trim.

Capacitors

C1	1 µF 35V electrolytic
C2	100 n polyester
C3	1 µF 35V electrolytic
C4	220 n polyester
C5	10 n "
C6,7	2 µ 2 25V electrolytic
C8	220 n polyester
C9,10	10 µ 35V electrolytic
C13,14	4 µ7 25V electrolytic
C15	10 µ 16V electrolytic

Semiconductors

IC1,2	LM3900
D1,2	1N914
ZD1	5.1V Zener 400mW
LED1	

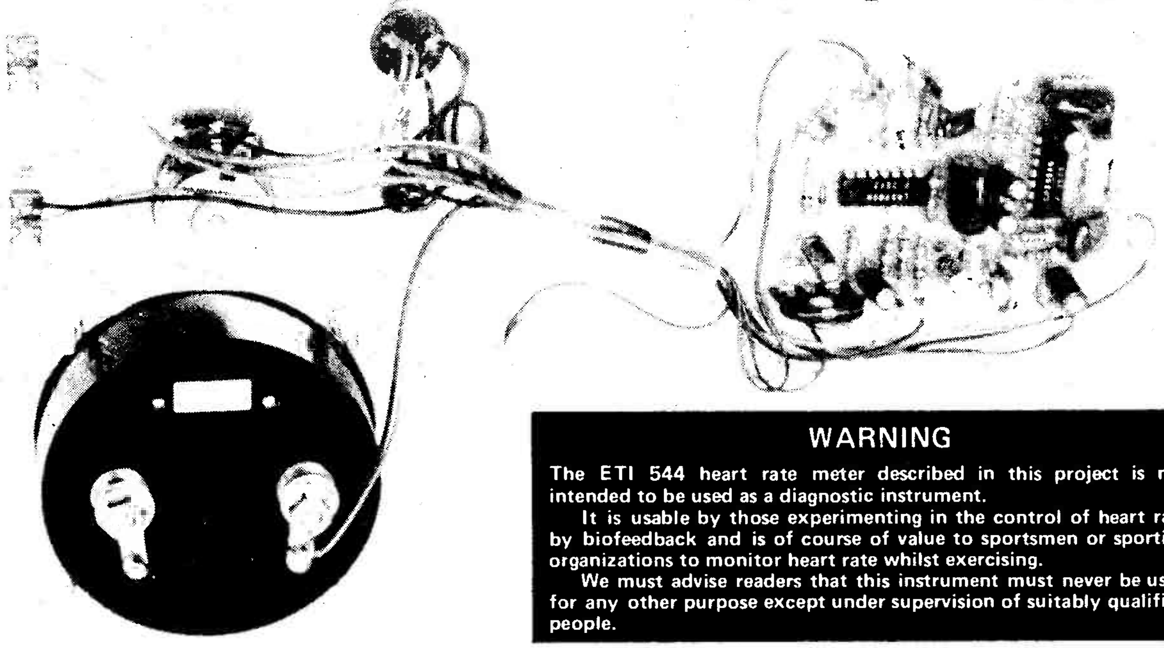
Miscellaneous

Meter 1mA FSD
PC board ETI 544
Box to suit
9V battery
2 x 9V batteries
One single pole switch
One double pole switch
LDR ORP12 or similar
12V 30mA bulb

CONSTRUCTION

There is no need to use the box that we used either — any suitable one will do. Just use the wiring diagram supplied to connect up the unit.

The sensor was made from a spring clip type of clothes peg, by mounting the bulb on one leg of the peg and the LDR on the other. Holes must be provided in the peg so that the light can pass through to the LDR. Fix the bulb and LDR into position with a little epoxy cement. The area around the rear of the LDR should be painted black or covered with tape to prevent all light other than that from the bulb reaching it.



WARNING

The ETI 544 heart rate meter described in this project is not intended to be used as a diagnostic instrument.

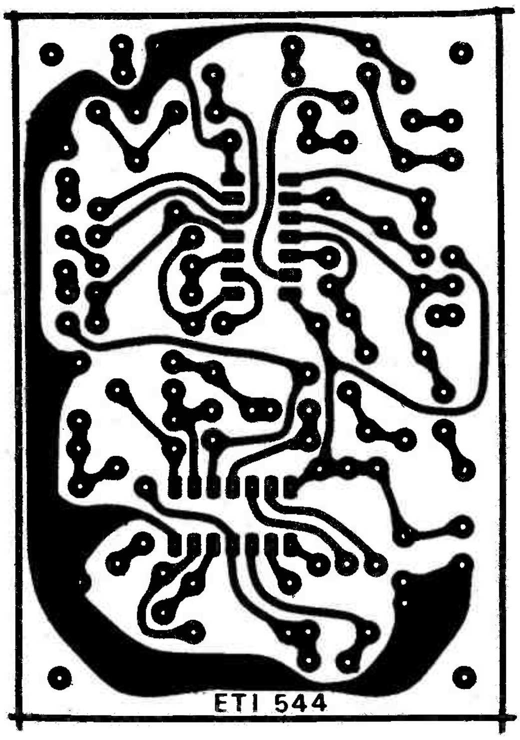
It is usable by those experimenting in the control of heart rate by biofeedback and is of course of value to sportsmen or sporting organizations to monitor heart rate whilst exercising.

We must advise readers that this instrument must never be used for any other purpose except under supervision of suitably qualified people.

USING THE MONITOR

To use the monitor simply clip the sensor to the ear lobe or to the fleshy part of the finger or thumb. Now adjust the sensitivity upward until the LED justs starts to flash regularly — indicating that heart beat is being detected reliably. The reading on the meter will start to rise and will become stable after about 25 seconds. Hereafter the reading will faithfully follow variations in heart rate.

Note that the finger or thumb should not be moved whilst taking a reading as this will cause a change in the flesh — which can be interpreted as a spurious heart beat thus giving an erroneous change in the indicated rate. ●



Full size 91 x 64mm.

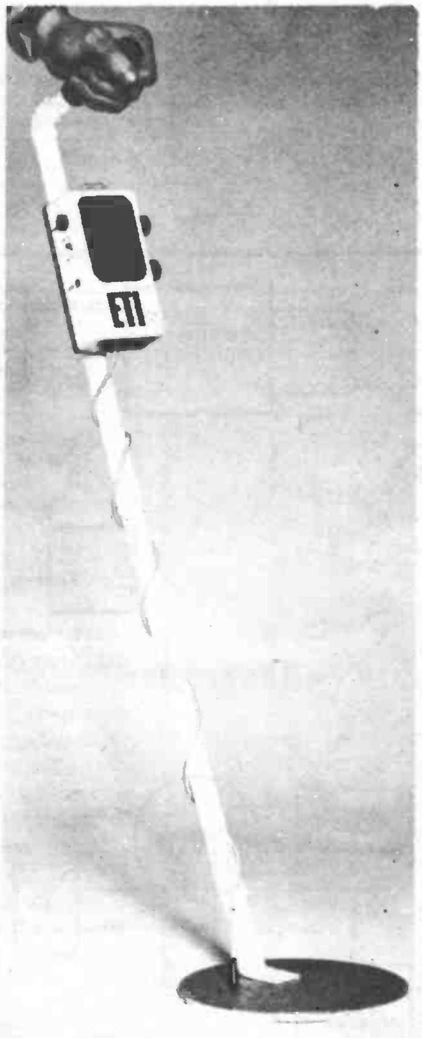
INDUCTION BALANCE METAL DETECTOR

A really sensitive design operating on a different principle from that of other published circuits. This Induction Balance circuit will really sniff out those buried coins and other items of interest at great depths depending on the size of the object.

"ANOTHER METAL LOCATOR," some of you will say. Yes and no. Several designs have been published in the hobby electronics magazines; some good, some downright lousy but they have invariably been Beat Frequency Oscillator (BFO) types. There's nothing wrong with this principle — they are at least easy to build and simple to set up. The design described here works on a very different principle, that of induction balance (IB). This is also known as the TR principle (Transmit-Receive).

