TOP PROJECTS

Volume 3

from Electronics Today

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TOP PROJECTS

Volume 3   from Electronics Today

PROJECTS

A MODERN MAGAZINES PUBLICATION

World Radio History

FM TUNER

All electronic design eliminates mechanical dial.

THE ETI 740 FM tuner has been designed to provide the highest possible performance consistent with a cost that we feel will be generally acceptable to most of our readers.

A very great deal of effort has been put into simplifying construction both mechanically and electronically, and similar effort has been expended on ensuring good appearance.

Virtually the entire unit consists of two printed circuit boards — one of which is directly soldered into the other.

Apart from the assembly of the two printed-circuit boards the only wiring necessary is the power cord, the antenna sockets, the three wires to the tuning potentiometer and the two to the tuning meter.

An all electronic dial assembly completely eliminates the hassles of pulleys and cords as in mechanical dials. Additionally the use of a commercial prealigned tuner module eliminates the need for alignment. These two measures greatly simplify construction.

The main printed-circuit board has been designed so that it may be assembled either as a single board or cut up and assembled as separate modules. If one wishes to construct the 10.7 MHz IF as a separate unit this is entirely possible without designing a new board layout. In fact we understand that boards for separate modules may be made available by Applied Technology Pty. Ltd.

Only three adjustments are necessary to align the complete tuner and these are relatively simple. Thus the tuner is quite readily constructable by anyone who can correctly handle a soldering iron — no special knowledge is required.
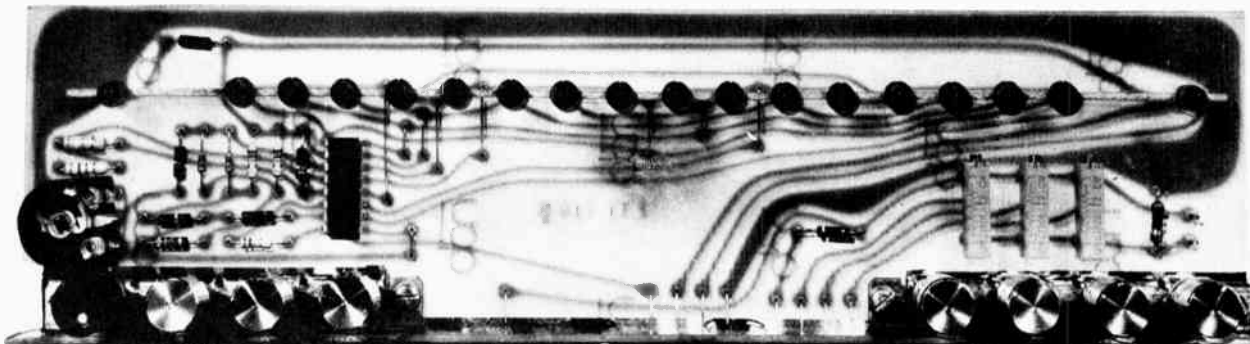
THE TUNER MODULE

Many different tuner modules were evaluated, even some we specially imported from overseas. We finally selected the newly released AP 2157 from Philips. This tuner is the preferred replacement for the Mullard LP1186 and combines good performance, reasonable price and ready availability. However any other varicap tuner module may be used if desired

The AP2157 is a varicap tuner and requires a stable three to 27 volt control voltage to tune across the range 87.5 to 108 MHz. The tuner uses bipolar transistors, three single varicaps and two 10.7 MHz tuned circuits to provide 20 dB of gain and reasonable rejection ratios.

THE DIAL

As with any kind of radio tuner the provision of a calibrated tuning dial presents problems from a cost and constructional point of view. A specially designed mechanical dial would be very expensive and would complicate the chassis metalwork — leading to further cost increases. The alternative approach of using an analogue meter to indicate frequency was also rejected because reasonably attractive meters with large scales are quite expensive also. Ultimately it was decided to use a digital dial based on the Siemens UAA 170 IC. The UAA 170 is an analogue to one-of-16 decoder and LED driver. Using this chip we can arrange LEDs in a row such that the LED illuminated indicates the frequency tuned. This is quite convenient as the control voltage
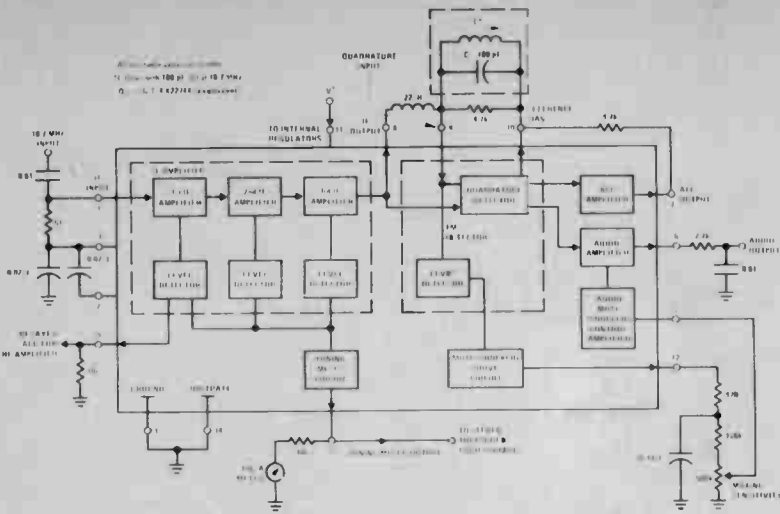

The electronic-dial mechanism.

Fig. 1. Block diagram of the LM3089 FM receiver IF system.

for the tuner module may also be used to drive the LED 'dial'. The tuned frequency is related to the control voltage in an exponential manner, so to have a linear dial it is necessary to use a network to tailor the control voltage before it is fed to the UAA 170.

The ETI technique provides a dial having a good appearance, adequate length of 130 mm and no moving parts. The power-on and stereo indicators are green LEDs and are arranged to be in line with the dial LEDs which are red.

In addition to the manual-tuning control, which is selected by a push button, three other push buttons each select any one of three stations, each of which can be selected at any point over the entire tuning range by an individual preset potentiometer. The LED dial arrangement automatically indicates the frequency of each preselected station (something that is quite difficult to do with a mechanical dial).

The 16 LED display provides 1.25 MHz resolution. In practice this is adequate and it was not considered necessary or economically justifiable to increase resolution by adding a further IC and set of LEDs.

IF AND DEMODULATOR

The output of the tuner is filtered by two ceramic filters (separated by a buffer stage) before being fed to a CA 3089 IC which is a complete FM IF and demodulator system containing over 80 transistors. The IC requires only one external tuned circuit (the quadrature detector coil) and provides AGC, AFC, muting, signal strength and tuning meter drive voltages.

In our circuit the muting level is set by an internal preset potentiometer and muting may be switched out by a front panel push button if desired. Another front panel push button selects AFC or manual tuning control, and a tuning meter is provided rather

than the more conventional signal strength meter. With FM very accurate tuning is required if minimum distortion is to be obtained and a tuning meter provides a much more accurate method than does a signal strength meter.

The CA 3089 is followed by an RC network to roll off the loop above 100 kHz, and an amplifier with a gain of three to provide an output level adequate for most power amplifiers.

DECODER

The stereo decoder used is the LM 1310 phase-locked loop IC, which does not require any external coils whatsoever. The use of this IC virtually eliminates the setting up of coils which is often a major stumbling block for beginners. The only adjustment which needs to be made on the decoder is to the frequency of

operation of the phase-locked loop. This adjustment is performed very simply by using a preset potentiometer together with the stereo indicator lamp as a monitor.
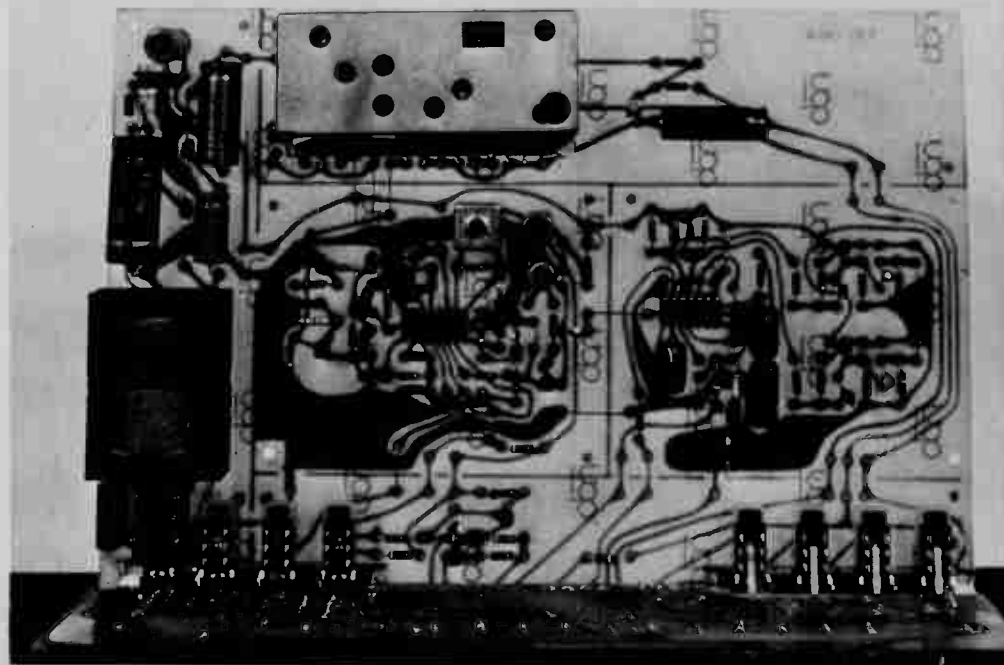
PILOT TONE FILTER

The stereo outputs from the decoder have de-emphasis applied and then are fed to unity-gain, active- low-pass filters to suppress the 19 kHz pilot tone, the 38 kHz sub-carrier and harmonics which would otherwise cause interference, when tape recording, with the bias oscillator of the recorder.

An LED driven by the decoder indicates when the loop is locked indicating also when a stereo signal is being received. A front panel push button provides a stereo-defeat facility by detuning the loop oscillator beyond the capture range of the loop thus forcing the decoder to provide a mono output.

POWER SUPPLY

The power supply provides via an IC regulator, + 15 volts for the general circuitry of the tuner. A voltage doubler provides a supply to a special voltage stabiliser, a TAA 550, which in turn provides a temperature stable supply of +32 volts as the reference source for the tuning potentiometer.

The second part of this article which starts on page 7 gives the full constructional details for this project. ●

Internal view of the main printed circuit board which houses most of the electronics.

FM TUNER

Full constructional details.

eti PROJECT 740

THE ETI 740 tuner has been designed with the aim of making it as simple as possible for the inexperienced hobbyist to build. The only components not mounted on the printed circuit boards are the fuse, input and output sockets, tuning meter and the tuning potentiometer. Interconnecting wires have been reduced to an absolute minimum. Whilst only two boards have been used, the main printed-circuit board has been laid out in such a way that it may, if so desired, be cut up if it is required to build the modules separately.

CONSTRUCTION

Components may be assembled on to the main circuit board in any sequence, but we recommend that the lowest height components, eg resistors and diodes, be fitted first followed by the larger components. Ensure that the diodes are inserted with the polarity as marked on the overlay and that integrated circuits are orientated correctly. The cbe connections shown on the overlay for the BC548 and BC558 transistors are correct for Philips devices. If other makes are used the connections may be different and should be carefully checked.

The tuner is installed by first securing it into position with a piece of double-sided tape. The terminals are then connected to the board by means of tinned-copper wire links. Pin 2 of the tuner module should only be connected to the main printed-circuit board if the main amplifier used in association with the tuner is not earthed. The transformer and the function switches are mounted directly onto the printed-circuit board.

Commence the assembling of the display board by installing the nine links shown on the overlay. To install the LEDs it is first necessary to cut a piece of fibre-glass board 230 mm long by 4 mm wide. By examining the photographs it is possible to see how this strip of fibreglass is used to align the LEDs and to correctly space them from the printed-circuit board. It will be noticed that some links pass beneath this strip and it is therefore advisable to file small notches for the links so that the strip sits down flat on the printed-circuit board. Do not force the LEDs over the strip, if they are tight, file the strip until they slip on easily. Note that all the LEDs are mounted so that the cathode lead, which is marked by either a body notch, a flat or a longer lead, is to the top of the display board.

The rest of the components may now be mounted taking particular care to locate the trim potentiometer flush with the board. If desired, although not essential, a hole may be drilled through the display board so that the trim potentiometer may be adjusted from the rear after the unit is mounted in the chassis. If the hole is not so drilled the potentiometer must be adjusted before the unit is mounted into the case.

The two boards are joined together by tinned-copper links. This should be carried out by first soldering 20 mm long tinned-copper leads to the display board (nine leads required). Bend these leads so that they lie flush with the board and then thread them through the mating holes in the main printed-circuit board. The display board should be positioned behind the mounting surface of the function switches and secured to the switches

by self-tapping screws or nuts and bolts.

The power switch and the mains transformer are both mounted directly onto the printed-circuit board and for safety's sake we feel that it is necessary to insulate these areas of the board with a layer of epoxy cement as shown in the photograph. It is also necessary to insulate the terminals on the top of the power switch (both used and unused).

We advise that the completed module now be carefully checked for any errors in component installation. Also check that all joints have been correctly soldered. The unit may now be temporarily connected up to the tuning meter, potentiometer and power cord and then connected to an amplifier for testing before final assembly (see section below).

After testing is satisfactorily completed the module may be installed in the case and all the controls and power lead etc properly connected. The front panel is secured to the front of the chassis with a little contact cement and is also secured by the potentiometer nuts. The polarized plastic window in the front panel is
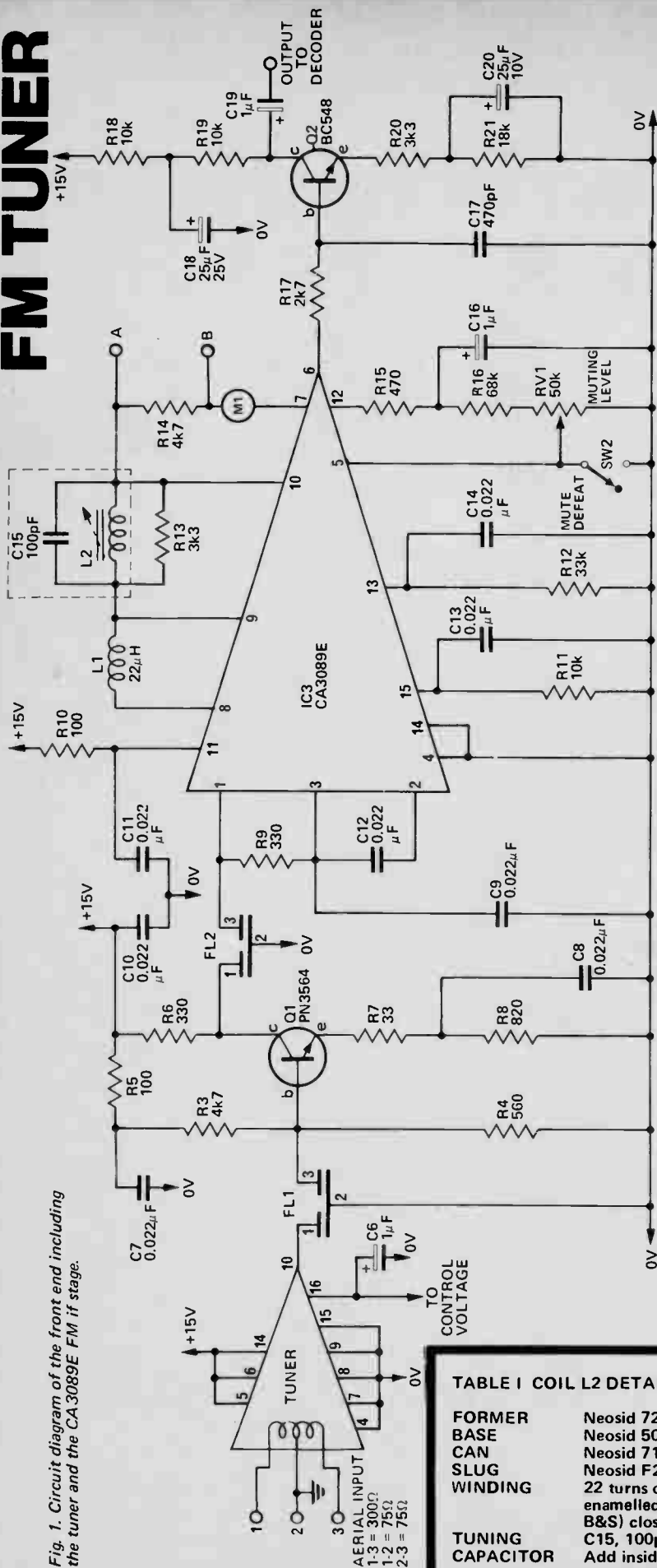
FM TUNER

Fig. 1. Circuit diagram of the front end including the tuner and the CA3089E FM if stage.

OUTPUT TO DECODER

R18 10k
R19 10k
C19 1µF
Q2 BC548
R20 3k3
C20 25µF 10V
R21 18k
0V
+15V
C18 25µF 25V
0V
C17 470pF
R17 2k7
A
B
M1
R14 4k7
C16 1µF
R15 470
R16 68k
RV1 50k
MUTING LEVEL
SW2
C15 100pF
L2
R13 3k3
C14 0.022µF
MUTE DEFEAT
R12 33k
L1 22µH
IC3 CA3089E
C13 0.022µF
R11 10k
+15V
R10 100
C11 0.022µF
R9 330
C12 0.022µF
C9 0.022µF
C10 0.022µF
FL2
Q1 PN3564
0V
R6 330
R7 33
R8 820
C8 0.022µF
R5 100
R3 4k7
R4 560
C7 0.022µF
+15V
FL1
C6 1µF
TO CONTROL VOLTAGE
TUNER
+15V
0V
AERIAL INPUT
1-3 = 300Ω
1-2 = 75Ω
2-3 = 75Ω

TABLE I COIL L2 DETAILS

FORMER	Neosid 722-1
BASE	Neosid 5027/6PLB
CAN	Neosid 7100
SLUG	Neosid F29
WINDING	22 turns of 0.63 mm enamelled wire (22 B&S) close wound.
TUNING CAPACITOR	C15, 100pF ceramic. Add inside can across coil leads.