All metal locators have to work within a certain frequency band to comply with regulations and a licence is necessary to operate them. This costs £1.20 for five years and is available from the Ministry of Posts and Telecommunications, Waterloo Bridge House, Waterloo Road, London S.E.1.

First a word of warning. The electronic circuitry of this project is straightforward and should present no difficulty even to the beginner. However, successful operation depends almost entirely upon the construction of the search head and its coils. This part accounts for three-quarters of the effort. Great care, neatness and patience is necessary and a sensitive 'scope, though not absolutely essential, is very useful. It has to be stated categorically that sloppy construction of the coil will (not may) invalidate the entire operation.



IB VERSUS BFO

The usual circuit for a metal locator is shown in Fig. 2a. A search coil, usually 6in or so in diameter is connected in the circuit to oscillate at between 100-150kHz. A second internal oscillator operating on the same frequency is included and a tiny part of each signal is taken to a mixer and a beat note is produced. When the search coil is brought near metal, the inductance of the coil is changed slightly, altering the frequency and thus the tone of the note. A note is produced continually and metal is identified by a frequency change in the audio note.

The IB principal uses two coils arranged in such a way that there is virtually no inductive pick-up between the two. A modulated signal is fed into one. When metal is brought near, the electromagnetic field is disturbed and the receiver coil picks up an appreciably higher signal.

However, it is impractical for there to be no pickup — the two coils are after all laid on top of each other. Also our ears are poor at identifying changes in audio level. The circuit is therefore arranged so that the signal is gated and is set up so that only the minutest part of the signal is heard when no metal is present. When the coil is near metal, only a minute change in level becomes an enormous change in volume.

BFO detectors are not as sensitive at IB types and have to be fitted with a Faraday screen (beware of those which aren't — they're practically useless) to reduce capacitive effects on the coil. They are however, slightly better than IB types when it comes to indentifying exactly where the metal is buried — they can pin-point more easily.

Our detector is extremely sensitive — in fact a bit too sensitive for some applications! For this reason we've included a high-low sensitivity switch. You may ask why low sensitivity is useful. As a crude example, take a coin lying on a wooden floor: on maximum sensitivity the detector will pick up the nails, etc., and give the same

ETI Project 549

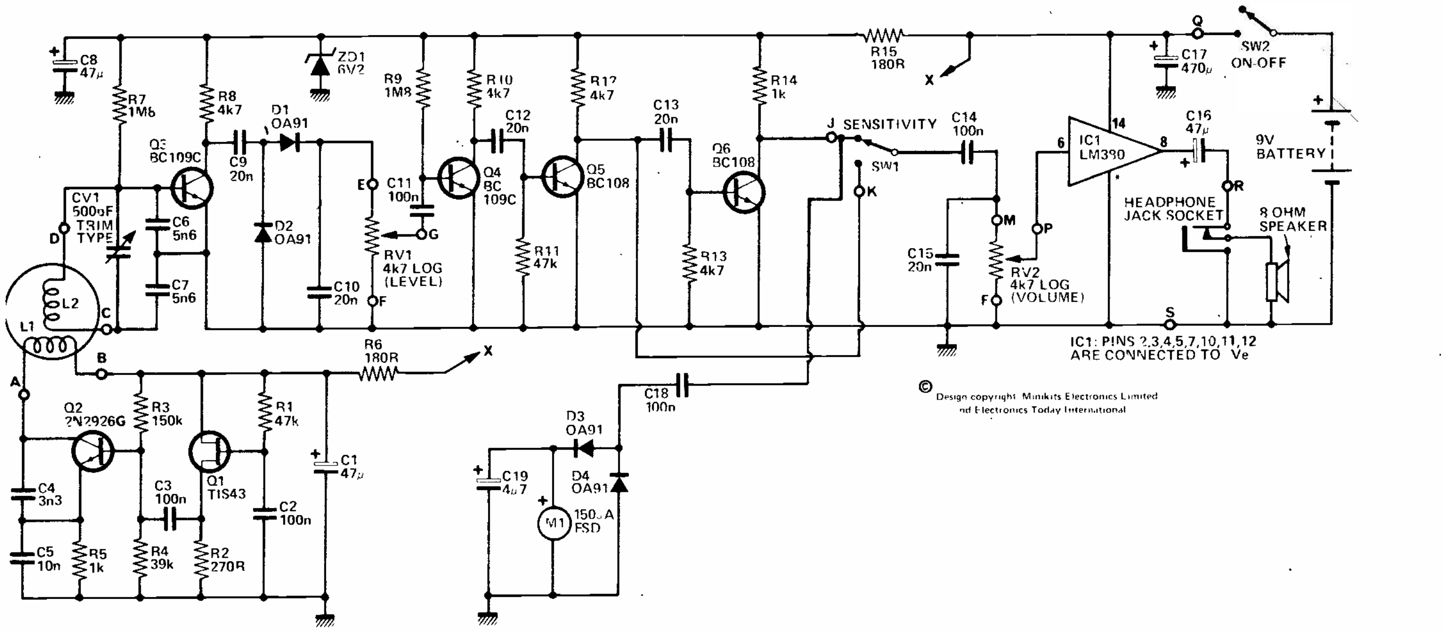


Fig.1 Complete circuit of the metal locator. Note that though the electronics is simple using very common parts, the whole operation depends on the coils Li and L2 which must be arranged so that there is minimal inductive coupling between the two. Note also that the leads from the circuit board to the search head must be individually screened and earthed at PCB.

readings as for the coin, making it difficult to find.

Treasure hunting is an art and the dual sensitivity may only be appreciated after trials.

Table 1 gives the distances at which various objects can be detected. These are static readings and only give an indication of range. If you are unimpressed with this performance you should bear two things in mind· first compare this with any other claims (ours are excellent and honest) and secondly bear in mind how difficult it is to dig a hole over 1ft of ground every time you get a reading. Try it — it's hard work!

COMPONENT CHOICE

The injunction Q1 is *not* the normal 2N2646; we found several examples of these erratic in their level — we are talking about tiniest fractions of one per cent which would normally not matter, but it *does* in this circuit. Even some examples of the TIS43 did not work well — see the note in How it Works. Secondly Q2 is deliberately a plastic type. Metal canned transistors usually have the collector connected to the case and due to the nature of the circuit we noted a very small change in signal level due to capacitive effects when metal can types were used.

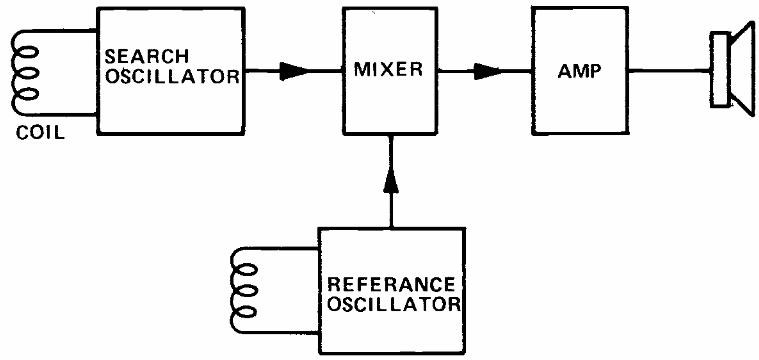


Fig.2a Block diagram of the common BFO type metal locator.

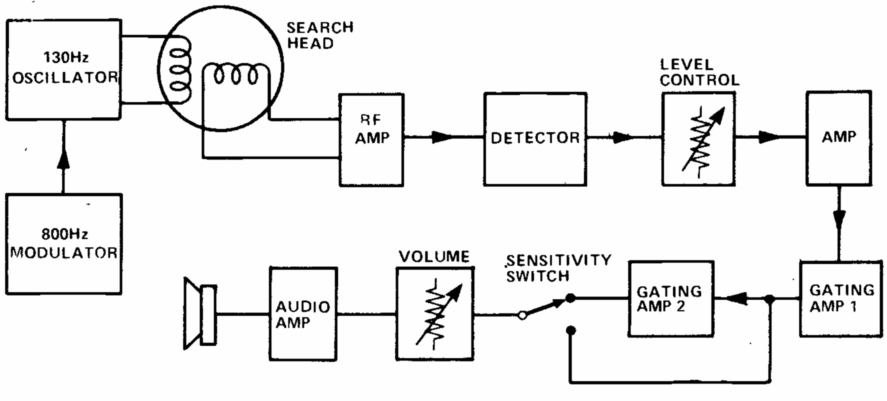


Fig2b Block diagram of our IB design.

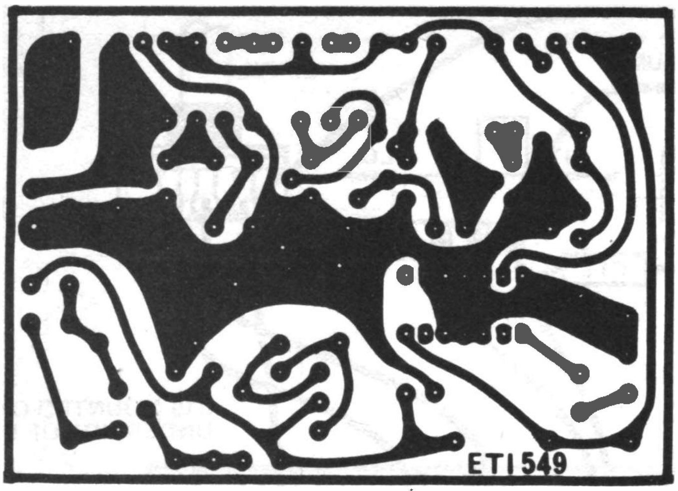


Fig.3 The PCB pattern. Most components other than the meter circuitry is built on this.

HOW IT WORKS — ETI 549

Q1, Q2 and associated components form the transmitter section of the circuit. Q1 is a unijunction which operates as a relaxation oscillator, the audio note produced being determined by R1 and C1. The specified components give a tone of roughly 800Hz. R1 can lie in the range 33k to 100k if a different audio frequency is desired.

Q2 is connected as a Colpitt's oscillator working at a nominal 130kHz; this signal is heavily modulated by C3 feeding to the base of Q2. In fact the oscillator produces bursts of r.f. at 800Hz. L1 in the search head is the transmitter coil.

L2 is arranged in the search head in such a way that the minimum possible signal from L1 is induced into it (but see notes on setting up). On all the prototypes we made we reduced this to about 20mV peak-to-peak in L2. L2 is tuned by C6 and C7 and peaked by CV1 and feeds to the base of Q3, a high gain amplifier. This signal (which is still modulated r.f.) is detected by D1, D2 providing the bias for D1. The r.f. is eliminated by C10 and connects to the level control RV1.

The signal is further amplified by Q4 which has no d.c. bias connected to the base. In no-signal conditions this will be turned off totally and will only conduct when the peaks of the 800Hz exceed about 0.6V across R11. Only the signal above this level is amplified.

On low sensitivity these peaks are connected to the volume control RV2 (any stray r.f. or very sharp peaks being smoothed by C15) and fed to the IC amplifier and so to the speaker.

The high sensitivity stage Q6 is connected at all times and introduces another gating stage serving the same purpose as the earlier stage of Q5. This emphasises the change in level in L2 even more dramatically. Note that RV1 has to be set differently for high and low sensitivity settings of SW1.

Whichever setting is chosen for SW1, RV1 is set so that a signal can just be heard. In practice it will be found that between no-signal and moderate-signal there is a setting for RV1 where a 'crackle' can be heard. Odd peaks of the 800Hz find their way through but they do not come through as a tone. This is the correct setting for RV1.

The stage Q6 also feeds the meter circuit. Due to the nature of the pulses this need only be very simple.

Since we are detecting really minute changes in level it is important that the supply voltage in the early stages of the receiver are stabilised, for this reason ZD1 is included to hold the supply steady independent of battery voltage (which will fall on high output due to the current drawn by IC1).

It is also important that the supply voltage to Q1 and Q2 does not feed any signal through to the receiver. If trouble is experienced (we didn't get any) a separate 9V battery could be used to supply this stage.

IC1 is being well underused so a heatsink is unnecessary.

Battery consumption is fairly high on signal conditions — between 60mA and 80mA on various prototypes but this will only be for very short periods and is thus acceptable. A more modest 20mA or so is normal at the 'crackling' setting.

Stereo headphones are used and are connected in series to present 16 ohms to IC1 reducing current consumption.

Selection of Q1 and Q2

We found that Q1 and to a lesser extent Q2 required careful selection. Q1 should be chosen for the minimum possible 'crackle' — so that the transition from no-signal to hearing the 800Hz is as definite as possible. Some transistors for Q1 and Q2 can produce higher odds peaks than others.

We have specified Q3 and Q4 types as BC109C (highest gain group) for although lower gain transistors worked for us, they left little reserve of level on RV1 and really low gain types may not work at all.

RV1 is the critical control and should be a high quality type — it will be found that if has to be set very carefully for proper operation.

The choice of an LM380 may seem surprising as only a small part of its power can be utilised with battery operation. It is however inexpensive and widely available unlike the alternatives (note it does not require d.c. blocking at the input).

Output is connected for an 8ohm speaker and to headphones. Stereo types are the most common and the wiring of the jack socket is such that the two sections are connected in series presenting a 16ohm load (this reduces current consumption from the battery).

CONSTRUCTION: CONTROL BOX

The majority of the components are mounted on the PCB shown in Fig. 3. Component overlay and the additional wiring is shown in Fig. 4.

Exceptional care should be taken to mount all components firmly to the board. The trimmer capacitor CVI is mounted at right-angles to the board, its tags being bent over and soldered firmly to the copper pads. This enables it to be trimmed with the box closed. A plastic trimming tool should be used if possible. Poor connections or dubious solder joints may be acceptable in some circuits — not in this one. Take care to mount the transistors, diodes and electrolytic capacitors the right way around.

The PCB is fitted into the control box by means of long screws and pillars. The control box has to be drilled to take the speaker, the pots, switches, headphone jack and the cable from the search head.

THE HANDLE ASSEMBLY

The handle is made totally from standard parts. The general construction can be seen in Fig. 5. This is made from Marley 22mm cold water plumbing available from many plumbing shops. The hand grip is that for a bicycle — also easily available and a perfect fit onto the plastic pipe. A right-angled elbow and two sleeve connectors are specified. The elbow should be glued firmly and one end of each of the connectors should be glued also.