PARTS LIST ETI 740

R7	Resistor	33ohm	5%	¼ or ½W
R5,10,24	"	100 "	"	"
R6,9	"	330 "	"	"
R15	"	470 "	"	"
R4	"	560 "	"	"
R8	"	820ohm	"	"
R2,25,26	"	1k	"	"
R37,56	"	1k	"	"
R48,54	"	1k5	"	"
R17,50	"	2k7	"	"
R13,20	"	3k3	"	"
R1,3,14	"	4k7	"	"
R27,28,49	"	4k7	"	"
R53,55	"	4k7	"	"
R41	"	8k2	"	"
R11,18,19	"	10k	"	"
R33,34	"	10k	"	"
R23,38	"	15k	"	"
R21	"	18k	"	"
R29,30, 31,32	"	22k	"	"
R12,51	"	33k	"	"
R40	"	39k	"	"
R47	"	47k	"	"
R16	"	68k	"	"
R22,39,52	"	100k	"	"
R43,45	"	120k	"	"
R46	"	150k	"	"
R42	"	220k	"	"
R44	"	820k	"	"
R35,36	"	1M	"	"
RV1	Potentiometer	50k TRIM TYPE		
RV2,3	"	5k TRIM TYPE		
RV4,5,6	"	50k MULTI TURN TRIM		
RV7	"	100k 10 TURN ROTARY		
C15*	Capacitor	100pF ceramic		
C31,32	"	220pF "		
C17,21	"	470pF "		
C29,30	"	0.001µF polyester		
C27,28	"	0.01µF polyester		
C7,8,9	"	0.022µF Disc ceramic		
C10,11,12	"	0.022µF Disc ceramic		
C13,14	"	0.022µF Disc ceramic		
C1	"	0.033µF 250V ac		
C23	"	0.047µF polyester		
C24,25	"	0.22µF polyester		
C26	"	0.47µF polyester		
C6,16,19	"	1µF TAG Tantalum		
C33,34	"	1µF TAG Tantalum		
C35	"	4.7µF 10V electro		
C22	"	22µF 16V TAG Tantalum		
C20	"	25µF 10V electro		
C18,36	"	25µF 25V electro		
C2	"	47µF 63V electro		
C3	"	1000µF 25V electro		
C4	"	100µF 63V electro		
C5	"	100µF 35V electro		
L1	Inductor	22µH		
L2	"	see table 1		
D1-D4	Diodes	EM401 or similar		
D5,6	"	1N914 or similar		
LED 1,18	Light emitting diode GREEN			
LED 2- LED 17	Light emitting diode RED			
Q1	Transistor	PN3564 or similar		
Q2,3,4,5	"	BC548 or similar		
Q6	"	BC558 or similar		
IC1	Integrated Circuit	7815		
IC2	" "	TAA 550		
IC3	" "	CA 3089		
IC4	" "	LM 1310 (14 pin)		
IC5	" "	UAA 170		

TUNER — PHILIPS — AP 2157

SW1-4	Switch Module	IRH P/N TS0361
SW5-8	" "	IRH P/N TS0362
M1	Tuning meter 50µA-0-50µA	
T1	Transformer PL 30/5 VA (Ferguson) or similar	
PCB	ETI 740 A ETI 740 B	

Fuse holder and 500 mA fuse
3 core flex and plug
Rubber grommet
Cable clamp
2 Earth lugs
75 ohm socket
2 pin plug and socket McMurdo P/N 12-01-01, P/N 18
2 WAY RCA socket McMurdo P/N 1291-03-02
4 12.7 mm tapped spacers (1/8 whit)
16 Screws 1/8 whit 6 mm long R.H.
8 Nuts 1/8 whit
150 mm Twin coax cable
50 mm 300 ohm ribbon
Knob for tuning pot
Chassis to fig 11
Front panel to10
Cover to fig 9
Rubber feet (4)
75 mm x 25 mm double sided tape.
10 pc board pins
250 mm x 35 mm circular polarized plastic

HOW IT WORKS – ETI 740

The AP2157 is a varicap tuner module which tunes frequencies within the range 88 to 108 MHz by means of a control voltage adjustable between 3.3 and 22 volts. The frequency tuned is not linearly related to the control voltage and a much higher increment of voltage per frequency increment is required at the high end of the band. The tuner operates on the heterodyne principle and hence the incoming signal is mixed with a local-oscillator frequency which is also varicap controlled so that a 10.7 MHz IF frequency (difference) is produced by the mixing process, the sum product of the mixing process being rejected by the following IF stages in the tuner.

The tuner is followed by an IF filter, FL1, and then by a transistor to compensate for the 10 dB loss in the filter. The transistor is followed by a further IF filter. The filters are followed by IC2, a CA3089 which is a complete IF amplifier, limiter and detector system. Thus from this chip we obtain an audio output, an output which can be used for muting, and an output voltage proportional to signal strength which can be used to control the gain of the RF stage (ie AGC).

The distortion introduced by this IC is dependant on the phase linearity of the quadrature coil L2. With a single tuned circuit the distortion is typically 0.5% whilst with a doubled-tuned circuit it is typically only 0.1%. However test equipment is needed to align the double-tuned coil and for this reason we have used the single-tuned circuit.

The output of IC2 is amplified by Q2 before being passed to the stereo-decoder IC3. The purpose of Q2 is to provide the gain necessary to obtain an adequate drive for the particular power amplifier used with the tuner. The gain is determined by the ratio of R19/R20 and may be altered by changing the value of R20.

The stereo-decoder IC, an LM1310, works on the phase-locked loop principle. The loop is locked to the 19 kHz subcarrier (if present) and decodes the stereo signal accordingly. The stereo outputs have the required 50 microsecond de-emphasis applied by R27/C27 and R28/C28. Each output is then taken through a low-pass filter (Q3 and Q4) which gives an added 4 dB rejection of the 19 kHz pilot tone (which is already 34 dB down) and an extra 20 dB rejection of the 38 kHz which is already 45 dB down. Additional filtering was not considered necessary. The stereo-defeat facility is carried out by raising the phase-lock loop frequency out of the lock range of the loop.

The +15 volt supply is derived from a full-wave rectifier followed by an IC regulator. The voltage required for the varicaps is derived by a voltage doubler which provides about 55 volts on C4. This is reduced to 32 volts by R1 and IC2. IC2 is an active zener specially designed for varicap supplies. The varicap supply is again filtered by R2 and C5 further to reduce the amplitude of any supply ripple which may still be present. This supply is then fed to the tuning potentiometers RV4,5,6 and 7, the end limits of these potentiometers being set by R48 and R49. In the AFC mode the AFC voltage derived by the CA3089 IF stage is used to control, via Q4 and Q5, the voltage at the top of the tuning potentiometers and hence provides automatic tuning within a small capture range.

The output of the station selector network is fed to IC5 as well as to the tuner. This IC is an analogue-to-one-of-sixteen decoder and LED driver. One of the 16 display LEDs will be alight – which one is on depends on the input voltage. The LEDs come on at sixteen equally spaced voltages between the limits of the two voltages as set on pins 12 and 13 of the UAA 170 IC. The input voltage to the IC is modified by a diode-resistor network (D5, D6 etc) to compensate for the non-linear relationship of frequency versus tuning voltage of the tuner. Thus this network provides a reasonably linear dial scale.
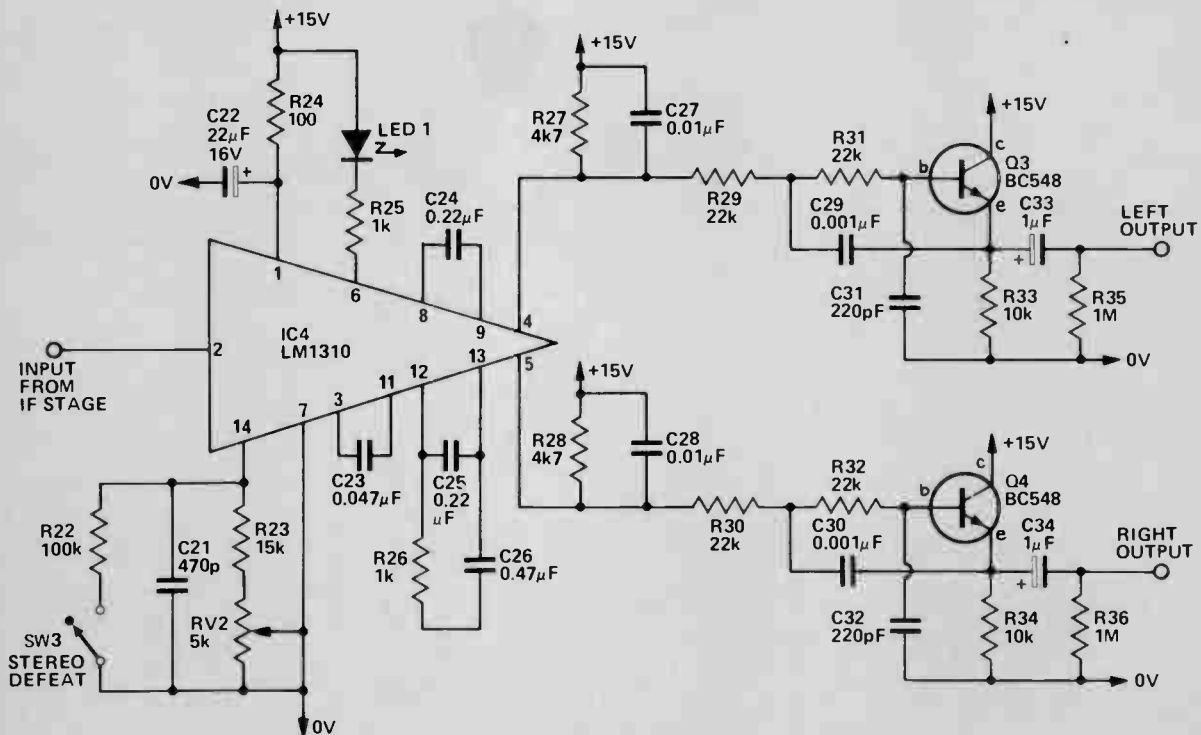

Fig. 2. Circuit diagram of the stereo-decoder stage.
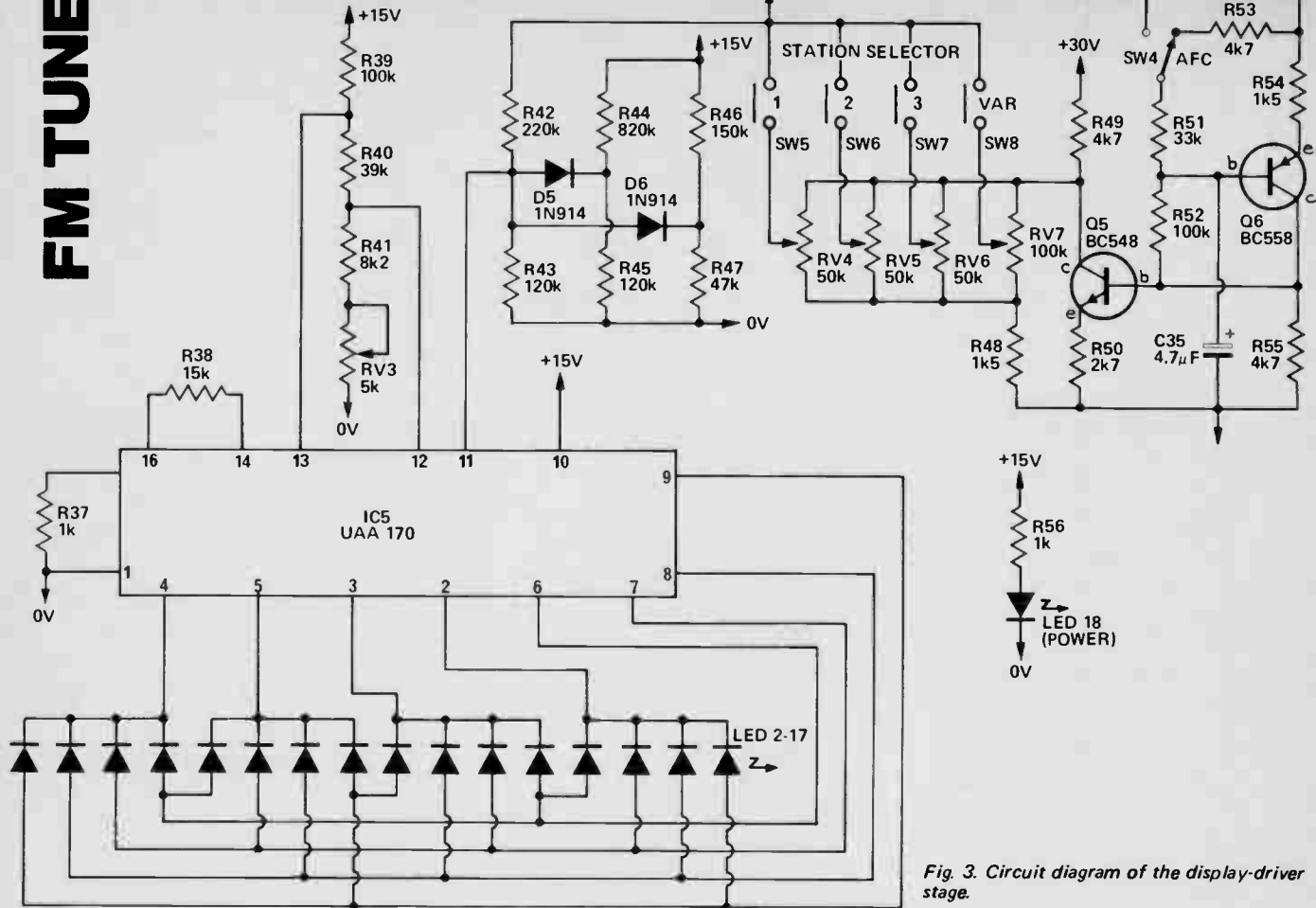
FM TUNER

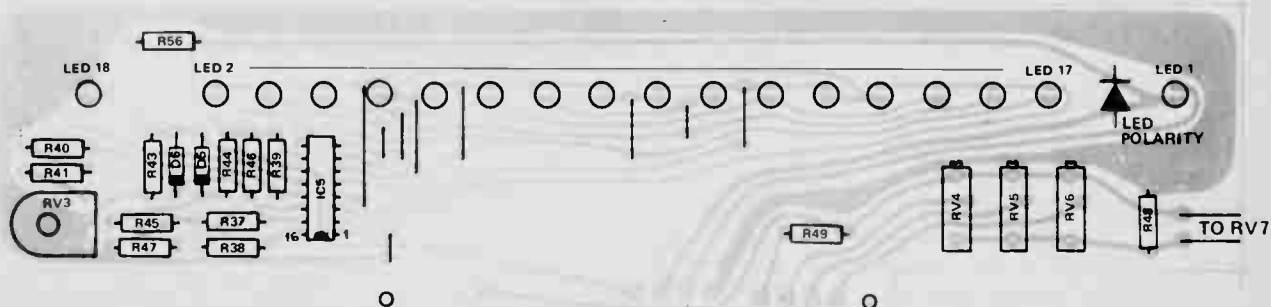Fig. 3. Circuit diagram of the display-driver stage.

Fig. 5. Power supply circuit.

NOTE
C1 CAN BE ANY VALUE BETWEEN
0.01μF AND 0.33μF BUT MUST
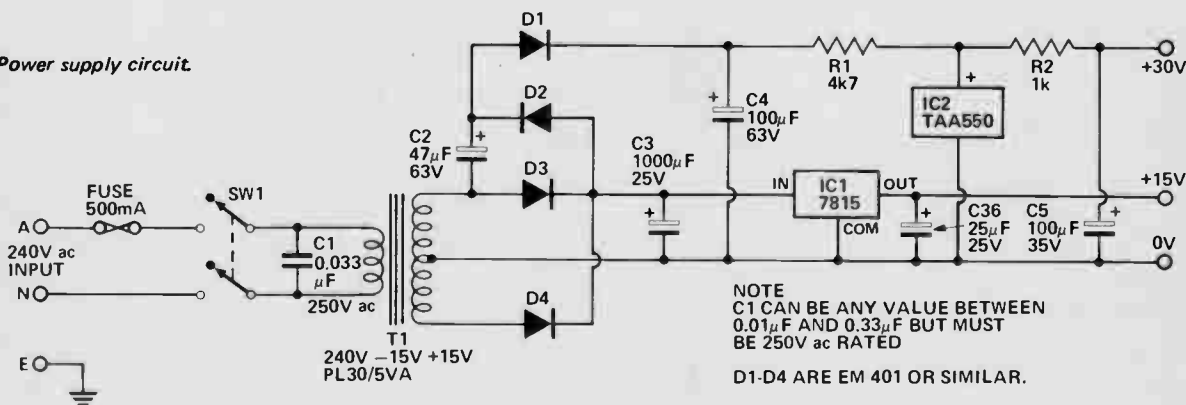BE 250V ac RATED

D1-D4 ARE EM 401 OR SIMILAR.

Fig. 4. Component overlay for the display board.
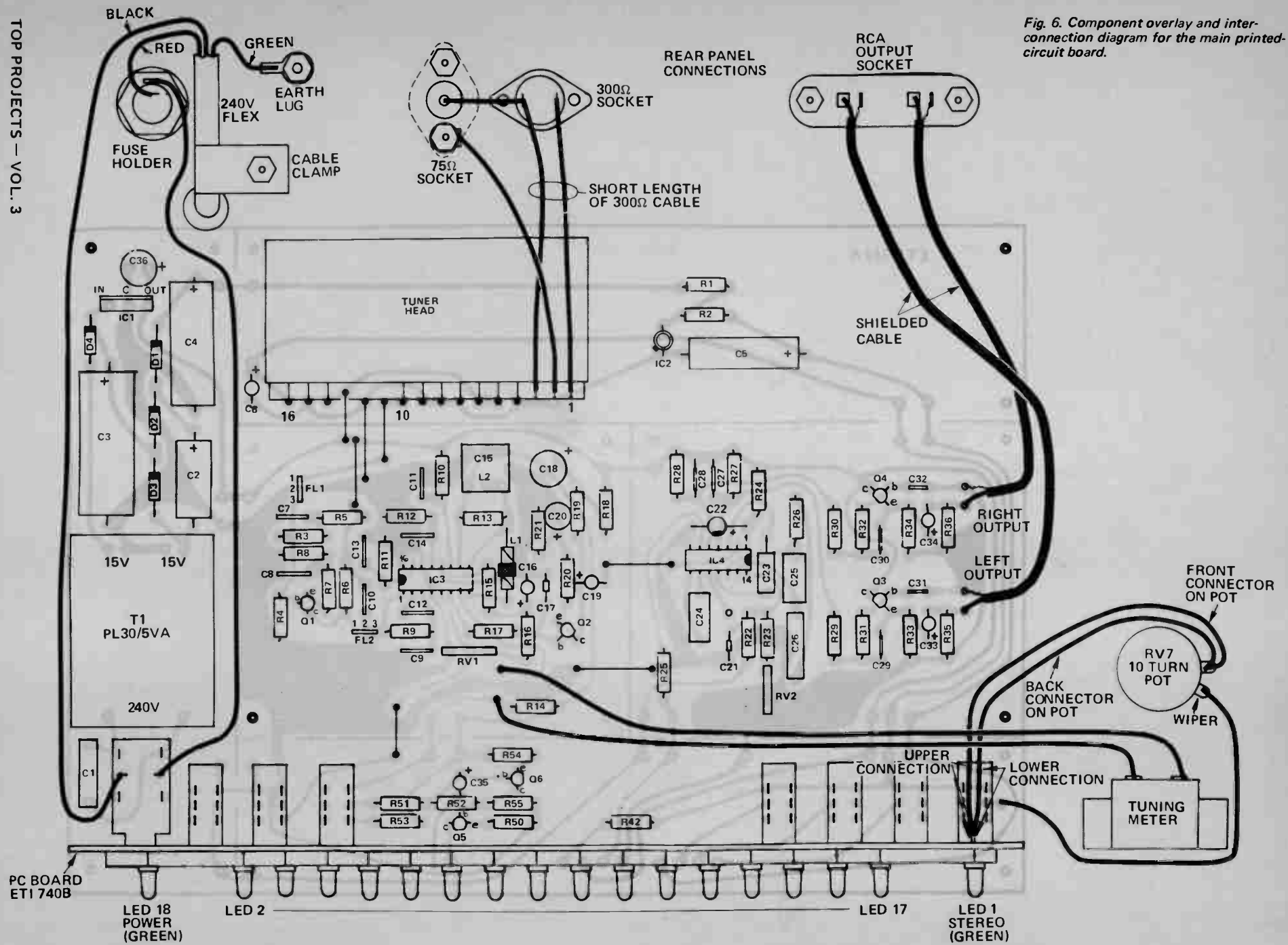
Fig. 6. Component overlay and inter-connection diagram for the main printed-circuit board.
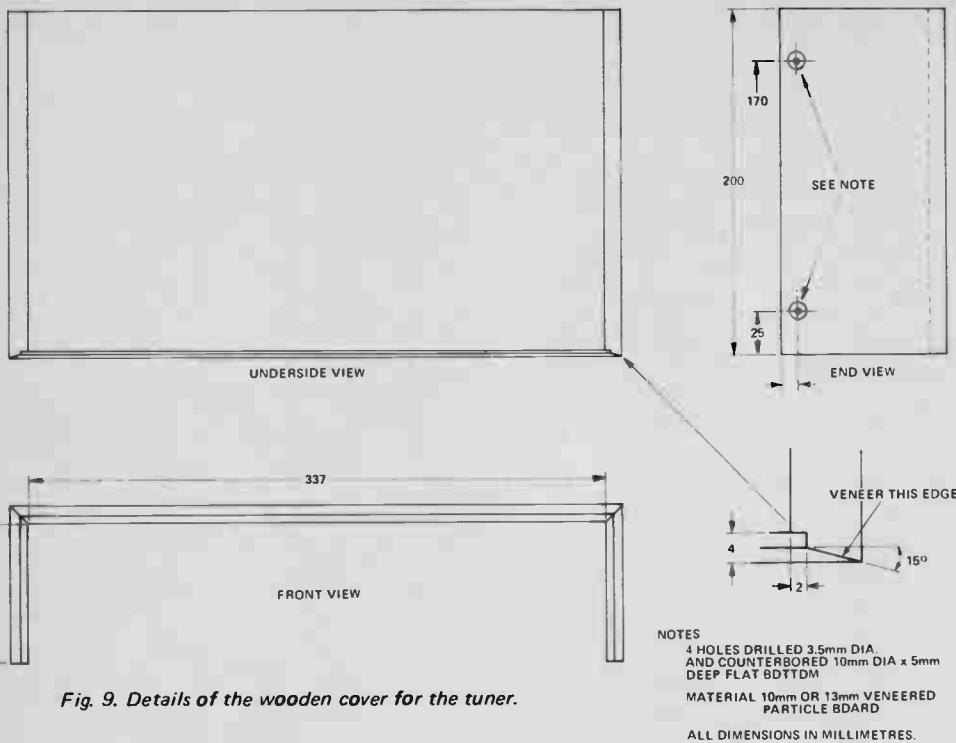
FM TUNER

UNDERSIDE VIEW

FRONT VIEW

86

337

Fig. 9. Details of the wooden cover for the tuner.