ETI Project 549

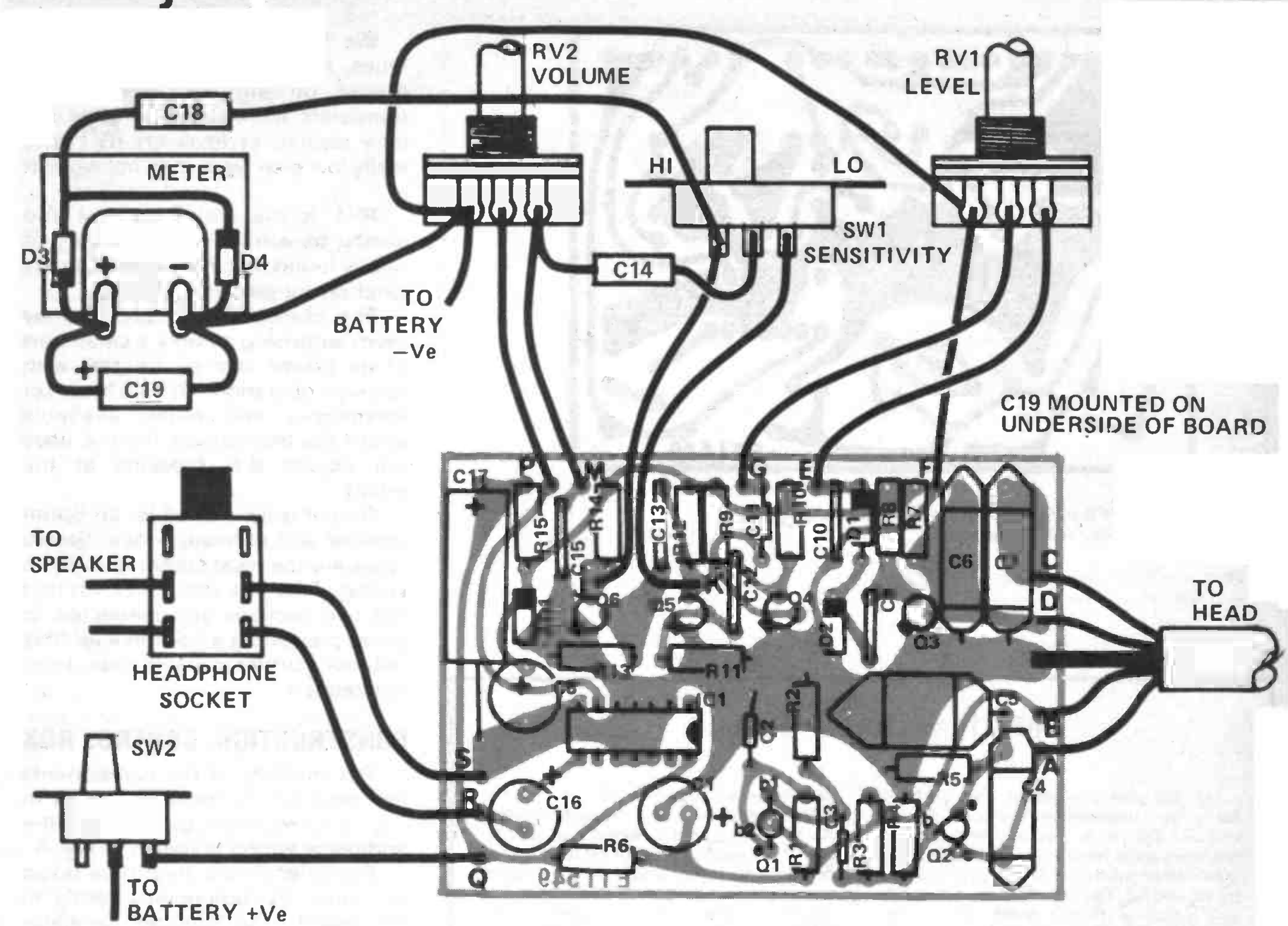


Fig. 4. The component overlay and wiring diagram to other parts of the circuit not on the PCB.

PARTS LIST — ETI 549

Resistors

R1 11	47k	¼W, 5%
R2	270R	¼W, 5%
R3	150k	¼W, 5%
R4	39k	¼W, 5%
R5, 14	1k	¼W, 5%
R6, 15	180R	¼W 5%
R7, 9	1M8	¼W, 5%
R8, 10, 12,13	4k7	¼W, 5%

Potentiometers

RV1	4k7	log rotary
RV2	4k7	log rotary

Capacitors

C1,8,16	47μF 16V electrolytic
C2,3,11,14,18	100nF ceramic etc.
C4	3n3 polystyrene 5%
C5	10n polystyrene 5%
C6,7	5 n 6 polystyrene 5%
C9,10,12,13,15	20n ceramic etc
C17	470μF 16V electroytic
C19	4μ7 16V electrolyric
CV1	500p trimmer
	(Note 1n = 1000pF

Semiconductors

Q1	TIS43 Unijunction
Q2	2N2926 — see text
Q3, 4	BC109C
Q5, Q6	BC108
IC1	LM380 14 pin DIL
D1, 2, 3, 4	OA91
ZD1	6 2 volt 400m W Zener diode

MISCELLANEOUS

SW1 SW2, 2 pole 2 way slide switches
Stereo jack socket
Miniature (2¼in etc) 8ohm loudspeaker
L1, L2 — See text and drawings
Vero box (65-2520J)
PCB Board ETI 549
4 core, individually screened cable 1 5 metres
Battery clip (PP6)
Battery, PP6
Wood and laminate for search head
2 Control knobs 2BA Nylon Nut Bolt
M1 Signal level meter 150μA movement
Marley 22mm Cold Water Plumbing (see text)
Bicycle Grip

The reason for the connector near the base is to facilitate easy removal of the head and the control box for testing and initial setting up.

The control box is held to the handle by means of two pipe clips — again available from plumber's merchants.

The connection to the search head is by means of a 4½in length of tubing which has to be modified. Put 1½in of this tube into boiling water for about half a minute to soften the plastic, take it out and quickly clamp it into a vice to flatten half the length,

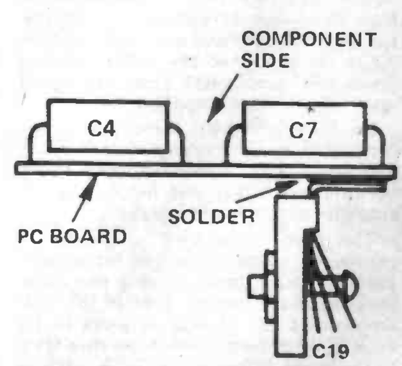
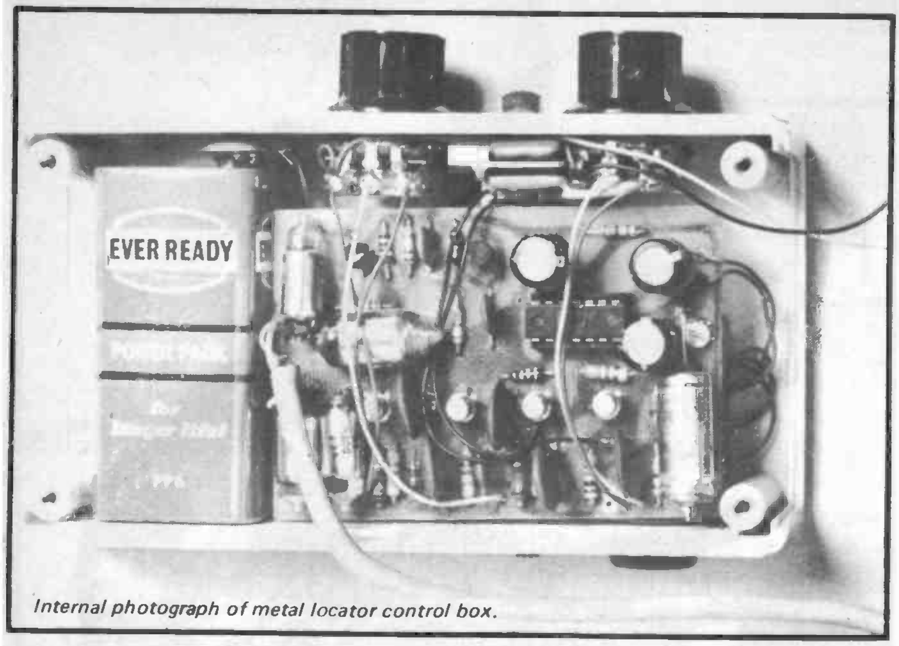


Diagram showing C19 mounted on copper side of P C Board



Internal photograph of metal locator control box.

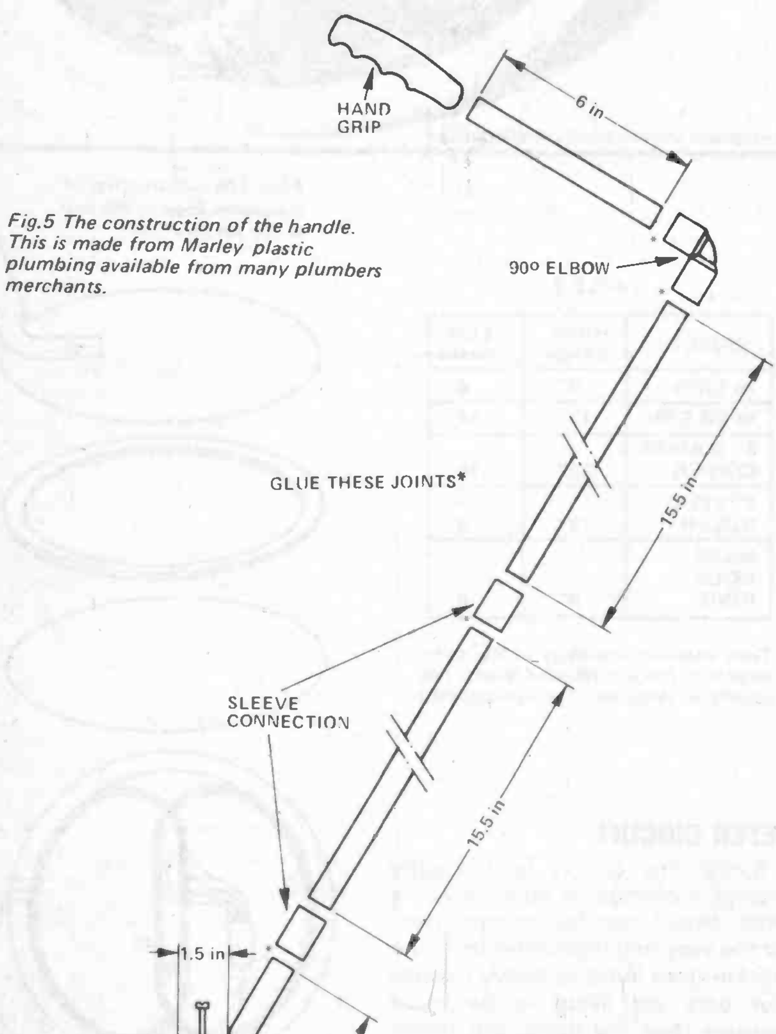


Fig.5 The construction of the handle. This is made from Marley plastic plumbing available from many plumbers merchants.

at the same time bending the flat to about 45° This will now lie across the top of the search head and is glued into position and held by a single 2BA nylon nut and bolt through the top of the search head.

THE COIL

Remember this is the key to the whole operation. The casing of the coil is not so critical but the layout is.

It is best first to make the 6mm plywood circle to the dimensions shown in Fig. 5. A circle of thinner plywood or hardboard is then firmly clued onto this — it's fairly easy to cut this after glueing. Use good quality ply and a modern wood glue to make this.

This now forms a dish into which the coils are fitted. The plastic connector to the handle should be fitted at this stage.

You'll now have to find something cylindrical with a diameter of near enough 140mm (5½in). A coil will then have to be made of 40 turns of 32 s.w.g. enamelled copper wire. The wire should be wound close together and kept well bunched and taped to keep it together when removed from the former. Two such coils are required: both are identical.

One of the coils is then fitted into the 'dish' and spot clued in six or eight places using quick setting epoxy resin: see photogaraph of the approximate shape.

L2 is then fitted into place, again spot gluing it *not* in the area that it overlaps L1. The cable connecting the coil to the circuit is then fed through a hole drilled in the dish and connected to the four ends. These should be directly wired and glued in place, obviously taking care that they don't short. The cable must be a four-wire type with individual screens — the screens are left unconnected at the search head.

You will now need the built up control box and preferrably a 'scope. The transmit circuit is connected to L1. The signal induced into L2 is monitored; at first this may be very high but by manipulating L2, bending it in shape, etc., the level will be seen to fall to a very low level. When a very low level is reached, spot glue L2 until only a small part is left for bending.

Ensure that when you are doing this that you are as far away from any metal as possible but that any metal used to mount the handle to the head is in place. Small amounts of metal are acceptable as long as they are taken into account whilst setting up.

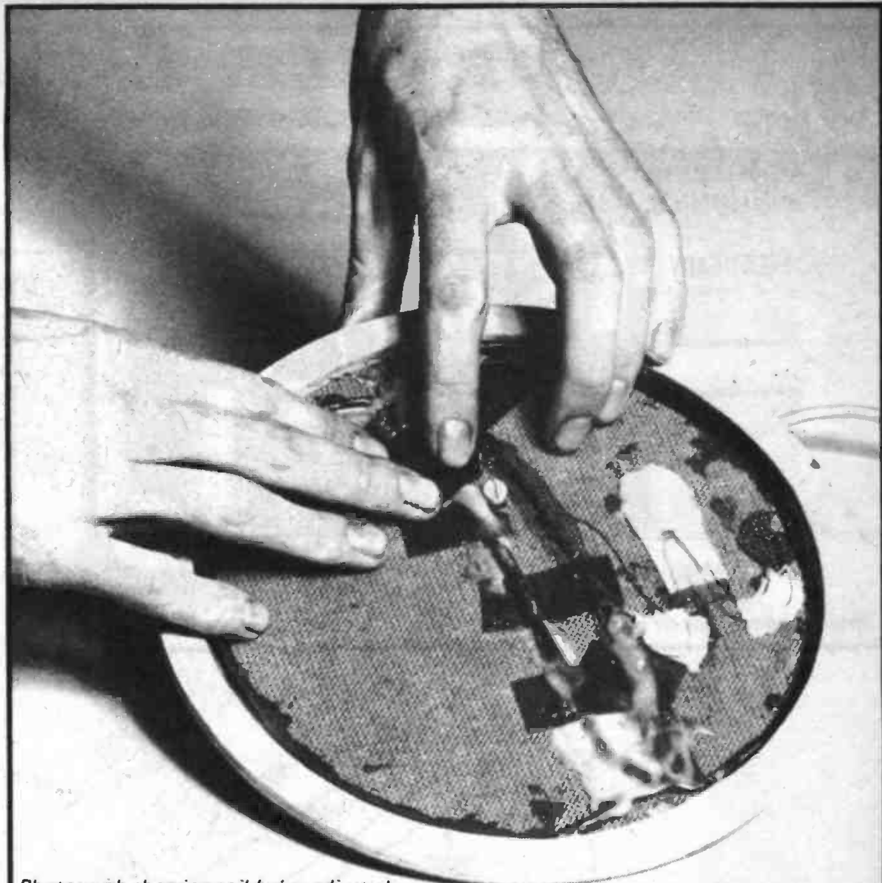
Now connect up the remainder of the circuit and set RV1 so that it is *just* passing through a signal to the speaker. Bring a piece of metal near the coil and the signal should rise. If it falls in level (i.e. the crackling disappears) the coil has to be adjusted until metal brings about a rise with no initial falling. CVI should be adjusted for maximum signal, this has to be done in conjunction with RV1.

Monitoring this on a scope may mean that the induced signal is not at its absolute minimum: this doesn't matter too much. Now add more spot gluing points to L2.

You should now try the metal locator in operation. If RV1 is being operated entirely at the lower end of its track, making setting difficult, you can select a lower gain transistor such as a BC108 for Q4.

When you are quite certain that no more manipulation of the coils will improve the performance, mix up plenty of epoxy resin and smother both coils, making certain that you don't move them relative to each other.

The base plate can then be fitted to enclose the coil, this should be glued in place.



Photograph showing coil being adjusted.

USING THE METAL LOCATOR

You will find that finding buried metal is rather *too* easy. 95% will be junk — silver paper being a curse. The search head should be panned slowly over the surface taking care to overlap each sweep: the sensitive area is somewhat less than the diameter of the coil.

This type of locator will also pick up some materials which are not metal — especially coke and it is also not at its best in wet grass.

Think very carefully about where you want to search: this is more important than actually looking. The area you can cover thoroughly is very, very small, but is far more successful than nipping all over the place. As an example of how much better a thorough search is, we thoroughly tried on 25 square feet of common ground (5ft x 5ft); we found over 120 items but a quick search initially had revealed only two!