170

200   SEE NOTE

25

END VIEW

VENEER THIS EDGE

4

15°

2

NOTES
4 HOLES DRILLED 3.5mm DIA.
AND COUNTERBORED 10mm DIA x 5mm
DEEP FLAT BOTTOM

MATERIAL 10mm OR 13mm VENEERED
PARTICLE BOARD

ALL DIMENSIONS IN MILLIMETRES.

340

19

256   284   320

18
33

67
89

8 HOLES 11.5 mm DIA

64.5

27   62   197   232   1 HOLE 10mm DIA

44.5   79.5   214.5   249.5   302

NOTES
ALL DIMENSIONS IN MILLIMETRES
MATERIAL SATIN ANODISED ALUNIMIUM

Fig. 10. Front panel
metalwork.

secured to the inside of the front panel
— again by contact cement. The tuning
meter is held in position by epoxy
cement to avoid having screws
protruding through the front panel.

TESTING

Switch on the power and check that
the +15 V and +30 V supplies are both
operating correctly. The power
indicator LED and one of the display
LEDs should be alight.

Select STEREO MODE, MUTING
OFF, AFC OFF and VAR. By rotating
the tuning potentiometer it should be
possible to sequentially vary the LED's
illuminated.

Adjust the tuning potentiometer
(RV7) so that its output is 3.5 volts
from the slider with respect to 0 volts,
and then adjust RV3 so that the first
and second LEDs are both equally
illuminated, (see below).

Connect an antenna and tune in a
strong audible signal. Measure the
voltage across R12 and adjust the
tuning for maximum reading (voltage
across R12 is proportional to signal
strength). Now adjust L2 so that the
tuning meter indication is exactly at
centre. Next adjust the tuning so that
the tuning meter indicates about half
scale away from centre and press the
AFC switch. The tuning meter should
move back to centre indicating that
the AFC circuit is working correctly.
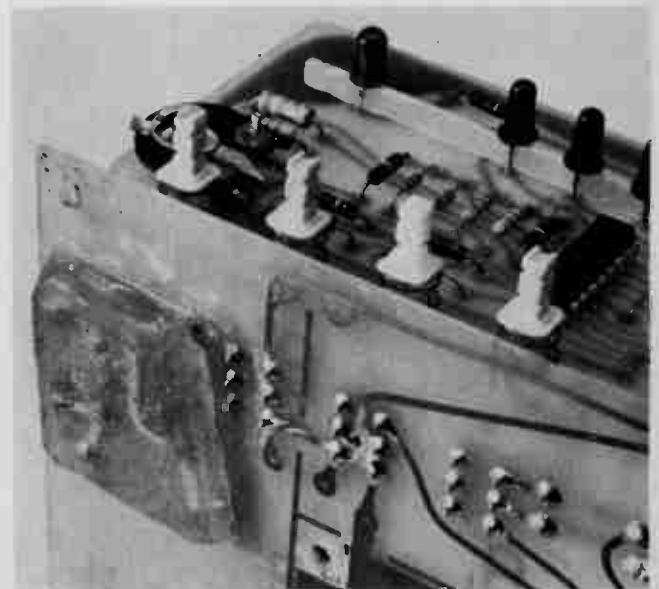
▲
This view shows how the solder joints at mains potential are insulated
with a layer of five minute epoxy. Note also RV3 on the display
board.

◄ This picture shows details of the mating of the main and display
boards. Note the alignment strip for LEDs, the mounting of the
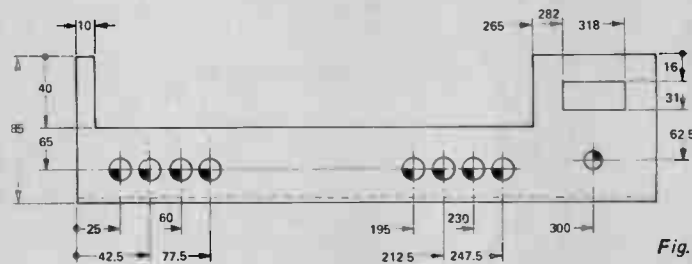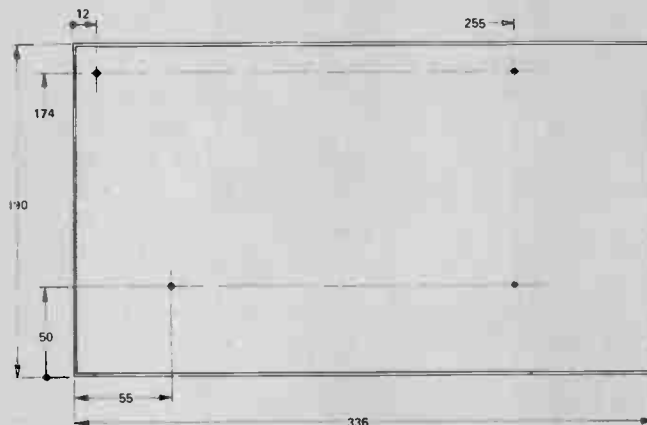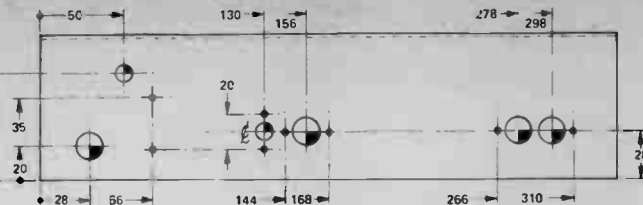switches and how the display board is secured to the switch bracket.

Now move completely off the station. The noise level will increase suddenly. Press in the muting switch and adjust RV1 to reduce the noise level so that it is almost inaudible. Do not try to eliminate *all* the noise as this may prevent weak signals from being heard.

Finally tune to a station which is known to be transmitting in stereo. A zone will be found in the adjustment of RV2 where the stereo indicator is on. Position RV2 to the mid position of this zone. The light should go off if the MONO switch is pressed. Note that the noise behind a stereo signal is higher than when in mono.

In some parts of Australia, FM stations may be spaced only 800 kHz apart — and the same LED may be illuminated when either station is tuned. Separate LED indication may be obtained by slightly readjusting RV3.

TUNER MODULE

The tuner module as supplied to us had provision for either 75 or 300 ohm inputs as shown on the circuit diagram. Philips have advised that all the AP 2157 tuner modules in stock at the moment are fitted with both inputs. They cannot guarantee that future stocks will have the 300 ohm input. To check if your tuner has a 300 ohm input measure the resistance between pins 1 and 3 of the tuner module with an ohmmeter; a low resistance indicates that the tuner has a 300 ohm input. If the tuner does not have a 300 ohm input it will be necessary to use a balun when using it with a 300 ohm antenna. Of course if the feed from the antenna is 75 ohms it may go straight into the tuner 75 ohm input.
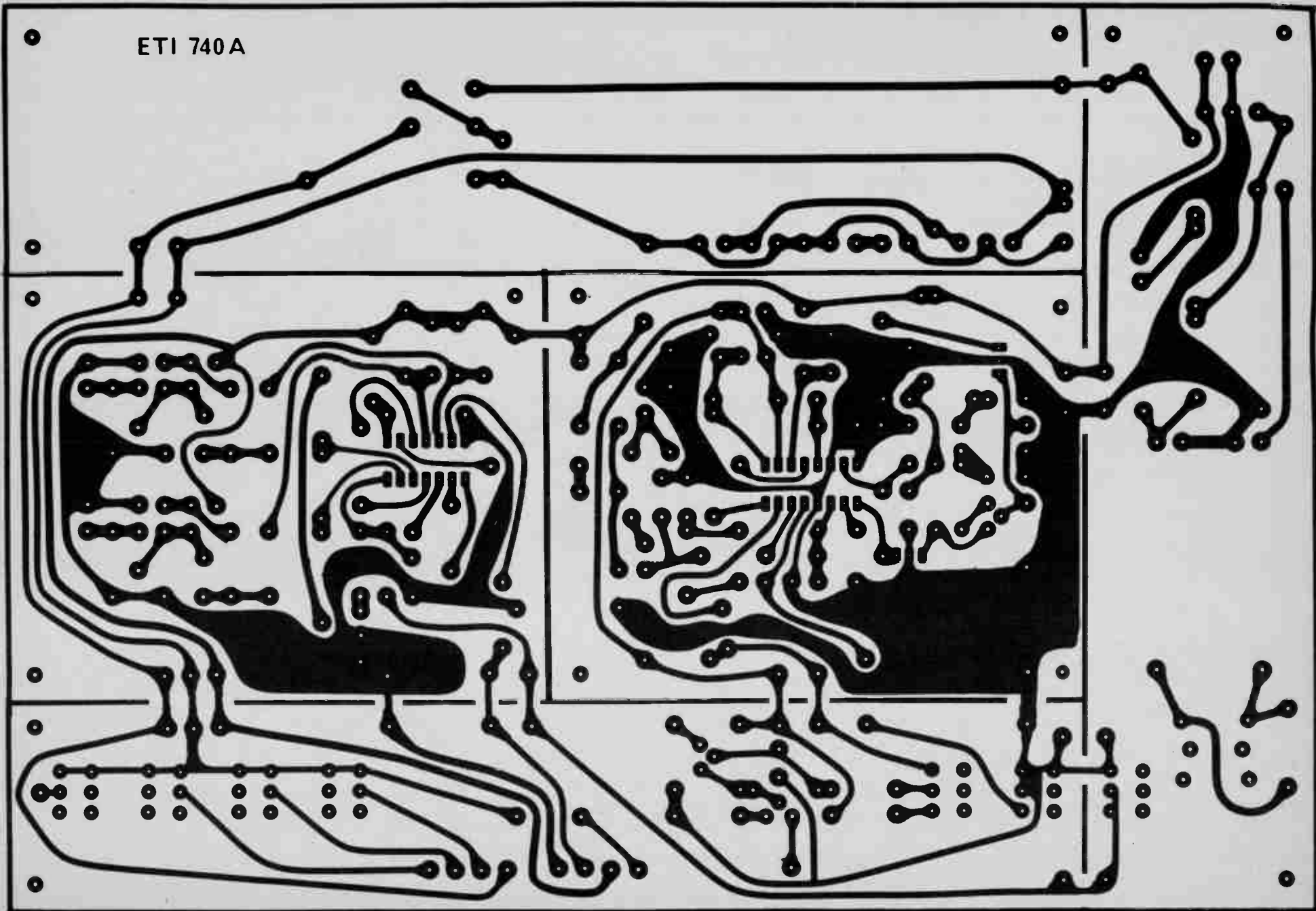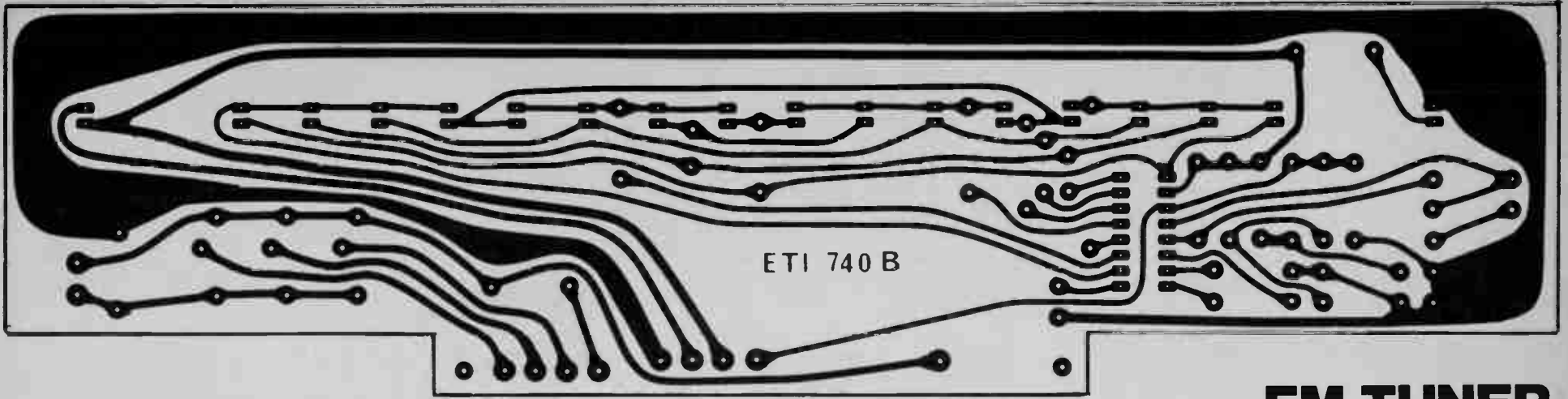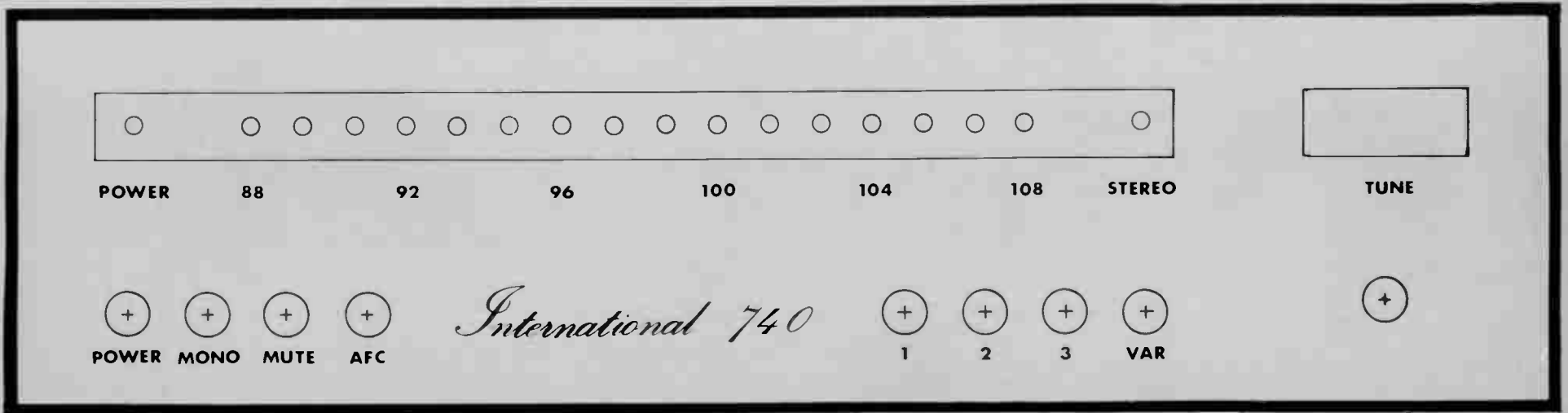

- 12 HOLES AT 3.5mm DIA
- 3 HOLES 10mm DIA
- 8 HOLES 13mm DIA
- 4 HOLES 15mm DIA

NOTES:
MATERIAL 1mm STEEL
ALL DIMENSIONS IN MILLIMETRES

DRILL HOLES TO SUIT COVER

12mm FOLD AT BOTH ENDS

Fig. 11. Chassis metalwork.

World Radio History
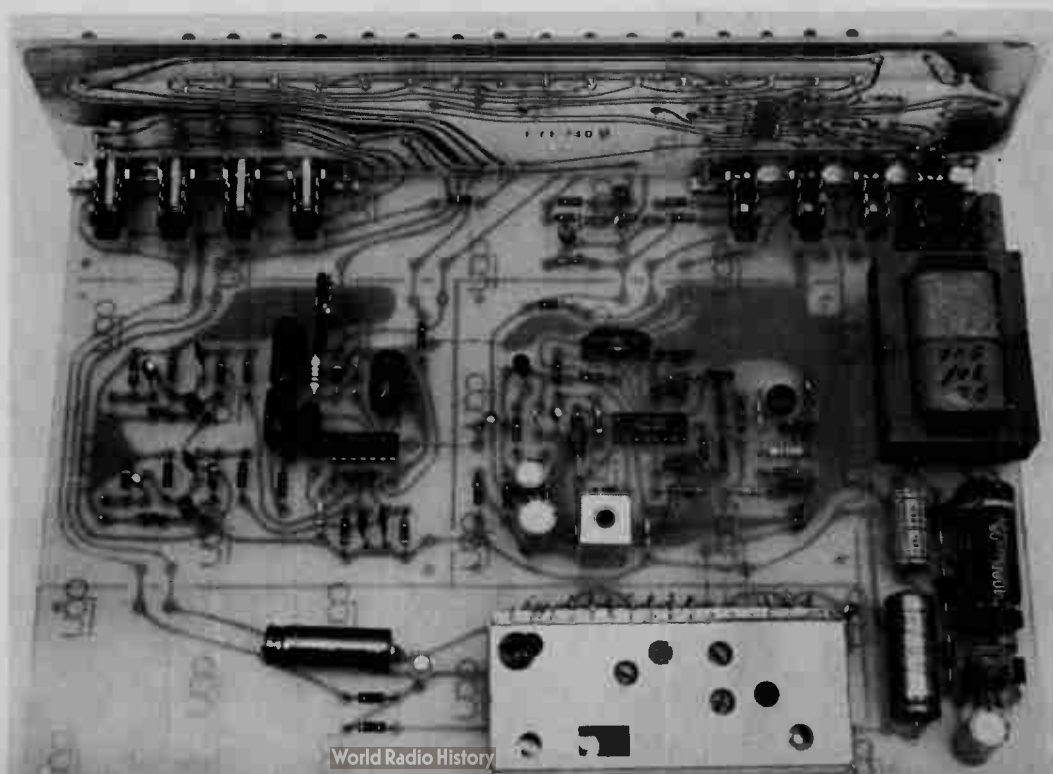
ETI 740A

Fig. 7a. Main printed-circuit board artwork. 253 mm x 177 mm.

ETI 740 B

FM TUNER

Fig. 7. Printed circuit layout for the display board. 253 mm long.

Fig. 8. Front panel artwork. Full size 340 x 89 mm.

POWER   88   92   96   100   104   108   STEREO   TUNE

International 740

POWER   MONO   MUTE   AFC   1   2   3   VAR

World Radio History

How to cut costs on your valuable P.C. board real estate...
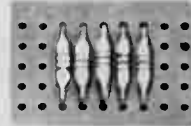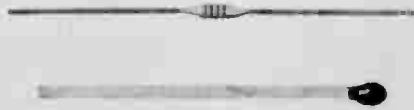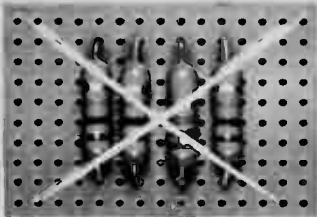
use type GLP miniature resistor.

IRH Components introduces the Metal Glaze type GLP resistor, a miniature ½ watt, with a maximum surface temperature rise of 50°C, the physical dimensions of many other ⅛ or ¼ watt resistors but a full ½ watt rating at 70°C ambient.

The smaller size allows .4" (10 mm) lead spacing as standard for horizontal printed circuit board mounting — reduces demand on expensive PC board real estate. Even greater packaging density can be achieved by vertical mounting.

Another IRH "FIRST," the Australian made GLP is a result of extensive research, development & testing for Australian conditions.

STOCK THE GLP resistor and you automatically stock ⅛ watt, ¼ watt and ½ watt and significantly reduce your resistor inventory. USE IT with confidence.

GLP FEATURES INCLUDE:

- ■ Low cost.
- ■ Small size. Length 5.5 mm Diameter 2.0 mm.
- ■ ⅛, ¼, ½ watt rating.
- ■ Thick film reliability.
- ■ 60/40 plated leads for excellent solderability.
- ■ Solvent resistant coating and colour bands.

irh

COMPONENTS
DIVISION OF NATRONICS PTY. LIMITED
The Crescent, Kingsgrove, N.S.W. 2208. Tel. 50 0111
74 Raglan Street, Preston, Vic. 3072. Tel. 44 5021

To: IRH components, The Crescent, Kingsgrove, N.S.W. 2208

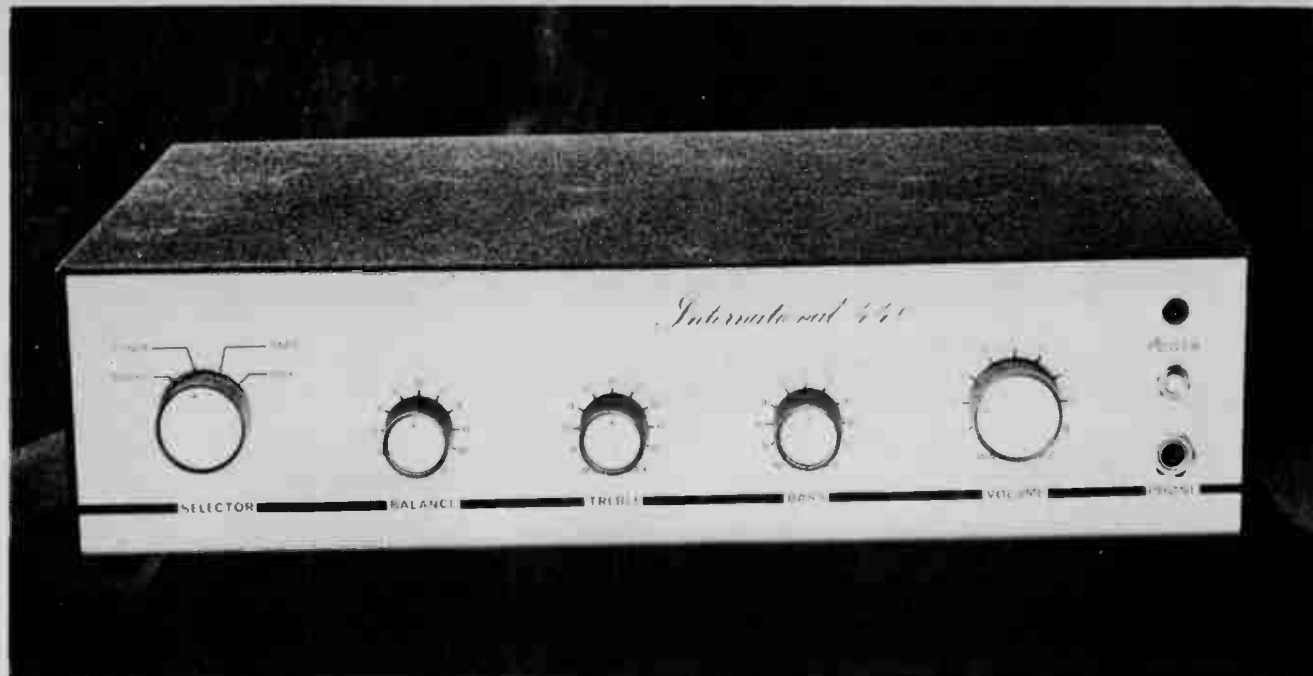Please forward your engineering bulletin featuring the GLP resistor.

NAME..

ADDRESS..

....POSTCODE..........

GLP/76

eti PROJECT 440
SIMPLE 25 WATT AMPLIFIER

Big performance at a low price.

WHEN designing this amplifier considerable effort was made to achieve several, generally incompatible, aims. These were to design an amplifier that gave high performance, was simple enough for the beginner to build BUT, was low in cost.

Since a high percentage of the cost of an amplifier is in the hardware, (e.g. chassis, potentiometers, switches etc) and this cost does not vary greatly relative to amplifier power output, we aimed at the highest possible power for reasonable cost. Thus the amplifier gives 25 watts RMS per channel which is about as much as can be obtained without component costs increasing dramatically.

To gain the required simplicity we used a single printed circuit board, to hold as much as possible of the electronics, thus keeping external wiring down to a minimum.

The result is a 25 watt-per-channel amplifier which has a distortion of
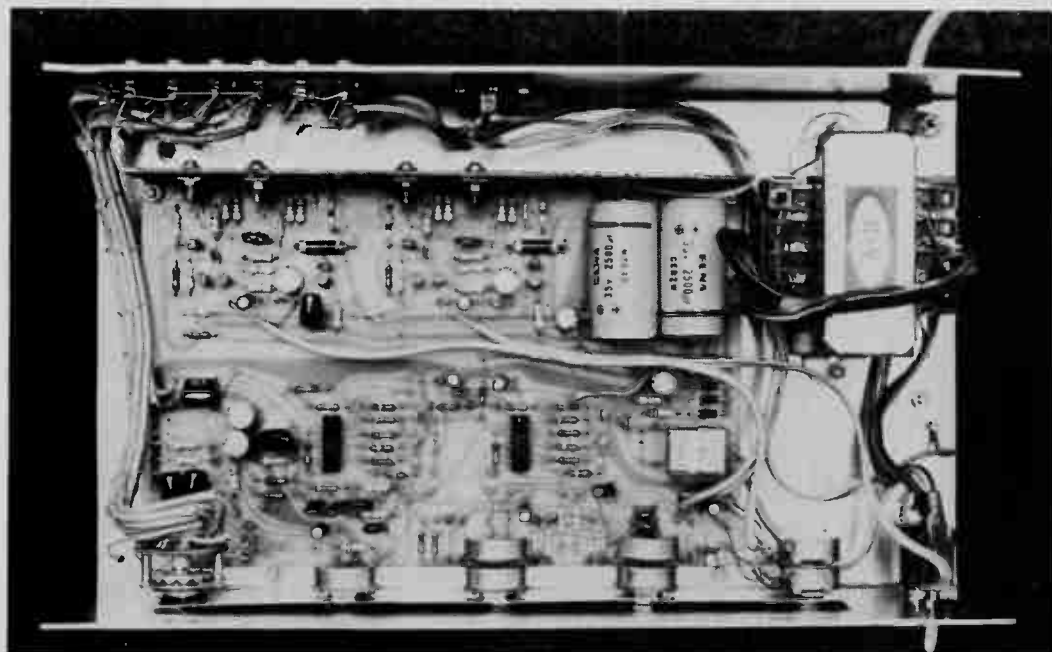
Internal view of the amplifier showing location of the major components.

Fig.1. Circuit diagram of the TCA220 triple-operational amplifier.

around 0.1%, costs about the same as some 12 watt-per-channel kitsets at present on the market and is extremely easy to build and set-up.

CONSTRUCTION

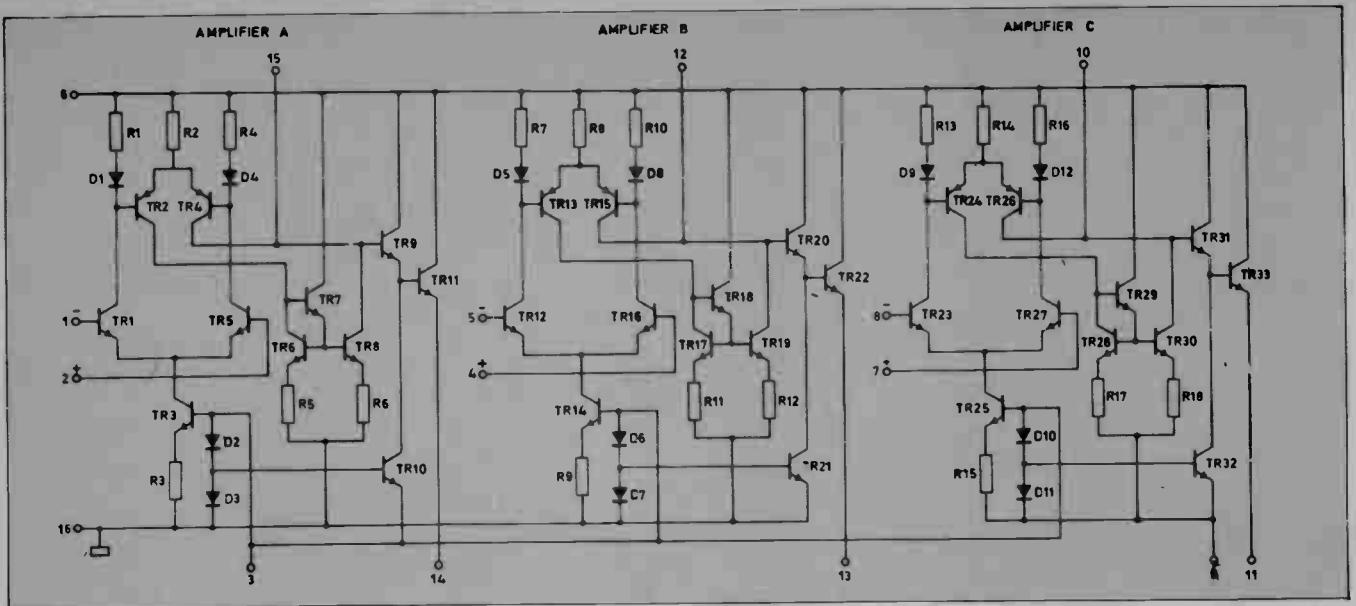The single printed-circuit board construction greatly simplifies things for the beginner. (See page 26 for circuit board pattern). The heatsink is attached to the rear of the board to hold the power transistors, and a bracket at the front holds the potentiometers. Before attaching these brackets assemble the components to the printed circuit board, as shown in the component overlay diagram Fig. 3,

doing all the linking required first. There are two links which go under resistors R49 and R50 in the power amplifier and these should be insulated with 1 mm spaghetti. All other links may be tinned copper provided that they are kept straight and flat on the board.

Although the components can be mounted in any order it is usually easier to mount the smallest (lowest height) components first, ie, resistors and diodes. These should be mounted flush on the surface of the board. The capacitors may now be mounted taking care not to damage the small ceramic capacitors by bending the leads too close to the body of the device. Make sure that electrolytic

capacitors are orientated correctly, i.e., the polarity is correct.

The transistors, apart from Q7,8,9,10,15,16,17 and 18 (which are on the heatsink) may now be fitted to the board. With the BC548 there are two different lead connections. The Philips type has a bent centre leg (the base) and these are the types shown on the overlay. If a different brand is used, ie one with the pins all in line, they must be inserted 180° around from that orientation shown. Transistors Q7,8,9 and 10 MUST be the Philips type. Hence, if you have a mixture, keep the Philips types for
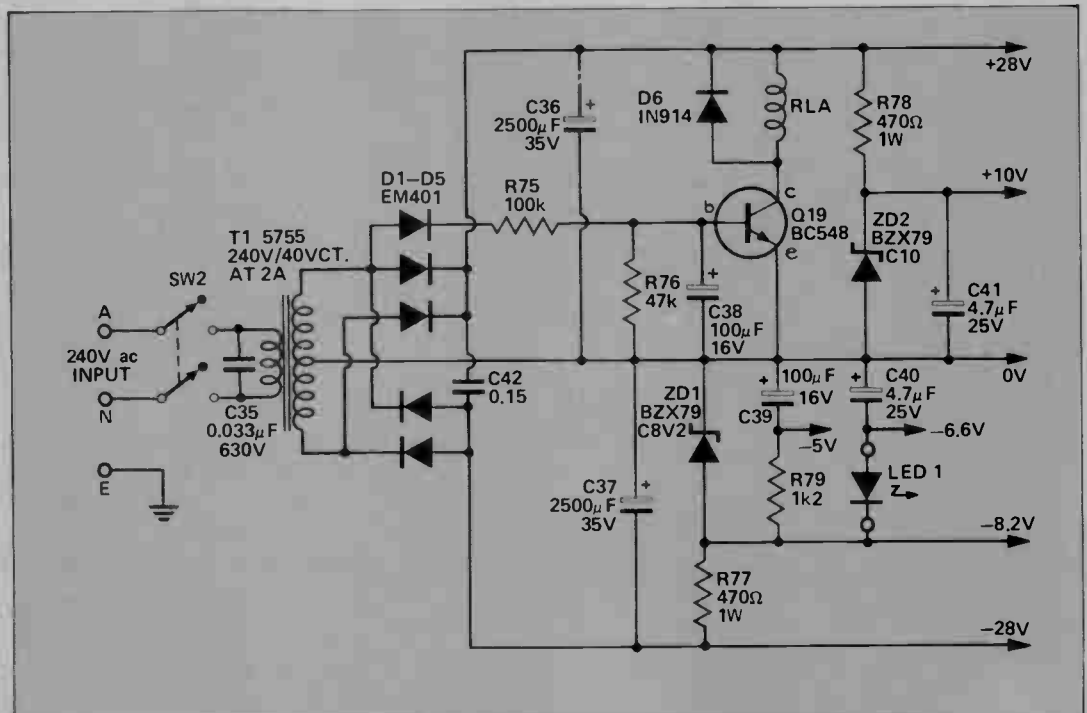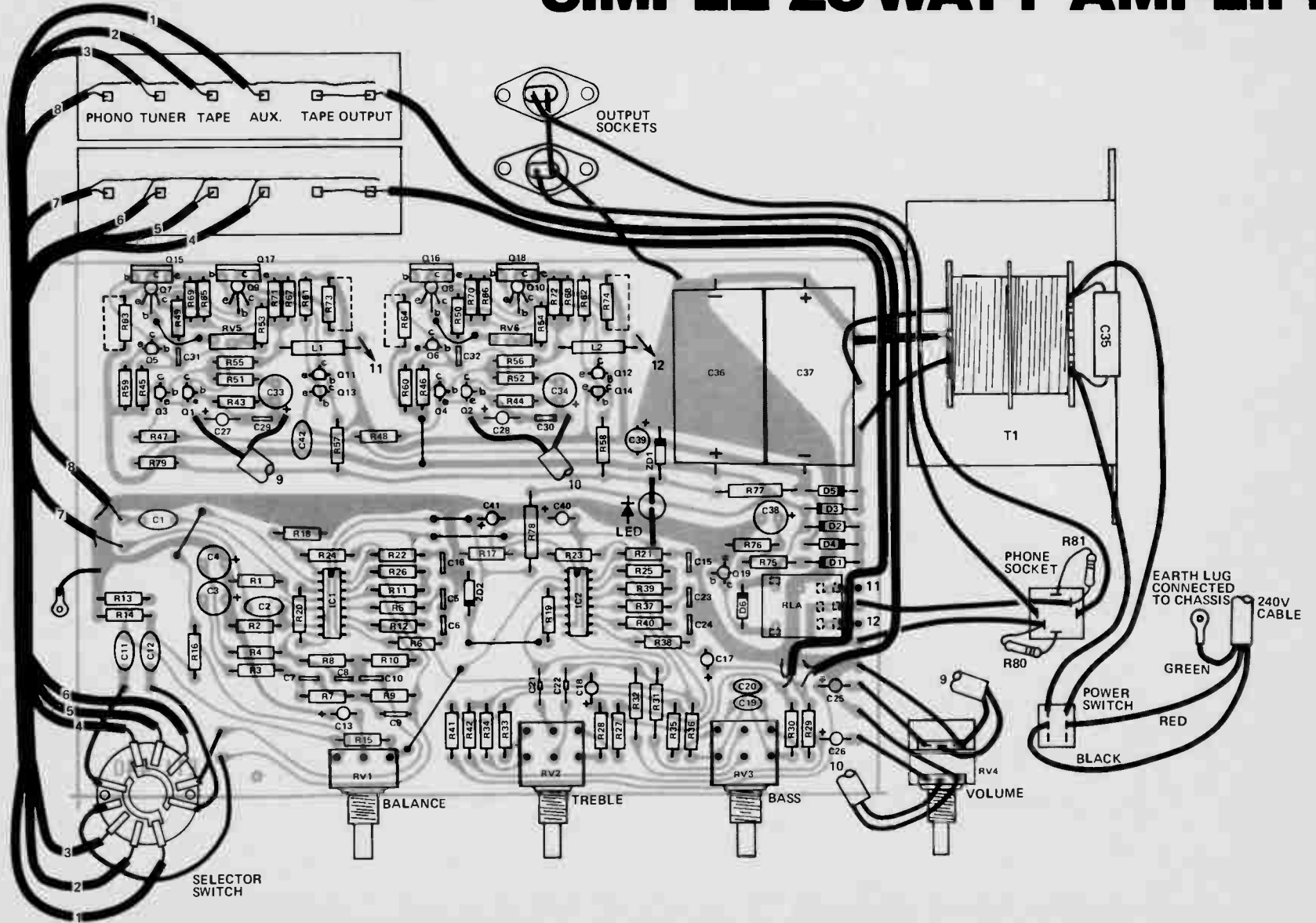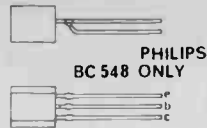
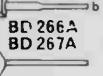Fig. 2. Power supply for the 25 watt amplifier.
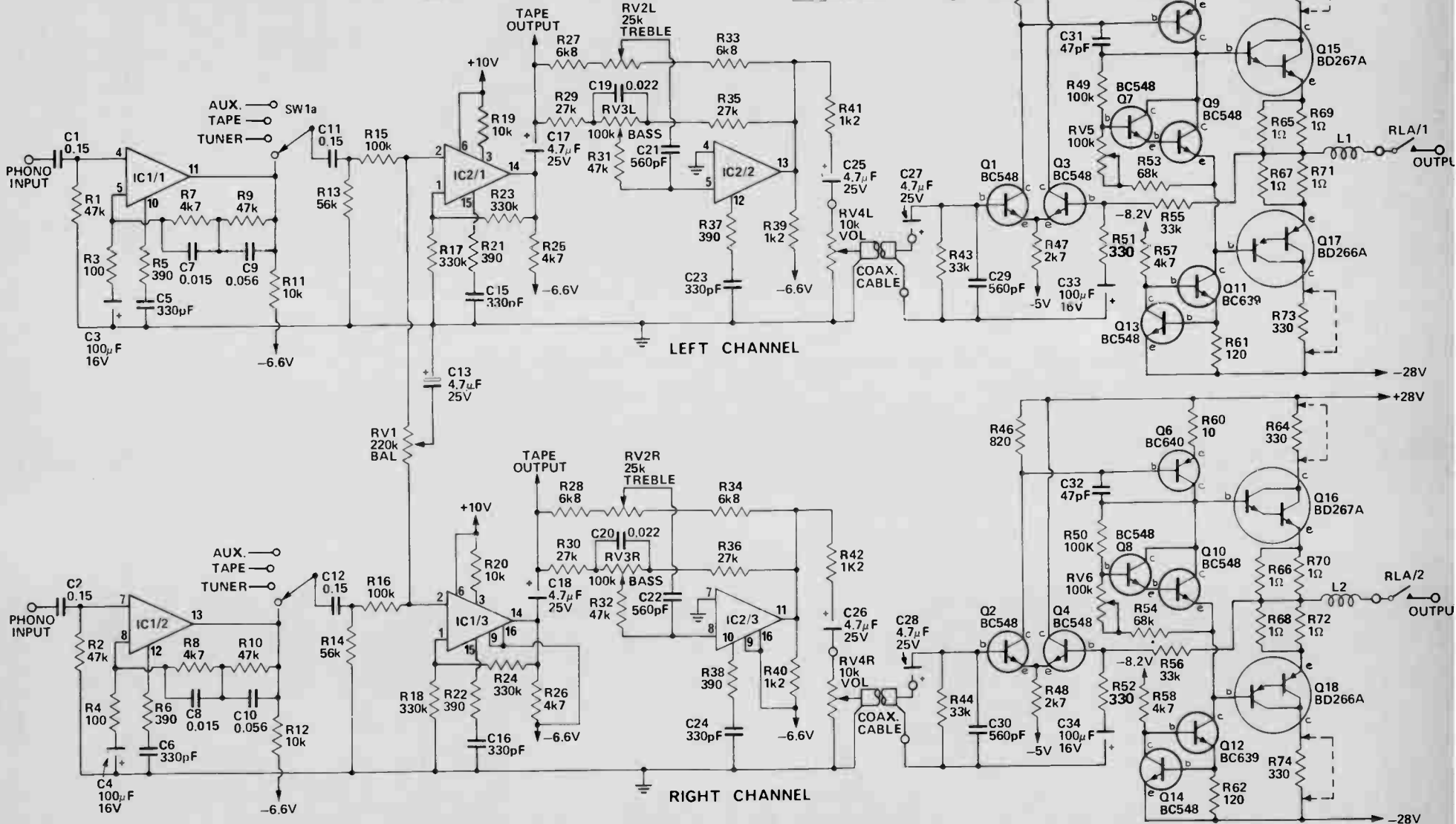
SIMPLE 25 WATT AMPLIFIER
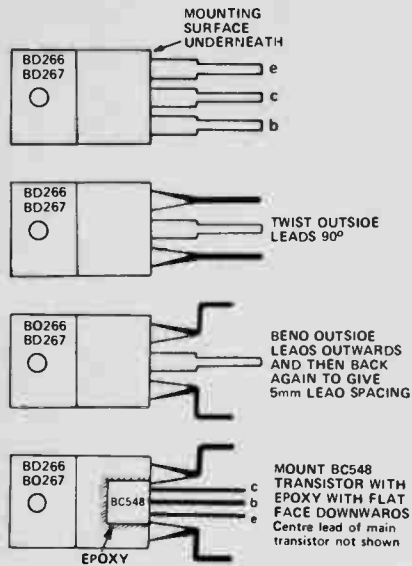
SIMPLE 25 WATT AMPLIFIER