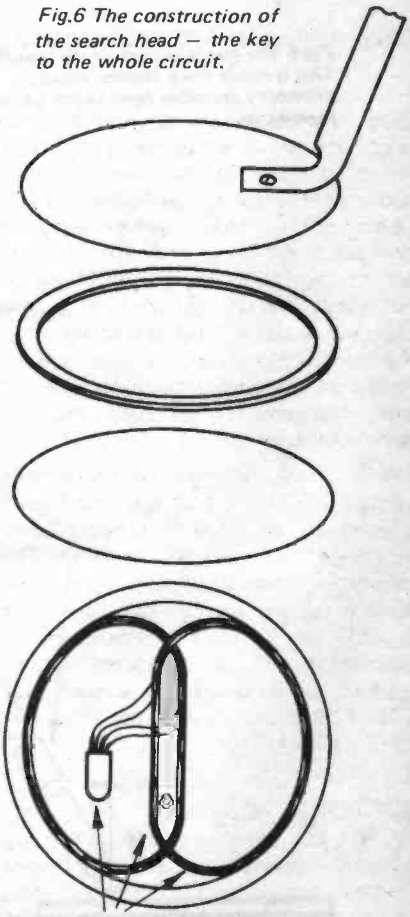
Treasure hunting is growing in popularity and those who do it seriously have adopted a code; essentially this asks you to respect other people's property, to fill in the holes you dig and to report any interesting finds to museums. And do get a licence — it must be the best bargain available at 25p a year (rather £1.20 for five years).

TABLE 1

OBJECT	HIGH SENS	LOW SENS
2p COIN	8"	6"
BEER CAN	17"	14"
6" SQUARE COPPER	22"	16"
6" STEEL RULER	12"	9"
MANS GOLD RING	8"	6"

Table showing sensitivity of the metal locator in free air. (Buried objects can usually be detected at greater depths.)

Fig.6 The construction of the search head — the key to the whole circuit.



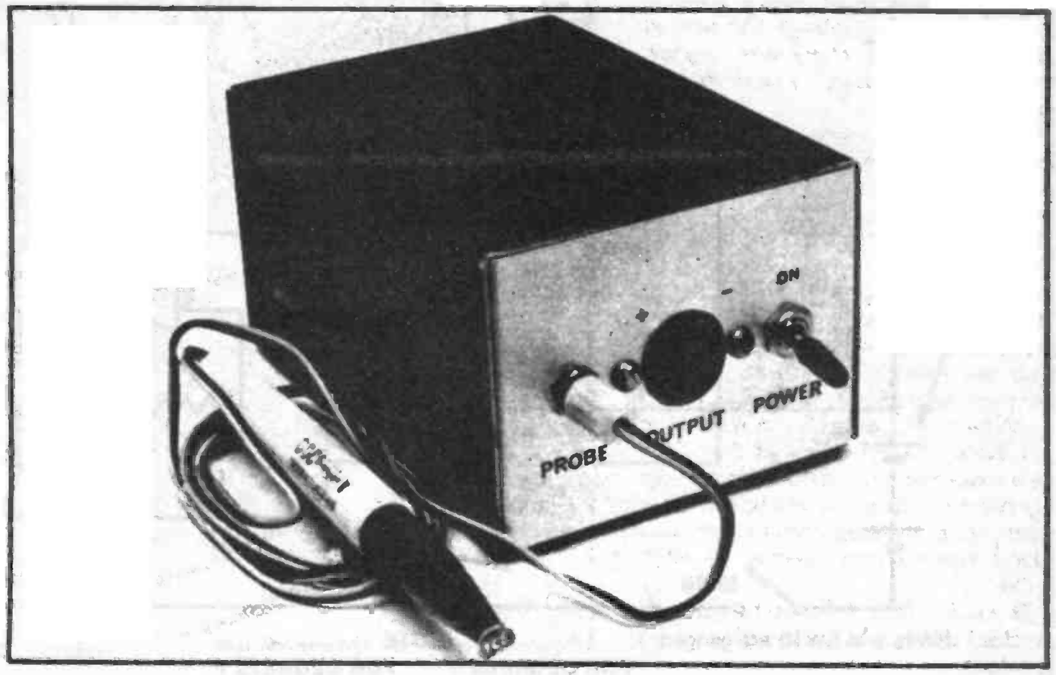
METER CIRCUIT

Since the circuit is basically sensing a change in audio level, a meter circuit can be incorporated. For the very first indication from the 'crackle' (see later) to heavy crackle your ears are likely to be more sensitive than the meter but thereafter it will come into its own.

This part of the circuit is optional and the components are not included on the board. ●

TEMPERATURE METER

eti project 130



Converter connects to any analogue or digital meter.

OUR original design concept for this unit was as a complete instrument based on our ETI 533 digital display (October 1975 and Top Projects No.3) sensor — this generating a temperature-proportional voltage which in turn is supplied to a voltage-to-frequency converter. We planned to use a timebase to generate the necessary strobe and reset pulses. However the cost and complexity of this arrangement was such that we decided against it.

What finally emerged was a simple temperature-to-voltage converter which can be used in front of *any* analogue or digital meter. The converter provides an output of 10 mV/degree which can be either Celcius or Farenheit depending on calibration. If a dedicated digital readout is required we suggest our ETI 118 digital voltmeter (October 1975 and Top Projects No. 3).

CONSTRUCTION

Whilst a printed-circuit board is by no means essential, using one certainly makes construction easier and improves the appearance. The potentiometers as shown in our prototype are single turn presets which are quite adequate if an analogue meter is to be used for the readout. However if a digital meter is to be used the extra accuracy of the readout would warrant ten-turn presets being used for RV1 and RV2, as setting accuracy is considerably improved.

The converter quite readily fits into a small aluminium case. Two nine volt batteries are used to power the unit and battery drain is low enough to ensure a life of many months.

A 3.5 mm jack is used to connect the sensor to the unit and the output to the meter is provided via an inexpensive two-pin speaker socket.

The probe is constructed by mounting the sensor-diode into the tip of a ball-point pen casing, or similar. The method may best be understood by reference to the drawing.

CALIBRATION

To calibrate the instrument, two accurately known temperatures are required. One may be water or oil at room temperature (ice water should not be used as there the temperature may vary several degrees between different points in the solution). The high temperature is best obtained by heating oil or water and allowing it to stabilise at around 80°C. A second smaller heat conductive container filled with water is then immersed in the larger container. This simple procedure prevents errors due to circulating currents in the larger volume of water. An accurate mercury-in-glass thermometer should be used to measure temperatures during the calibration procedure as detailed below.

SPECIFICATION

RANGE	0 to 100°C 32 to 212°F
OUTPUT	10 mV/degree
ACCURACY	± 1°
RESPONSE TIME	3 seconds