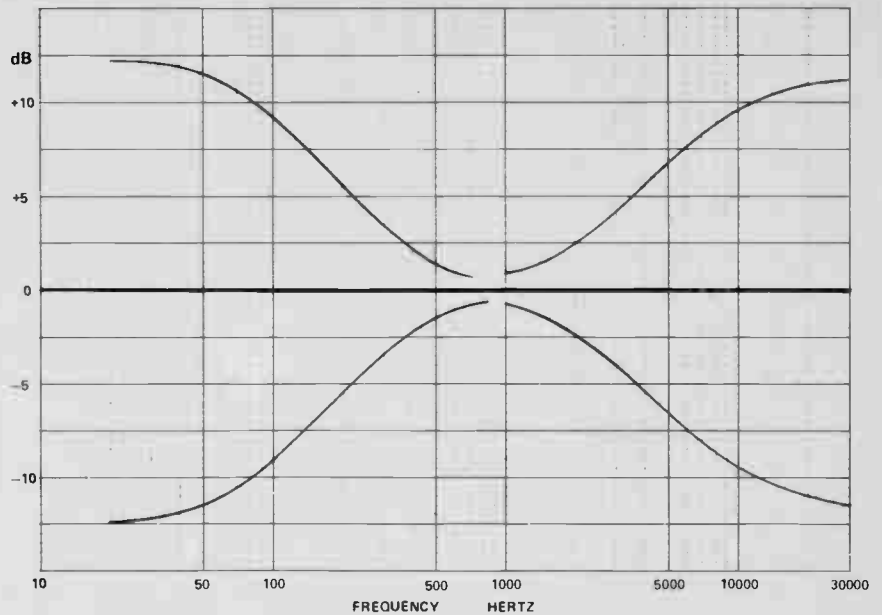Fig.5. How to prepare the power transistor leads for installation.

Fig.6. Tone control characteristics of the amplifier.

MEASURED PERFORMANCE OF ETI 440 AMPLIFIER

POWER OUTPUT — 25 + 25 watts into 8 ohms

FREQUENCY RESPONSE
+ 0
− 0.5 dB   15 Hz − 30 kHz
+ 0
− 3 dB   6 Hz − 80 kHz

CHANNEL SEPARATION — 1 kHz − 46 dB

HUM AND NOISE
(with respect to 25W)
Phono (10 mV) — 67 dB (unweighted)
Other inputs — 68 dB (unweighted)

INPUT SENSITIVITY
Phono — 2.5 mV   47k
Other inputs — 200 mV   47k

TOTAL HARMONIC DISTORTION

Power	Frequency	One channel only	Both channels
	100 Hz	0.1%	0.13%
12.5W	1 kHz	0.08%	0.16%
	10 kHz	0.12%	0.17%
	100 Hz	0.14%	0.5%
20W	1 kHz	0.12%	0.6%
	10 kHz	0.17%	0.8%
	100 Hz	0.5%	5.2%
25W	1 kHz	0.6%	4.8%
	10 kHz	0.7%	4.3%

TONE CONTROLS
Bass   12 dB boost at 50 Hz
        12 dB cut at 50 Hz
Treble   9 dB boost at 10 kHz
        9 dB cut at 10 kHz

DIMENSIONS — 340 x 88 x 210 mm

these positions. If a substitute is used for the BC639 and BC640 carefully check the pin connections as these types are unusual.

The integrated circuits may now be installed making sure that orientation is correct as indicated by the mark on the IC which is at the pin 1 end of the IC. Then mount the relay by passing the pins through the holes provided in the board and then bend the leads flush with the copper and solder them to the tracks.

The chokes L1 and L2 are made by winding about 25 turns of 0.4 mm copper wire (insulated) onto the body of a 10 ohm 1 watt resistor terminating the ends of the wire on the resistor leads. These may now be mounted on the board.

The balance, treble and bass controls should now have lengths of copper wire soldered to each of the terminals. They are then mounted, by passing the leads through the holes in the board, but are not soldered in position as yet. The front bracket should now be attached to the *component* side of the printed-circuit board and the potentiometers mounted to the panel. The leads from the potentiometers should then be drawn through the board as far as possible and then soldered in position. Then mount the heatsink bracket to the rear of the board using 9.6 mm spacers and countersunk screws.

The output transistors have to be prepared in a couple of ways before installation. The leads are too close

HOW IT WORKS – ETI 440 PREAMPLIFIER

In the preamplifier we have used two TCA220 integrated circuits each of which contain three identical operational amplifiers. These work similarly to the conventional op amp like the 709, 741 or 301 except the output is an emitter follower and needs a pull down resistor. An internal schematic diagram is given in Fig. 1. for those interested. Frequency compensation is accomplished by a 390 ohm resistor in series with a 330 pF capacitor connected to the appropriate terminal. The maximum voltage allowed on this IC is 18V. Since the output swing in the positive direction is less than that in the negative direction we have used +10V and −6.6V supplies to ensure equal clipping.

The magnetic pickup used on most good turntables has a low output and also needs equalization to perform correctly. We used part of the TCA 220 (IC1-1 and IC1-2) to amplify this signal (about 60 times or 35 dB at 1 kHz) and to provide the equalization required (+13 dB at 100 Hz and −14 dB at 10 kHz referred to the gain at 1 kHz). The output of this amplifying stage connects to the switch SW1 which selects the desired input. The signal from the cartridge is amplified before the selector switch to improve the signal-to-noise ratio.

After the selector switch we have the balance control (RV1) which attenuates either left or right channel as desired. The signal is then amplified, by a factor of two, to recover what is lost in the balance-control network and also to buffer the signal to give a low impedance output. The output drives the tone-control network and also the tape-output sockets.

The tone-control section uses the last sections of the TCA220 (IC2/2, IC2/3) with the bass and treble controls in the feedback network. These controls provide about 10 dB of boost and cut of both bass and treble. Resistors R27 and R33 set the limit of the treble boost and cut, while C21 controls the actual frequency where the treble control starts. Resistors R29 and R35 control the bass limits while C19 sets the frequency. The output of the stage is connected to the volume-control potentiometer RV4.

POWER AMPLIFIER

The power amplifier is of conventional design using a differential pair Q1 and Q3 followed by a common-emitter amplifier stage, Q5. working at a constant current (5 mA) supplied by Q11 and Q13. The output of Q5 is buffered by the output transistors Q15 and Q17. These are darlington transistors and have a current gain (Hfe) of over 750 at 3A. These transistors are biased

on slightly (10 mA) to remove cross-over distortion and the bias is set by measuring the voltage across R63 or 73 (3V) while adjusting RV5. After bias adjustment is completed these resistors are shorted out to allow full power capability. Transistors Q7 and Q9 are physically joined onto Q15 and Q17 to provide accurate temperature indication and to ensure thermal stability.

The gain of the power amplifier stage is 100 and is set by the ratio of R55/R51. The earth reference for the power-amplifier input stage is supplied via the coax cables connecting to the preamplifier.

POWER SUPPLY

The power supply is a full wave rectifier with a centre-tapped transformer supplying ± 28V to the main amplifiers. The supplies for the preamplifier are obtained from a 10 V zener ZD2 and a 8.2V zener ZD1. The actual negative supply to the preamplifier comes via the LED on the front panel and is about −6.6 volts (1.6V across LED). A smooth −5V is also derived from the −8.2V and is used for the differential pair in the main amplifier.

The relay RLA is used to prevent the switch on transient reaching the speakers. After switch on there is a delay due to C38 of about 4 seconds before the speakers are connected. On switch-off the delay is only about 1 second.

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together, and since they are mounted close to the board the transistors may be damaged if the leads are just pulled apart. Figure 5 shows the lead bending process which should be done carefully with a pair of long nose pliers. After bending, a BC548 (Philips only) should be epoxyed with flat side onto the face of these transistors.

It is preferable to use one of the slow drying epoxies as they appear to withstand the elevated temperature better. If such epoxy is dried in the 100-130°C range it will normally dry in about 30 minutes. Before glueing, however, it is best to scratch the type number on to the side of the output transistor to aid later identification.

When dry, the transistors can be mounted using insulation washers and a smear of silicon grease if available. The leads of the BC548 have to be bent out a long way but they should be long enough. If a small soldering iron is used these transistors can now be soldered in without removing the heatsink.

The rotary switch and volume control can now be mounted on to the front bracket. There are four links from the board to the rotary switch as shown in Figure 4, the rest of the connections going to the rear panel. There are also four links to the volume control and two coax cables which go

PARTS LIST				
R65, 66	Resistor	1Ω	½W	5%
R67,68	"	1Ω	"	"
R69,70	"	1Ω	"	"
R71,72	"	1Ω	"	"
R59,60	"	10Ω	"	"
R3, 4	"	100Ω	"	"
R51,52	"	330Ω	"	"
R61,62	"	120Ω	"	"
R80,81	"	220Ω	1W	"
R63,64	"	330Ω	½W	"
R73,74	"	330Ω	"	"
R5,6,21	"	390Ω	"	"
R22,37,38	"	390Ω	"	"
R77,78	"	470Ω	1W	"
R45,46	"	820Ω	½W	"
R39,40,41	"	1k2	"	"
R42,79	"	1k2	"	"
R47,48	"	2k7	"	"
R7,8,25	"	4k7	"	"
R26,57,58	"	4k7	"	"
R27,28	"	6k8	"	"
R33,34	"	6k8	"	"
R11,12	"	10k	"	"
R19,20	"	10k	"	"
R29,30	"	27k	"	"
R35,36	"	27k	"	"
R43,44	"	33k	"	"
R55,56	"	33k	"	"
R1,2,9,10	"	47k	"	"
R31,32,76	"	47k	"	"
R13,14	"	56k	"	"
R53,54	"	68k	"	"
R15,16,49	"	100k	"	"
R50,75	"	100k	"	"
R17,18	"	330k	"	"
R23,24	"	330k	"	"
RV1 Potentiometer		220k lin single gang rotary		
RV2	"	25k lin dual gang rotary		
RV3	"	100k lin dual gang rotary		
RV4	"	10k log dual gang rotary		
RV5,6	"	100k trim pot		
C31,32 Capacitor		47pF ceramic		
C5,6,15	"	330pF "		
C16,23,24	"	330pF "		
C21,22	"	560pF "		
C29,30	"	560pF "		
C7,8	"	0.015µF polyester		
C19,20	"	0.022µF "		
C35	"	0.033µF 630 V		
C9,10	"	0.056µF polyester		
C1,2	"	0.15µF "		
C11,12,42	"	0.15µF "		
C13,17,18	"	4.7µF 25V electro		
C25,26,27	"	4.7µF 25V "		
C28,40,41	"	4.7µF 25V "		
C3,4,33	"	100µF 16V "		
C34,38,39	"	100µF 16V "		
C36,37	"	2500µF 35V "		
L1,2	Choke	25 Turns 0.4mm Cu Wire on a 10Ω 1W Resistor		
D1 – D5	Diode	EM401 or similar		
D6	"	1N914 " "		
LED1				
ZD1		BZX79 8V2		
ZD2		BZX79 C10		
Q1,2,3	Transistor	BC548 " "		
Q4,13,14,19	"	BC548 " "		
Q7,8,9,10	"	BC548 Philips only		
Q5,6	"	BC640		
Q11,12	"	BC639		
*Q15,16	"	BD267A or B		
*Q17,18	"	BD266A or B		
*insulation washers needed				
IC1,2 Integrated Circuit TCA220				

RLA Relay 2c/o contacts 1250Ω coil
T1 Transformer 40V cT @ 2A A&R 5755
SW1 Switch Rotary 2 pole 4 position
SW2 Switch miniature toggle 240V
Stereo Phone Socket
Two 6way RCA sockets
Two 2pin DIN sockets
CHASSIS
HEAT SINK
POT: SUPPORT BRACKET
COVER
ESCUTCHEON - rear panel
escutcheon — 3 small knobs — 2
large knobs — 4 rubber feet — 2
9.6mm spacers — 3 core flex & plug
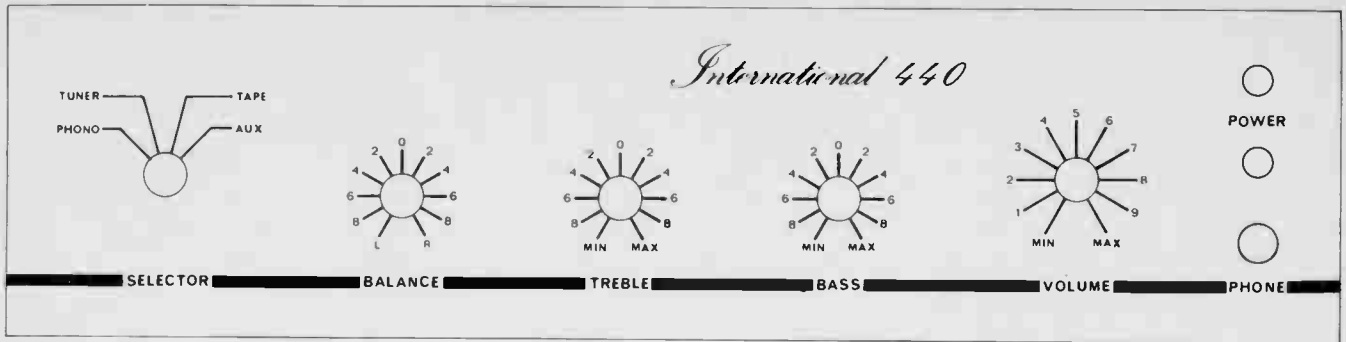rubber grommets.

SIMPLE 25 WATT AMPLIFIER

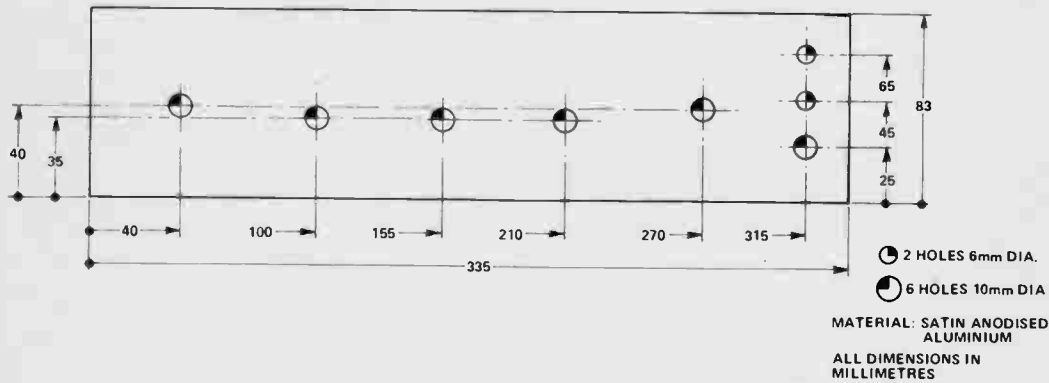Fig. 7. Front panel artwork. Full size 335 x 83 mm.
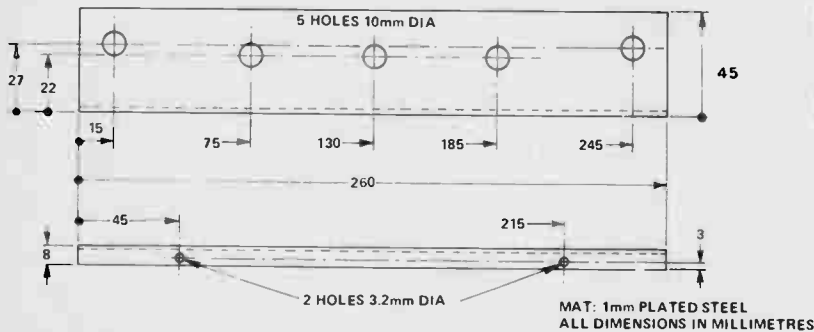

Fig. 8. Front panel details.

2 HOLES 6mm DIA.

6 HOLES 10mm DIA

MATERIAL: SATIN ANODISED
ALUMINIUM

ALL DIMENSIONS IN
MILLIMETRES

Fig. 9. Potentiometer support bracket.

5 HOLES 10mm DIA

2 HOLES 3.2mm DIA

MAT: 1mm PLATED STEEL
ALL DIMENSIONS IN MILLIMETRES
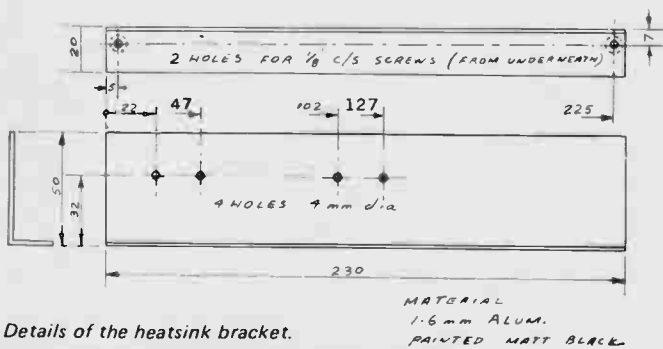
Fig. 10. Details of the heatsink bracket.

2 HOLES FOR 1/8 c/s SCREWS (FROM UNDERNEATH)

4 HOLES 4mm dia

MATERIAL
1·6 mm ALUM.
PAINTED MATT BLACK

Detail of power transistor assembly and
installation. Note compensation transistors
glued to output transistors (see text) and
mica insulators between power transistors and
chassis.

from the volume control to the
main-amplifier inputs.

The chassis can now be assembled by
mounting the transformer (terminals
on the outside), the front panel, the
phono socket, LED, speaker sockets,
the 6-way RCA sockets, the rubber
feet, the grommet for the power cord
and the power cord itself. The screw
for the cable clamp also mounts one of
the rubber feet.

The printed-circuit board module can
now be temporarily installed. If the
potentiometers used have a long
threaded portion (this depends on the
brand) there may be room for extra
nuts to hold the module and front
panel on. If not, the nuts will have to
be removed and refitted on the outside
of the front panel. The module is held
in by the potentiometer and by two
self-tapping screws into the heatsink
from the underside. Due to the
variations in alignment of the
mechanical parts, the location of the
holes in the heatsink cannot be
accurately determined. Therefore
these holes have been left undrilled
and can now be marked through the
holes in the chassis. The unit can now
be removed to facilitate drilling these
holes to a size suitable for the self

Fig. 11. Chassis details

MATERIAL
1 mm Steel

◑ 2 HOLES 15 mm

◕ 7 HOLES 10·3 mm

◔ 2 HOLES 6·4 mm

○ 25 HOLES 3·5 mm

4 HOLES FOR SELF TAPPERS

MATERIAL
BLACK MARVIPLATE
OR SIMILAR

SECTION A A

tappers. Be careful not to damage the printed circuit board, and to remove any shavings during this process.

Connect coax cable from the phono input and the tape output, long enough to reach the rear panel socket. Leads to join the output of the main amplifier to the relay, and leads from the relay long enough to reach the phono socket can be installed along with the lead from the speaker common and the LED leads. To facilitate the assembly pins should be installed to the board where the transformer is connected.

The 240 V input cable can now be joined to the switch and then to the transformer primary along with the capacitor C35. The earth wire shall be bolted directly onto the chassis as shown. To prevent possible personal injury the switch and the transformer primary terminals should be taped up with insulation tape.

The printed-circuit board module can now be permanently reinstalled. The transformer secondary can now be connected and the rest of the wiring installed. The phono socket along with R80 and R81 can be wired according to Fig. 3.

This completes the assembly of the unit which is now ready for testing.

TESTING

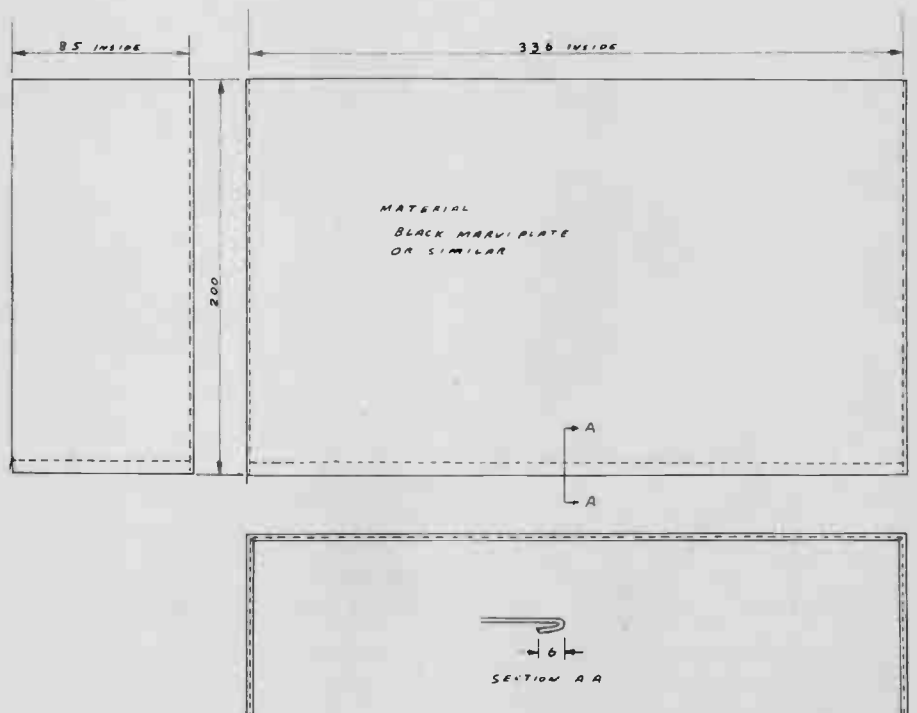Providing all components are in the correct place and all interconnections

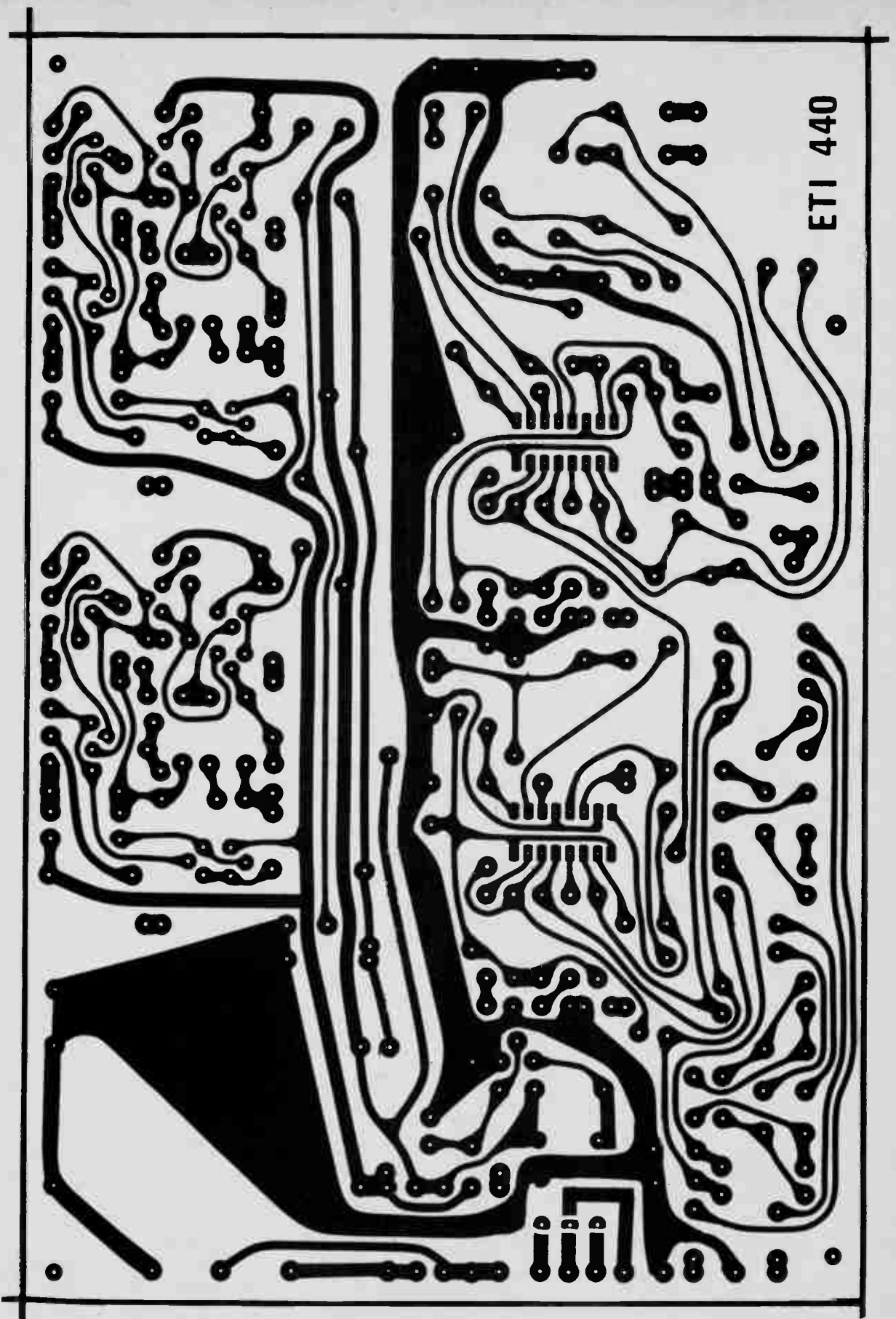Fig. 12. Cover for the amplifier.

Fig. 13. Full-size printed circuit layout for ETI 440.

SIMPLE 25 WATT AMPLIFIER

are correct the only adjustment is that to set the bias current in the output transistors.

Before switching on rotate the trim potentiometers, RV5 and 6, fully clockwise i.e. toward the transformer. Switch on without speakers connected and measure the voltage across R63 and adjust RV5 to give about 3 volts. Repeat the process with the other channel and R64 and RV6. The resistors R63, 64, 73 and 74 can now be shorted out (after switching off) by short links of wire soldered onto the leads of the resistor.

If a fault exists in the output stage, either a transistor is shorted to the heatsink or the bias setting is faulty etc. In such a case the resistors R63, 64, 73 and 74 will overheat and may burn out. This effectively protects the output transistors. ●

FAULT FINDING

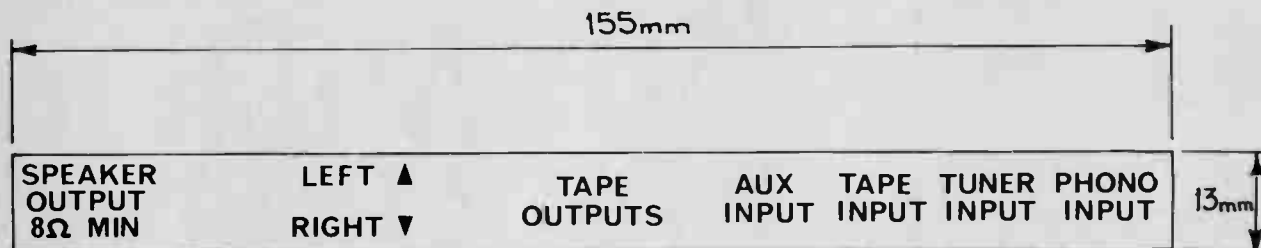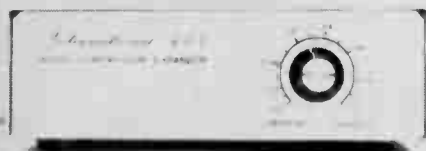| PROBLEM	POSSIBLE FAULT AND CHECKS
R63 or R73 gets hot (only one)	shorted insulation on Q15 or Q17
R63 and R73 gets hot (both)	bias current too high
Bias current not adjustable down to within limits	Q7 and/or Q8 faulty or wrong polarity. Voltage between base of Q15 and base of Q17 should be about 2.3 Volts
Bias current too low or zero	check output voltage, if about 0V then possible shorted Q7 or Q8
Output voltage high (near supply rail)	check current source Q11 is working Voltage across R61 should be about 0.65V. Check voltage across R45 it should be almost 0V (output high) if it is suspect Q5. If not check voltage at base of Q1 and Q3. Q3 should be higher than Q1 if so suspect Q1 or Q3
Output voltage low	check voltage across R45 should be about 0.7V if >0.7V suspect Q5. If less than 0.5V measure voltages at base of Q1 and Q3. Q3 should be lower than Q1 if so suspect Q1 or Q3
Main amplifier has no gain	faulty or disconnected C33, R51 or R53 wrong value
Main amp appears OK but pre amp does not work	check supply voltages or pin 6 (+10 V) and pins 9 and 16 (−6.6 V) Check output voltage of each individual amplifier. They should all be about 0V if not check components in local area.

155mm

SPEAKER OUTPUT 8Ω MIN	LEFT ▲ RIGHT ▼	TAPE OUTPUTS	AUX INPUT	TAPE INPUT	TUNER INPUT	PHONO INPUT	13mm

Fig. 13. Artwork for rear panel.

World Radio History

ACTIVE CROSSOVER

Optimize your multi-way system with this electronic approach to crossover design.

NO SINGLE loudspeaker can adequately handle the whole range of audio frequencies in high-fidelity reproduction. Thus to obtain the best possible fidelity we must resort to multiple speaker systems where each driver is designed to cover one portion only of the audio spectrum.

This means that some method must be used to divide the audio spectrum, from the amplifier, so that an individual driver only receives the band of frequencies for which it was designed. This is especially important for midrange and tweeter drivers for they are seldom capable of handling frequencies lower than a specified limit without being damaged.

PASSIVE CROSSOVERS

In simple systems a single capacitor may be used to block low frequencies and pass only highs to a tweeter. But unfortunately such a capacitor only provides 6 dB per octave attenuation. With some tweeters this attenuation is not sufficient to suppress the resonant frequency of the tweeter. The driver could thus be damaged when operated at high power levels. Additionally, the presence of frequencies other than those in the desired pass — band leads to high levels of intermodulation distortion and a general 'muddiness' of reproduction.

Hence all good multi-way systems use networks which provide at least 12 dB per octave attenuation, in the stop band, to control the audio band presented to each drive unit. A typical network for a three-way system is given in Fig.1. To keep power losses down in such networks the coils must have dc resistances of less than one ohm. This means that heavy gauge wire must be used, making the coils large and expensive. Additionally the high value of capacitance required would normally call for the use of non-polarized electrolytics, however, there are several disadvantages with these, Firstly, the tolerance on non-polarized electros is plus or minus 50%! This means that a crossover using them could quite easily give a system which had peaks and/or deep holes in the response. Additionally such capacitors have disadvantages such as
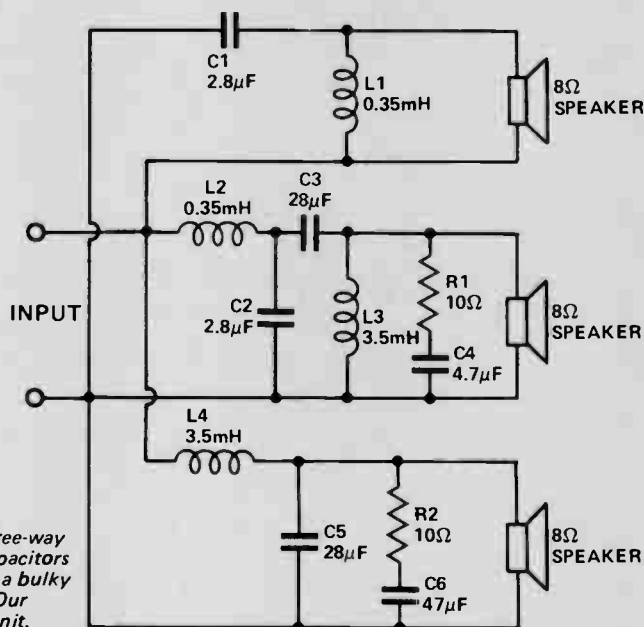

Fig. 1. A conventional three-way crossover system using capacitors and air-cored inductors is a bulky and very expensive unit. Our drawing shows a typical unit.

limited life, fairly low working voltages and problems due to leakage. Thus all good crossovers use polyester capacitors which, again, are rather expensive.

This all leads to the fact that, for a multi-way high-fidelity system, the crossover can and should be quite expensive. In fact it can cost almost as much as the bass driver!

Many people try to save money by trimming crossover cost — they use lighter wire and electros — and then wonder why an otherwise expensive system does not sound right. *The crossover design is one of the most important features of the whole system — it is better to compromise on a less expensive woofer than to compromise on the crossover.*

SPECIFICATION

Cutoff Slope (High pass)	12 dB / octave
(Low pass)	6 dB / octave
Maximum Output	2 V rms.
Distortion (at 2 V out)	< 0.05%
Noise (Below 2 V)	86 dB
Cutoff Frequency	As required
Input Impedance	47 k
Output Impedance (Buffered)	< 10 ohm
Minimum Load (Buffered)	500 Ohm
Frequency Response (Sum of all ouputs) 20 Hz to 20 kHz	± 1 dB

ACTIVE CROSSOVER

TCA 220

INPUT 1 −	1		AMP. 1&2 −Ve SUPPLY
INPUT 1 +			COMP 1
BIAS			OUT 1
INPUT 2+			OUT 2
INPUT 2−			COMP 2
+Ve SUPPLY			OUT 3
INPUT 3 +			COMP 3
INPUT 3 −	8	9	−Ve SUPPLY AMP 3 ONLY

* SEE TABLE 1

R8 33k · IC1/2 · R12 10k · E · BASS OUTPUT
R6 33k · R10 390 · R11 1k · C6 560p · RV1 10k
R7 33k · R9 33k · C5 330p
C4 1µF

+7.5V · R22 33k · IC2/1 · BASS OUTPUT BUFFERED · M
C17 1µF · L · INPUT FROM RV1 · R21 33k · R23 390 · R24 390 · C18 330p · −7.5V

C25 0.047 · IC3/1 · MID + HIGH OUTPUT BUFFERED · U
R · INPUT FROM RV2 · R37 33k · R38 390 · R39 390 · C26 330p · −7.5V

SW1 · B · C · R3 470k · C2 0.015
R2 220k · R13 33k
INPUT · A · C1 1µF · R1 47k · IC1/1 · 1 · 14 · 2 · 15 · R4 390 · R5 1k · C3 330p · −7.5V

+7.5V · R15 33k · F · MID + HIGH OUTPUT(3 WAY)
C8 · IC1/3 · R18 10k · G · HIGH OUTPUT (2 WAY)
C7 · R14 33k · R16 390 · R17 1k · C9 330p · −7.5V
C10 560p · RV2 10k
D · PREAMP OUTPUT

R28 33k · IC2/2 · R31 10k · MID OUTPUT · N · RV3 10k · S · C20 560p
R25 33k · F · R26 33k · R27 33k · R29 390 · R30 1k · C19 330p · −7.5V

+7.5V · R41 33k · IC3/2 · V · MID OUTPUT BUFFERED
C27 0.047 · R40 33k · R42 390 · R43 390 · C28 330p · −7.5V

R32 33k · IC2/3 · R36 10k · HIGH OUTPUT · P · RV4 10k · T · C24 560p
D · C21 · C22 · R34 390 · R35 1k · R33 33k · C23 330p · −7.5V
*SEE TABLE 1