TEMPERATURE METER

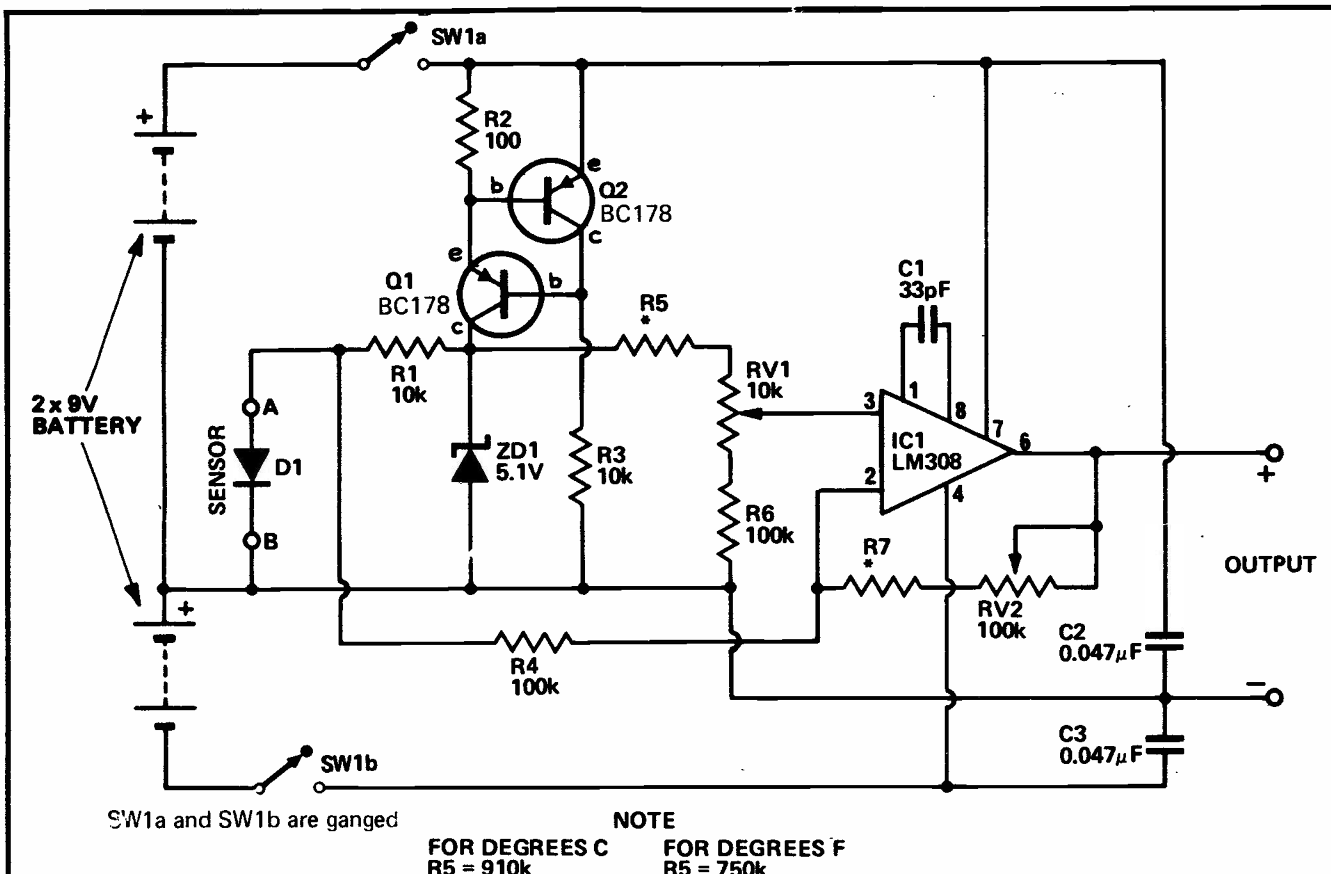


Fig. 1. Circuit diagram of the temperature meter.

1. Place the sensor and thermometer into the cool solution, allow a little time for stabilisation, and then measure the voltage from the converter and the temperature. Record these two readings.
2. Place the sensor and thermometer into the hot solution and measure the voltage and temperature as before. The voltage change between the first and second readings should be equal to the temperature change times 10 millivolts.
3. If the voltage versus temperature is not as specified in step 2 adjust RV2 and repeat steps 1 and 2 until it is. Note that varying RV2 changes the voltage at both the hot and the cold positions. It is the correct slope, or rate of change that we are after at the moment.
4. When the correct rate of change has been set as above place the sensor and thermometer into the cool solution and adjust RV1 to obtain a reading of 10 mV per degree. That is if the solution is at 25°C adjust RV1 to obtain a reading of 0.25 V.

Due to the spread of diode characteristics from one device to another the necessarily small adjustment range of RV1 and RV2 may not allow all diodes to be calibrated with the resistor values specified. If this is found to be the case it may be necessary to change the value of R5, R6 or R7.

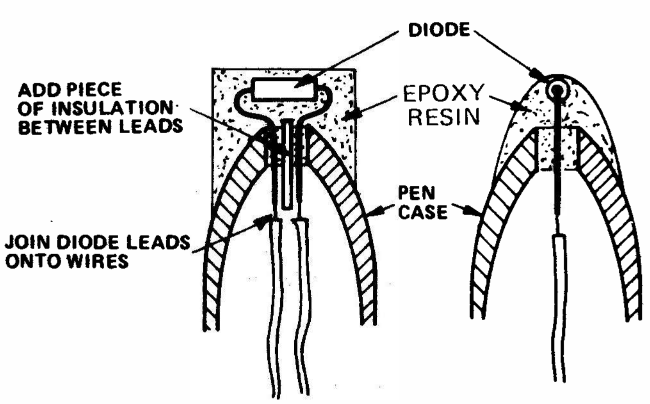


Fig. 2. This diagram shows how the sensor is mounted into a ball-point pen casing or similar.

PARTS LIST

R1,3	Resistor	10k	½W 5%
R2	"	100	½W 5%
R4,6	"	100k	½W 5%
R5,7	"	See Fig. 1 and test.	
RV1	Potentiometer	10k * trim type	
RV2	"	100k * " "	

*for digital readout a multiturn trim potentiometer is recommended.

C1	Capacitor	33pF ceramic	
C2,3	"	0.047μF polyester	
D1	Diode	1N914	
ZD2	Zener Diode	5.1V, 400mW	
Q1,2	Transistor	BC558, BC178	
IC1	Integrated Circuit	LM308	

Metal box
Two 9V batteries (PP3 etc.)
Two pole toggle switch
PC board ETI 130
3.5mm plug and socket
Two pin plug and socket for output

HOW IT WORKS – ETI 130.

A forward biased diode has a temperature coefficient of about −2 mV/°C. That is the normal voltage across a silicon diode of nominally 0.6 volts will decrease by two millivolts for every degree C increase in temperature. This change with temperature is sufficiently linear over the range of 0 to 100°C to use it as a temperature sensor.

What the ETI 130 circuit does is to amplify this voltage and to provide offset compensation for the normal 0.6 volt drop across the diode.

Transistors Q1 and Q2 provide a constant-current source of about 5 mA into the zener diode ZD1 such that a very stable five volt reference is obtained which is independent of the battery supply voltage. (V supply greater than 6 V.) The forward bias current through the sensor diode is about 0.5 mA as provided by R1. This current is low enough to prevent errors due to self heating of the sensor diode.

The voltage across the sensor diode is amplified by IC1 (a very high input-impedance operational amplifier) whose gain is fixed at the ratio of (R7 + RV2)/R4. The necessary offset is provided by RV1 which is adjusted to cancel the normal 0.6 volt drop across the diode. By selecting the correct values for R5 and R7 as shown on the circuit diagram the indication of temperature in degrees C or F may be obtained.

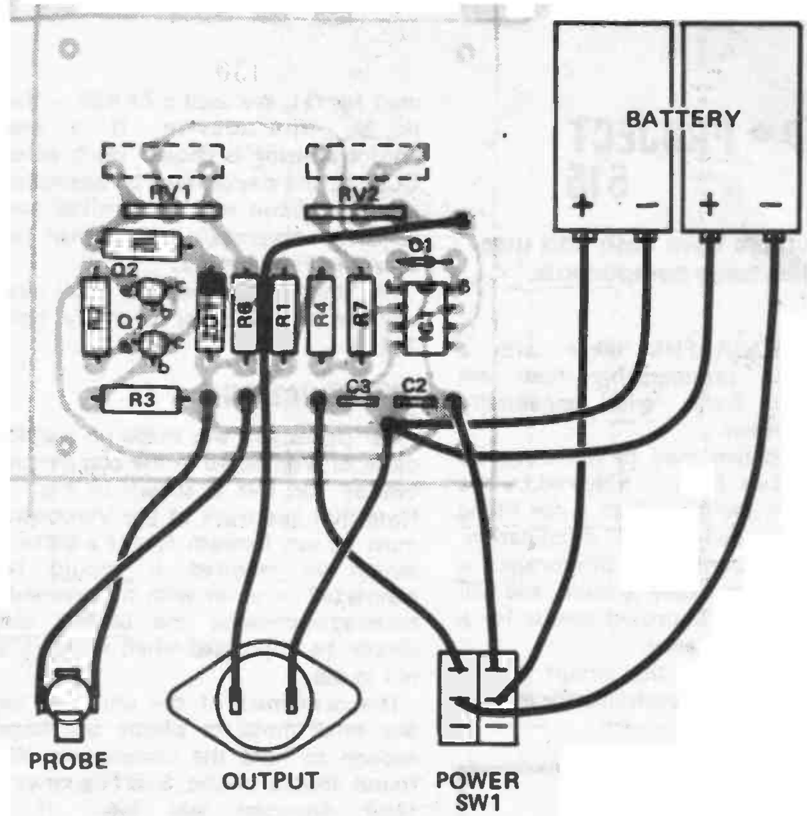


Fig. 3. Component overlay and interconnection diagram.