R45 390 · R46 390 · IC3/3 · W · HIGH OUTPUT BUFFERED
C29 0.047 · R44 33k · C30 330p · −7.5V

+7.5V · C31 25µF 25V · TO PIN 6 IC2,IC3
0V · 0V
−7.5V · C32 25µF 25V · TO PINS 9,16 IC2,IC3

Q1 BD135 · +7.5V
SW2 · A · INPUT 240V ac · N · E · T1 240V/18VCT
H · D1 · C11 470µF 25V · R19 1k · ZD1 8.2V 400mW · C15 25µF 25V
D2 · C13 10µF 25V · ZD2 8.2V 400mV · 0V
J · C14 10µF 25V · C16 25µF 25V
D3 · C12 470µF 25V · R20 1k · Q2 BD136 · −7.5V
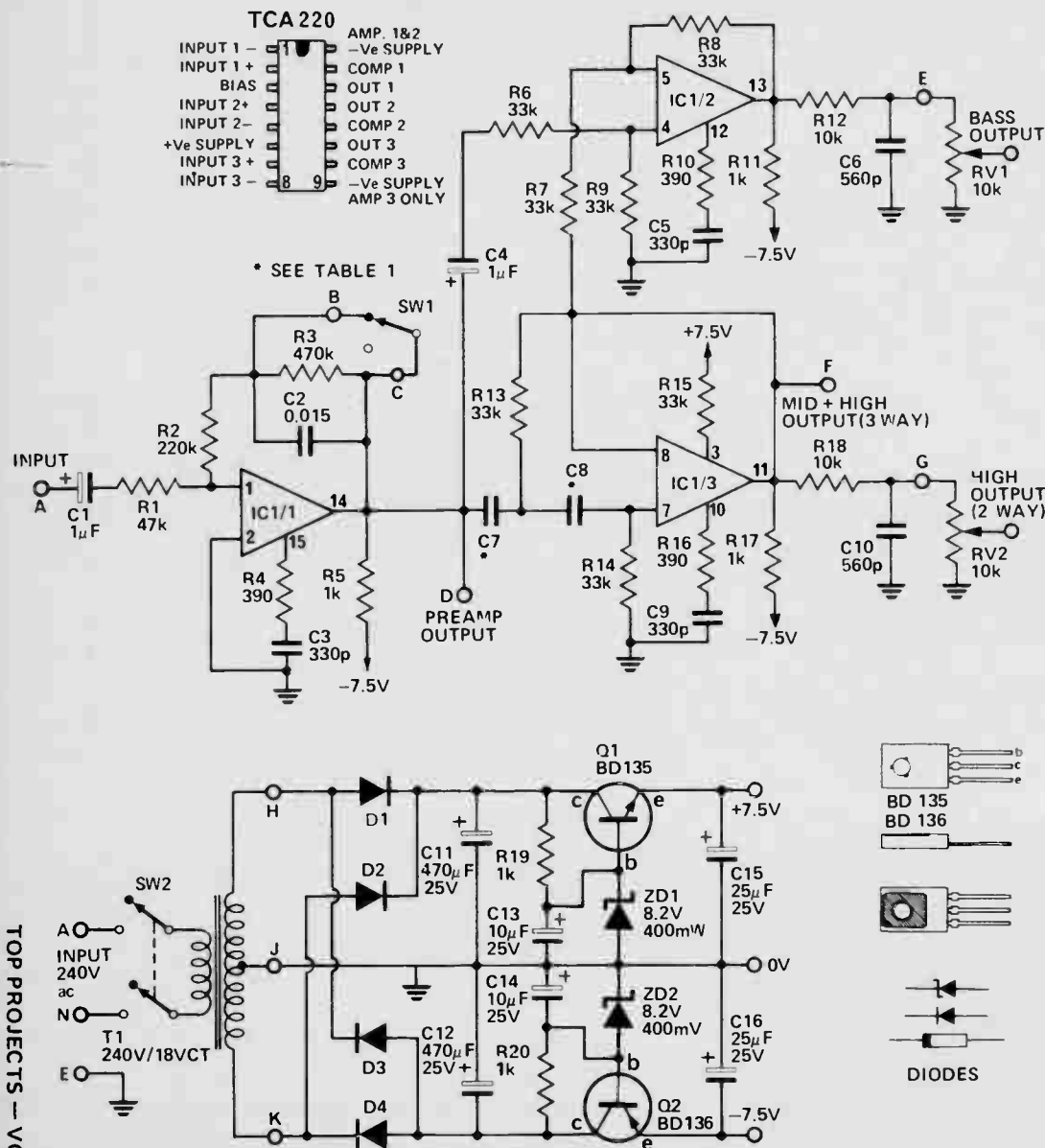K · D4

BD 135 · BD 136
b c e

DIODES

Fig. 2. Circuit diagram of the basic two-way electronic crossover and its power supply.
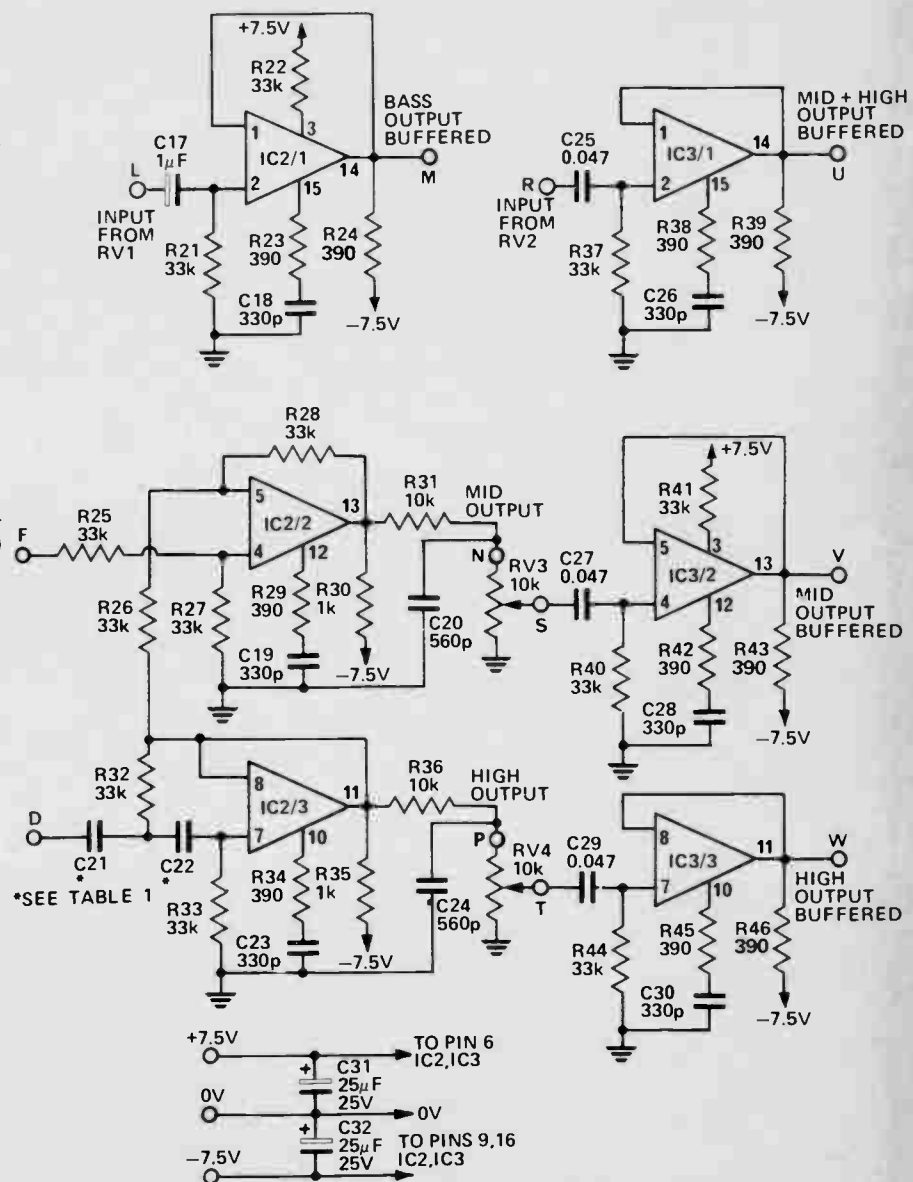
Fig. 3. Circuit diagram of the mid/high crossover board which provides four output buffer amplifiers.

The input signal is initially amplified by IC1/1. Switch SW1 together with R3 and C2 provide a maximum of 10 dB of boost below 50 Hz at a rate of 6 dB per octave. The frequency at which the boost comes in may be altered by selecting a value of C2 such that its reactance is 220k at the frequency where the woofer is normally 3 dB down. Thus if the turnover frequency is required to be 100 Hz the value of C2 should be halved.

If the boost facility is not required R3, C2 and SW1 should be deleted and a link installed between points B and C. The mid frequency gain is set by R2/R1 to about 13 dB and the input impedance is equal to the value of R1, that is, 47 k.

The first high-pass filter consists of IC1/3 where R13, R14, C7 and C8 set the cut-off frequency. The values of C7 and C8 required may be found from Table 1. This output is the high range in a two way system, or the mid plus high of a three-way system. This signal, when subtracted from the input signal by IC1/2 gives the bass range output. A second high-pass filter, where C21, C22, R32 and R33 form the frequency determining network, gives the output for the tweeter in a three-way system. This when subtracted from the mid-plus-high signal leaves the mid only as required.

Each of these outputs goes to a level set potentiometer and then is buffered by amplifiers IC2/1 and IC3/1,2,3. These outputs are now capable of driving loads in excess of 500 ohms. If the crossover is to be used to drive a constant and known load (that is, it is to be used on only one type of amplifier) the buffer amplifiers may be omitted and the outputs taken directly from the potentiometers.

The full-wave power supply provides plus or minus 13 volts which is regulated down to plus or minus 7.5 volts, by series regulators Q1 and Q2, where zeners ZD1 and ZD2 provide the necessary reference. If the unit is to be powered from the power amplifier C11, 12, and D1 to D4 should be deleted. Resistors R19 and R20 are altered to suit as shown in Table 2. The collector of Q1 now goes to the positive supply rail of the amplifier and the collector of Q2 to the negative supply rail. If the amplifier supply rail is above plus and minus 20 volts, or if both printed circuit boards are being used, (that is it is a buffered three way system) a heatsink must be added to Q1 and Q2.

PARTS LIST – ETI 433A

2-WAY SYSTEM

R4,10,16	Resistor	390	¼W	5%
R5,11,17	"	1k	¼W	5%
R19,20	"	1k	¼W	5%
R12,18	"	10k	¼W	5%
R6,7,8,9	"	33k*	¼W	2%
R13,14,15	"	33k	¼W	5%
R1	"	47k	¼W	5%
R2	"	220k	¼W	5%
R3	"	470k	¼W	5%

*These may be any value between 15k and 82k provided they are all the same value and preferably 2%.

RV1,2 Potentiometer 10k lin.

C3,5,9	Capacitor	330 pF ceramic	
C6,10	"	560 pF ceramic	
C2	"	0.015 μF polyester	
C1,4	"	1 μF Tag tantalum	
C13,14	"	10 μF 25V Electro	
C15,16	"	25 μF 25V Electro	

C11,12	Capacitor	470 μF 25V Electro	
C7,8	"	See Table 1.	

D1-D4 Diode EM401, 1N4005 or similar
ZD1,2 Zener Diode 8.2 volt 400 mW
Q1 Transistor BD135 or similar
Q2 Transistor BD136 or similar
IC1 Integrated Circuit TCA220
T1 Transformer 240V/18V CT 150 mA
SW1 toggle or slide switch SPDT
SW2 Toggle switch DPDT 240V rated
PC Board ETI 433A

PARTS LIST – ETI 433B

3-WAY WITHOUT BUFFERS
All 2-way system PLUS

R29,34	Resistor	390	¼W	5%
R30,35	"	1k	¼W	5%
R31,36	"	10k	¼W	5%

R25,26,27,28	Resistor	33k*	¼W	2%
R22,32,33	"	33k	¼W	5%

* These may be any value between 15k and 82 k provided all are the same value and preferably of 2% tolerance

RV3,4 Potentiometer 10k Lin

C19,23	Capacitor	330 pF ceramic	
C20,24	"	560 pF ceramic	
C21,22 See Table 1.			

IC2 Integrated Circuit TCA220
PC board ETI 433B

3-WAY SYSTEM WITH BUFFERS ADD

R24,39,43,46	Resistor	390	¼W	5%
R23,38,42,45	"	390	¼W	5%
R21,37	"	33k	¼W	5%
R40,41,44	"	33k	¼W	5%

C18,26,28,30	Capacitor	330 pF ceramic	
C25,27,29	"	0.047 μF polyester	
C17	"	1 μF TAG Tantalum	
C31,32	"	25 μF 25V electro	

IC3 Integrated Circuit TCA220

R21	33k
R22	33k
R23	390
R24	220
R25	2% •
R26	2% •
R27	2% •
R28	2% •
R29	390
R30	1k
R31	10k
R32	33k
R33	33k
R34	390
R35	1k
R36	10k
R37	33k
R38	390
R39	220
R40	33k
R41	33k
R42	390
R43	220
R44	33k
R45	390
R46	220
C17	1
C18	330p
C19	330p
C20	560p
C21	•
C22	•
C23	330p
C24	560p
C25	0.047
C26	330p
C27	0.047
C28	330p
C29	0.047
C30	330p
C31	25
C32	25

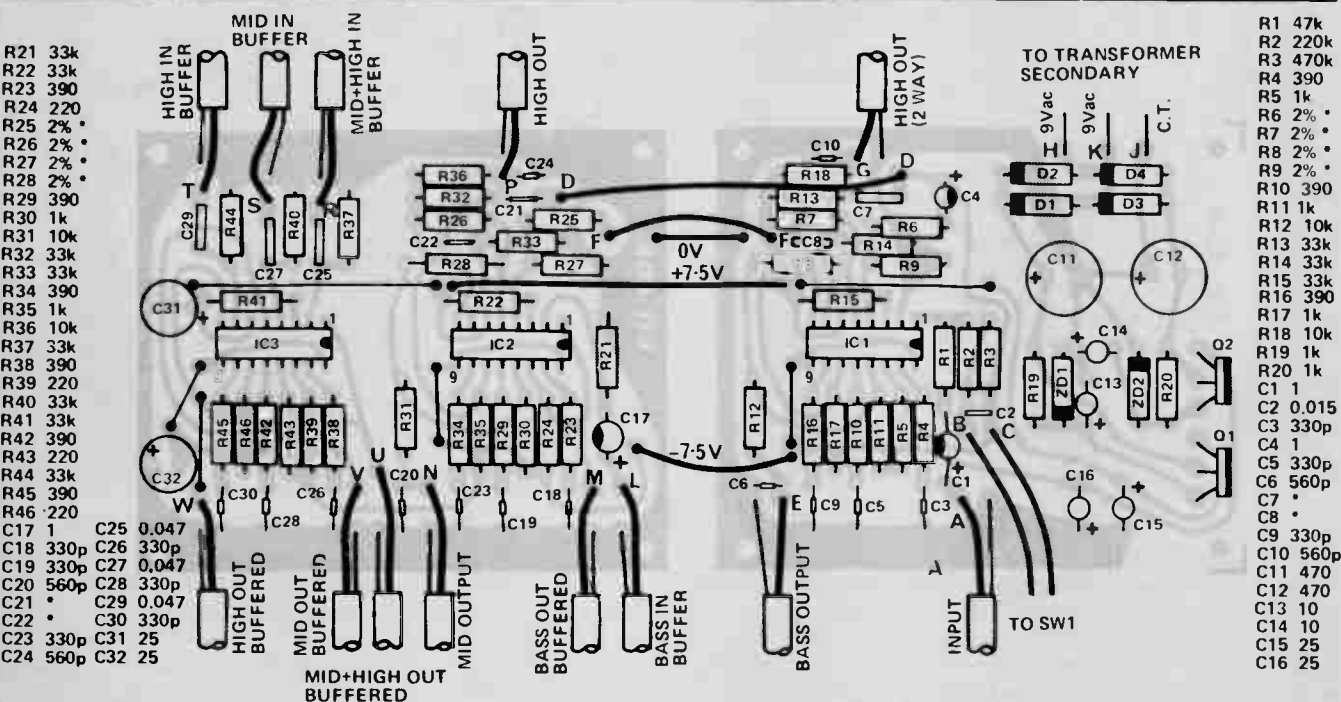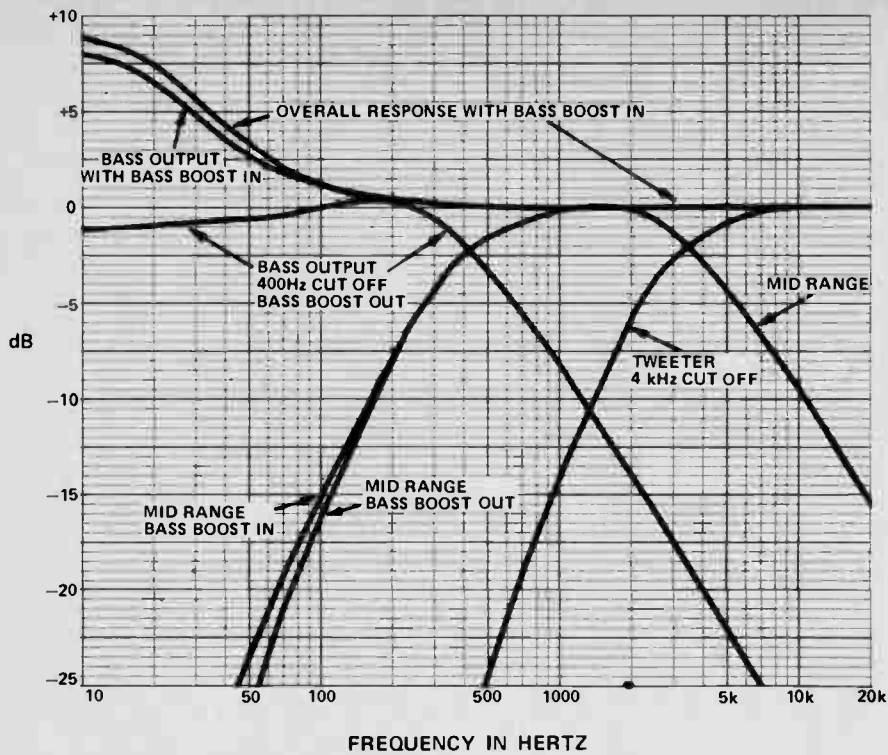|	
R1	47k
R2	220k
R3	470k
R4	390
R5	1k
R6	2% •
R7	2% •
R8	2% •
R9	2% •
R10	390
R11	1k
R12	10k
R13	33k
R14	33k
R15	33k
R16	390
R17	33k
R18	10k
R19	1k
R20	1k
C1	1
C2	0.015
C3	330p
C4	1
C5	330p
C6	560p
C7	•
C8	•
C9	330p
C10	560p
C11	470
C12	470
C13	10
C14	10
C15	25
C16	25

Fig.4. Component overlay for complete three-way system capacitance values are in microfarads except where otherwise noted.

Response curves of the active filters.

Graph labels:
- OVERALL RESPONSE WITH BASS BOOST IN
- BASS OUTPUT WITH BASS BOOST IN
- BASS OUTPUT 400Hz CUT OFF BASS BOOST OUT
- MID RANGE
- TWEETER 4 kHz CUT OFF
- MID RANGE BASS BOOST IN
- MID RANGE BASS BOOST OUT
- dB
- FREQUENCY IN HERTZ

TABLE 1	
CROSS OVER FREQUENCY IN HERTZ	VALUE OF C7,8 or C21, 22 in μF
100	0.082
130	0.068
150	0.056
200	0.047
230	0.039
270	0.033
330	0.027
400	0.022
500	0.018
600	0.015
750	0.012
1000	0.0082
1300	0.0068
1500	0.0056
2000	0.0047
2300	0.0039
2700	0.0033
3300	0.0027
4000	0.0022
5000	0.0018
6000	0.0015
7500	0.0012
9000	0.001

ACTIVE CROSSOVER
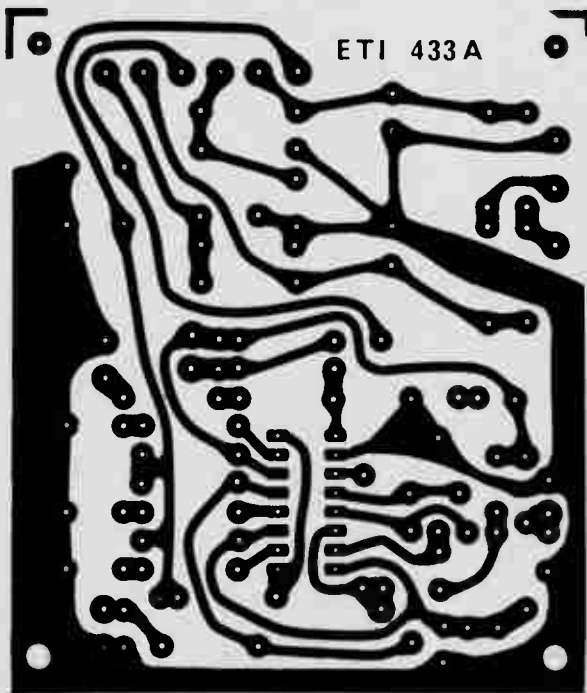
Fig. 5. Printed-circuit layout for the two-way board. Full size 77 x 90 mm.
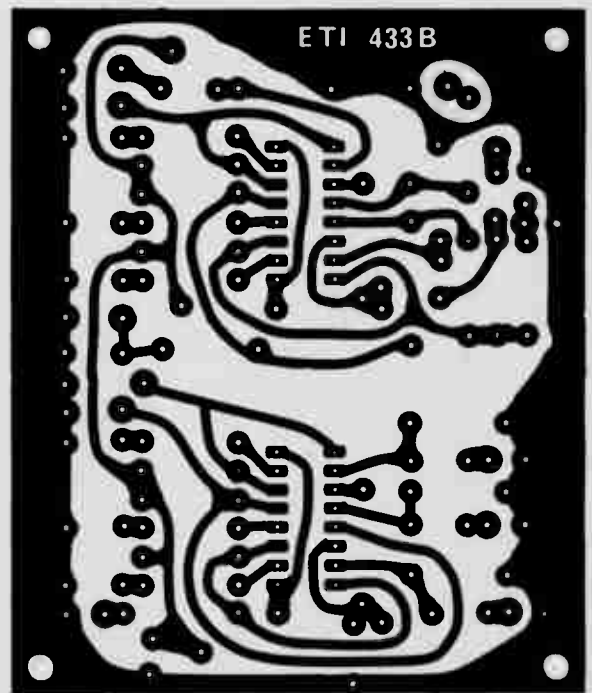
Fig. 6. Printed-circuit layout for the add-on three-way board. Full size 77 x 90 mm.