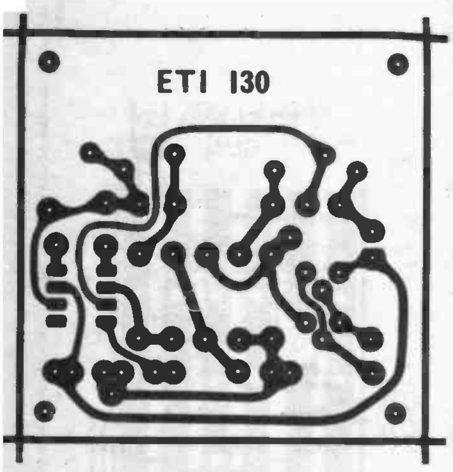
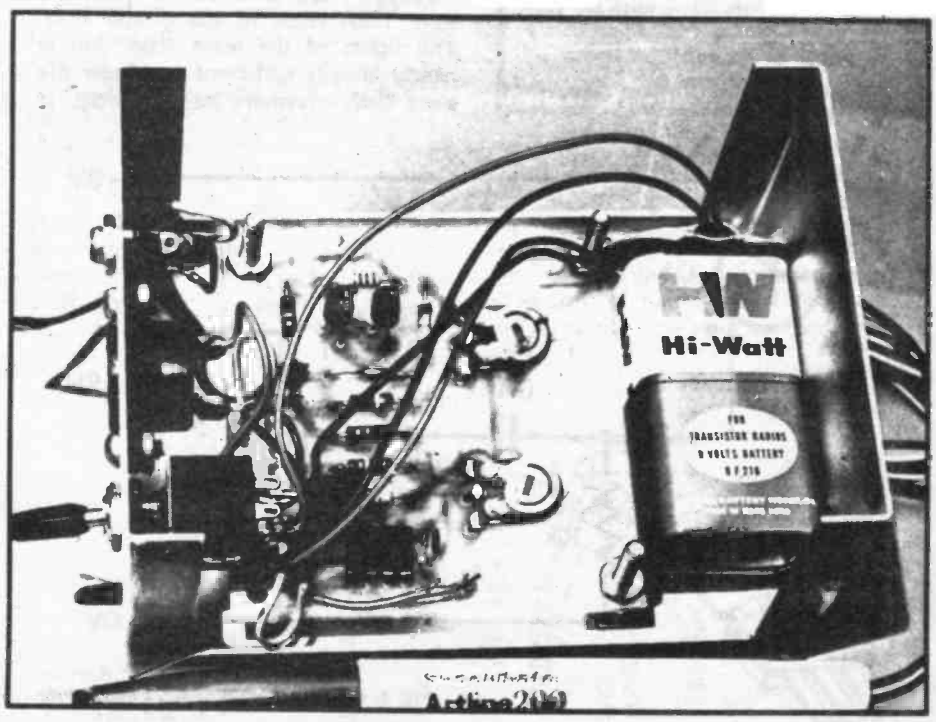


Fig. 4. Printed circuit pattern. Full size 63 x 63 mm.



Internal view of the completed temperature converter. Note also the probe at front.

Slave-flash unit

ETI PROJECT 515

This simple slave flash unit uses only five basic components.

PHOTOGRAPHS taken with a single photographic flash are often harsh, with unnaturally sharp shadows.

This problem may be overcome by using a slave flash – triggered by the light from the main flash – for filling in and/or background illumination. The unit described in this project is very simple and easy to build, and will provide vastly improved results for a very moderate outlay.

Figure 1 shows the circuit of the slave unit. Any phototransistor may be used for Q1. We used a BPX25 – this is an npn device. If a pnp phototransistor is chosen (such as an OCP71), the device must be assembled into the circuit with the emitter and collector reversed, rather than as shown in Figs. 1 and 2.

The unit is powered by a small nine volt battery (such as Eveready type 216).

HOW IT WORKS

Normally the phototransistor Q1 has high resistance – the actual value depending upon the level of ambient light. When the sudden light from the main flash illuminates Q1, its resistance suddenly falls and the resultant positive going pulse is impressed – via C1 – onto the gate of the SCR. The SCR immediately triggers thus setting off the flash.

CONSTRUCTION

Our prototype was made on a small piece of Veroboard – the component overlay for this is shown in Fig. 2. Note that one track of the Veroboard must be cut beneath C1. If a battery switch is required it should be connected in series with the nine-volt battery; otherwise the battery can simply be unplugged when the unit is not in use.

The containers of the unit may be any small metal or plastic box large enough to hold the components. We found that a plastic SCOTCH sticky tape dispenser was ideal. If a transparent box is used, the phototransistor may be mounted directly onto the Veroboard, if not it must be mounted externally.

OPERATION

Usually there is no need to locate the slave flash close to the master unit. The lights of the main flash unit is nearly always sufficient to trigger the slave flash anywhere inside a room. If the unit is used externally it may be necessary to orientate the slave flash so that the phototransistor is looking into the light from the main unit.

Before an exposure is made, the master flash unit should be set off once or twice to ensure that enough light is reaching the slave flash to ensure reliable triggering.

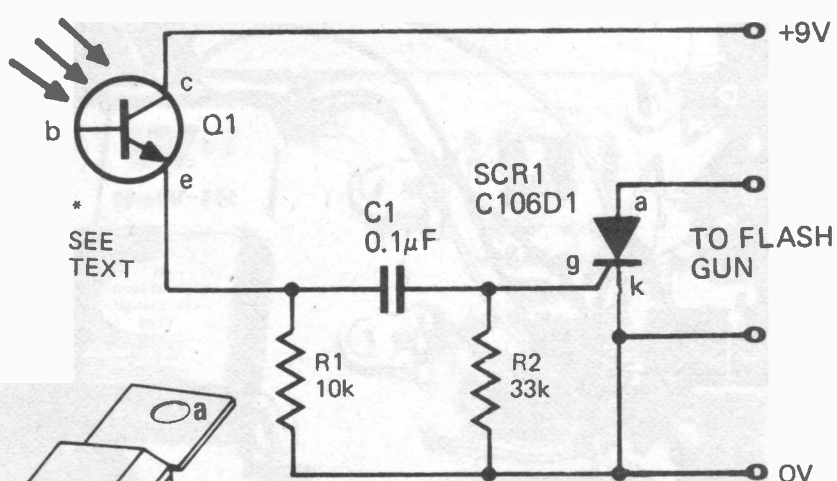
Make sure that all flash units are fully charged before taking photographs.

Calculate the F stop required for the main flash and stop down the camera accordingly. The slave flash must now be positioned such that an adequate exposure will be given to the background with the previously determined camera stop.

If the slave is used as fill, some adjustment to the exposure may be necessary and this is best found by trial and error. ●

PARTS LIST ETI 515

R1	–	resistor 10k ½ watt 5%
R2	–	resistor 33k ½ watt 5%
C1	–	capacitor 0.1μF 100 volt polyester
SCR1	–	thyrister type C106D1
Q1	–	phototransistor – any type typical BPX25 NPN, OCP71 PNP, MEL12 NPN



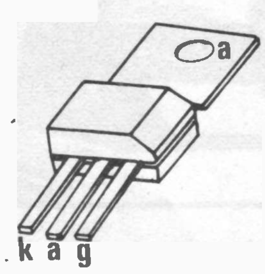


Fig. 1. Circuit diagram of slave flash unit.

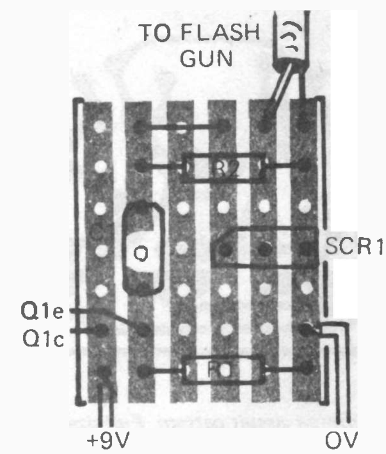


Fig. 2. How the components are located on the Veroboard; note that a break is made in one track of the Veroboard underneath C1.