ACTIVE APPROACH

Having now established that effective conventional crossovers cost money, we may now wonder if that money could be spent in a better way by using a completely different approach. There is a better way, but until recently it has been much too expensive to be generally used. The method is to use an electronic crossover, after the preamplifier, followed by separate power amplifiers for each driver. This is feasible because a power amplifier can now be built at a cost which is about the same as that of the passive crossover. Indeed quite a few manufacturers are bringing out systems based on this principle.

Even well-designed crossovers have several serious disadvantages. As we have already said they are expensive, they waste power, they reduce damping factor (in the crossover region damping factor may drop to less than unity) and they only perform correctly into their designed load impedance. Practical drivers exhibit

32
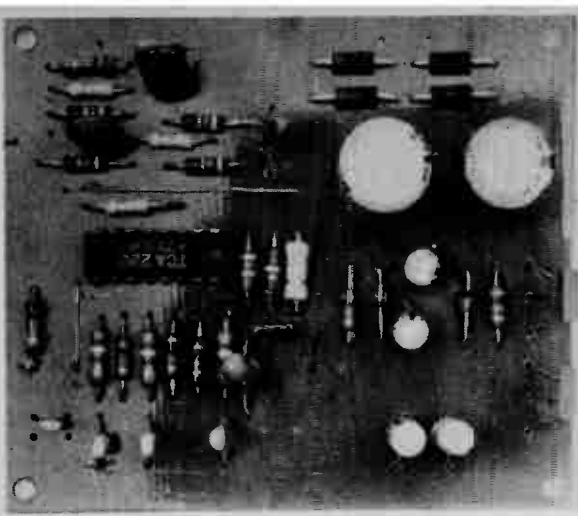
The basic two-way electronic crossover.
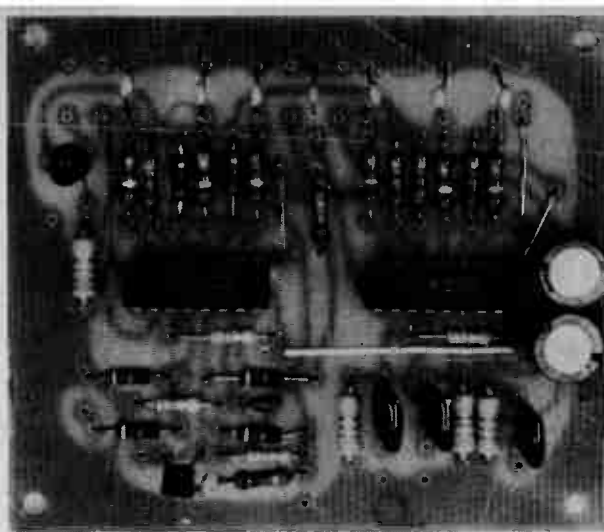
This board provides three-way crossover plus output buffers if required.

their nominal impedance only over a very small portion of their passband, and impedance may well increase to several times the nominal value at the high end of the range. It is possible to compensate for this, to some extent, by using extra networks across the driver (the series RC networks in Fig. 1) — but this adds even more expense. Further, it is very difficult to alter the crossover frequency and also difficult to trim the crossover for best results.

However, if we were to use an electronic crossover incorporating active filters, we overcome most of the problems mentioned in a single stroke. The bulky and expensive inductors and the large and expensive capacitors are eliminated. Damping factor is restored (due to separate amplifiers being used to drive each speaker directly) and it is quite easy to change or trim the crossover frequency as desired.

Further, as electronic crossovers may have gain, it is quite a simple matter to match the various drivers of the system for sensitivity. This can be only achieved, in passive designs, by attenuating the more sensitive units down to the level of the least sensitive unit. A process which can be quite wasteful of amplifier power.

Of course with active crossovers, as with anything, there are disadvantages. In active filters we generally use operational amplifiers to implement the filters and therefore, bandwidth and noise become considerations. Further, as said before, a separate amplifier is required for each driver or group of drivers — and this can be expensive.

Nevertheless the technique is now quite feasible and is certainly worthwhile. Consequently we have developed a minimum — expense method of building a very fine system based on active filter techniques.

This article describes a basic two or three-way active filter system which may be incorporated into existing amplifiers. The next article in this book describes an active filter/amplifier combination based on the 422 amplifier (page 40). A suitable three-way speaker system for use with this amplifier was described in the December 1975 issue of Electronics Today.

DESIGN FEATURES

There are several different approaches which may be used in the design of active filters. The first and most commonly used method, is to use separate filters for the bass, mid and high range speakers. This method is capable of compensating for amplitude, if the components are chosen correctly, but not for phase. In fact there has to be a phase change of 180° between filters to eliminate the hole that would otherwise occur at the crossover point. This is the reason for the tweeter being reversed in phase when a conventional crossover is used in a two-way system.

Another design approach, and the one that we have elected to use, is to use an active high-pass filter to generate the signal for the tweeter, and to subtract this signal from the input signal in a differential amplifier in order to generate the bass output. This substraction process generates the required crossover characteristic with both amplitude and phase taken in to account.

Initially we were worried because the bass output had a slight peak before the cutoff point but the peak is necessary to maintain that response when phase is taken into account. When the output of all channels are

summed the combined response is within plus or minus one quarter of a dB of being flat over the whole range.

With this type of active filter the initial slope can be varied by adjusting the feedback resistor (R13, R32) to give a slow rolloff (Bessel filter) or to give a slight peak and fast cutoff (Chebishev). The sharper the initial cutoff the greater the apparent peak in the bass response.

As several operational amplifiers are required to implement this design we elected to use the TCA 220 triple operational amplifier. This IC, as well as containing three op-amps in the same package, is cheaper than using three separate op-amps of the 741 type or similar. Unlike the 741 type of op-amp, the TCA 220 requires a pull-down resistor on each output and a compensation network. An additional resistor is required to bias each complete IC. The use of the TCA 220 simplifies and cheapens the construction of the filter system considerably.

With active filter crossovers it is a relatively simple matter to alter the gain-versus-frequency characteristic of the filter, within its pass-band, in order to compensate for non-linearities in the associated driver. An example of this kind of compensation is our inclusion of low frequency equalisation for the woofer. Most woofers begin to drop off in the 50 to 100 hertz region. This may be corrected to some extent by adding boost below this turnover frequency. In our design we have provided 6 dB of boost which may be switched in when desired and which is limited to a maximum of 10 dB. The 10 dB limit is necessary to prevent the amplifier being over driven at low frequencies even at fairly low average listening levels.

The turnover frequency may be

ACTIVE CROSSOVER

selected by means of a simple component change to suit the driver in use. This equalisation technique can effectively extend the low frequency response by another octave, eg, from 50 hertz down to 25 hertz.

CONSTRUCTION

The configuration of the electronic crossover used will depend very much on the system into which it is to be built. The prospective builder should therefore carefully determine his individual requirements before commencing to build a system.

If a fixed load is to be driven (ie, numbers of amplifiers) as would be the normal case, the buffer amplifiers are not required, and the output may be taken directly from the potentiometers.

It must also be decided whether you want a two-way or a three-way system. Rather than use three separate amplifiers to drive the woofer, mid and tweeter drivers separately, it may be better to use a conventional crossover for the mid/high crossover

and a two-way electronic crossover for the bass/mid.

Mono or stereo? If a stereo unit is to be built only one power supply is required and the bass-boost switch and the level potentiometers can all be dual units.

If the amplifier has a dual power supply with voltages exceeding ± 10 volts it may be used to power the crossover. This course of action will save one transformer, four power diodes and the filter capacitors.

Mechanical layout is not given as the unit will most probably best be mounted within the amplifier case.

Keep it well clear of the power transformer and mount it using insulated spacers. This is necessary to avoid the possibility of earth loops which will cause a high hum level.

Full component overlays are given for all alternatives but only the circuitry required should be assembled. In a three-way system without buffers one section of IC2 is not used. In this case just leave out the components associated with the

unused section in order to reduce power consumption.

If the unit is being powered from the main amplifier, or a three-way system with buffers is being used, a heatsink is required. The heatsink recommended is a piece of aluminium 60 x 85 mm bent into a 'U' shape and mounted vertically on the end of the board. The transistors should be insulated from the heatsink.

For a stereo system delete the power supply components on one of the boards (up to C15 and C16) and just link the two boards together. ●

TABLE 2	
MAIN AMPLIFIER SUPPLY VOLTAGE	VALUE OF R19,R20
± 10-15 V	1 k
± 15-20 V	1.8 k
± 20-25 V	2.7 k
± 25-30 V	3.9 k
± 30-40 V	5.6 k
± 40-50 V	8.2 k
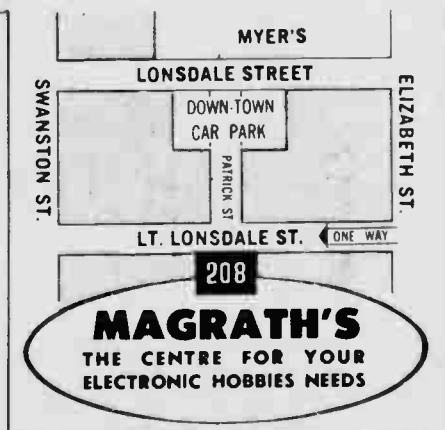
CROSSOVER AMPLIFIER
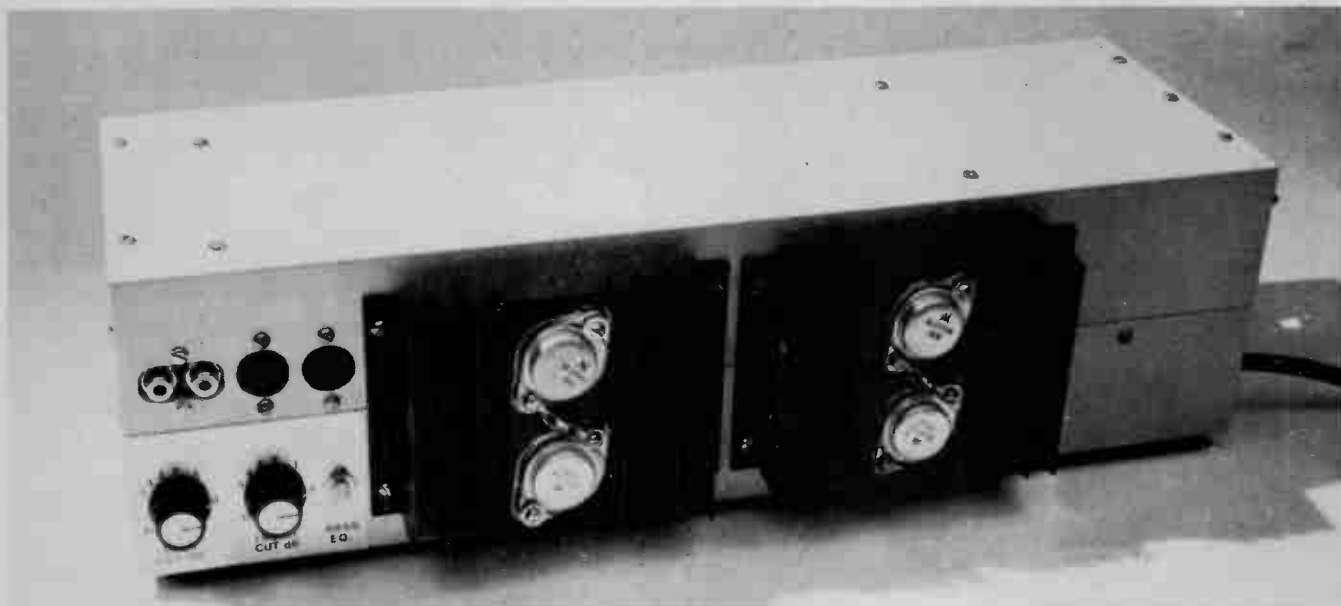
One approach to an electronic crossover system.

THIS article gives details of a complete high-fidelity system which uses the active-crossover boards described in the last article in this book. The system described is not intended to be considered as the only possible way, merely as an example of the way in which a system may be built.

The system described uses two 422 power-amplifier modules, but any other amplifier could equally well be used eg, the 440 amplifier. A two-way system is described, that is, one amplifier is used for the high frequencies and one amplifier is used for the low frequencies for each speaker system. Thus only two two-way crossover boards are used together with the two amplifier boards and the power supply to make the complete system.

CONSTRUCTION

We built our prototype into two pieces of channel aluminium as may be seen in the photographs. The aluminium channel used had dimensions of five inches by two inches and we used a piece 380 mm long for each side. Unfortunately this particular extrusion seems to have fallen a victim to metrication, the only section that seems to be available now is 100 x 50 mm which unfortunately is too small. However an equivalent can readily be made from 1.6 mm aluminium bent up as required. We suggest that you make your chassis about 430 mm long as we found ours to be a little cramped.

The heatsinks used were the Mullard 35D x 75 mm and these were assembled as detailed in the 422 amplifier section (page 40) The printed circuit boards were also assembled as detailed in that section. Printed-circuit pins should be used for all connections to the board as this makes interconnection of the unit much easier.

The location of the individual modules and components can be seen from the internal photograph of the unit. If construction similar to ours is used, with the transformer close to one end of the printed circuit boards, some trouble with hum may be encountered in the main amplifiers closest to the transformer. We overcame this problem by using these amplifiers for the high channels and by reducing their bass response by changing C4 from 100 microfarad to 2.2 microfarad. With this modification the response of the amplifier will drop off below 300 Hertz. thus reducing hum, but will still be adequate for high

channel use. If the high channel response is required to be lower than 300 Hertz then the transformer must be mounted further away from the amplifier modules.

Some care must be taken to prevent earth loops causing problems. The wiring of the power cables is as shown in Fig. 1, the most important being the zero volt line. The zero volt lines of both boards are linked by a heavy cable and the common side of the transformer is joined to the centre of this link. The common for the speakers is also joined to this same point. Make sure that this junction is insulated so that a short does not occur when the unit is closed up. The plus and minus 40 volts are taken to the crossover board which has the regulator on it, and the plus and minus 7.5 volts is linked between the two boards. The zero volt line for the crossover boards is taken via the signal output leads to the appropriate amplifier board.

Due to the power dissipation in the regulator for the crossover, a heatsink must be used. We simply bolted the crossover boards onto the end panel by means of a piece of angle aluminium, and bolted the transistors onto the end panel using insulating washers. We used a piece of cardboard

CROSSOVER AMPLIFIER
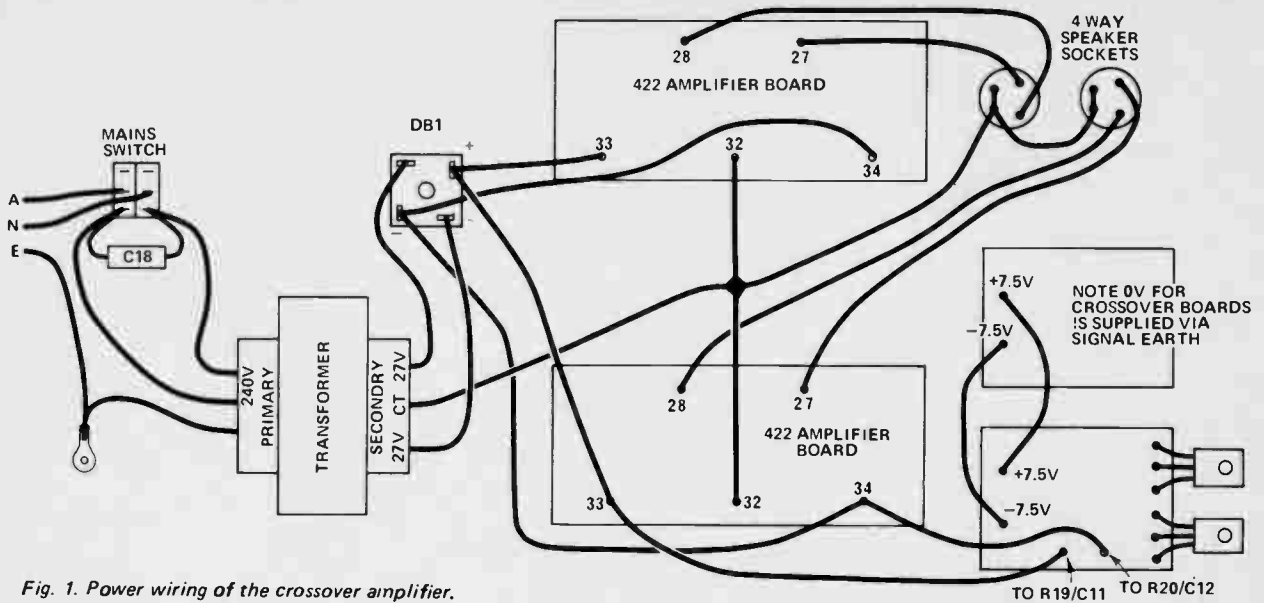
Fig. 1. Power wiring of the crossover amplifier.
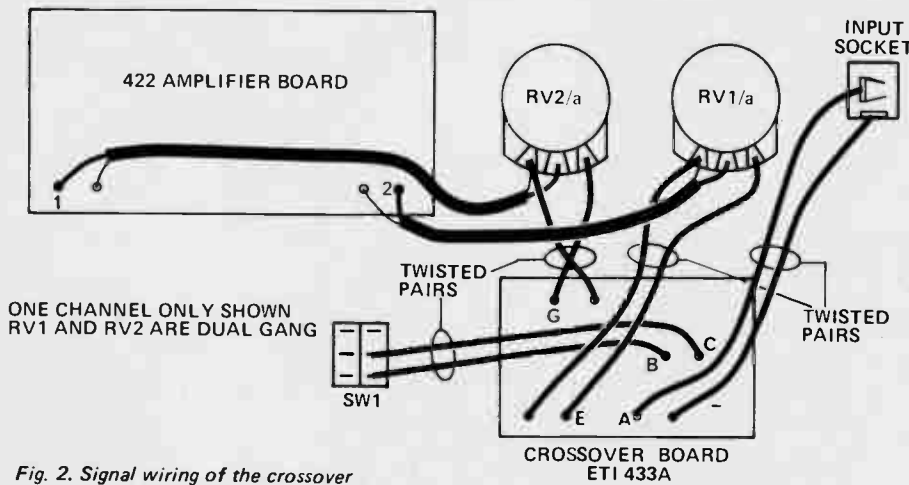
Fig. 2. Signal wiring of the crossover amplifier.

ONE CHANNEL ONLY SHOWN
RV1 AND RV2 ARE DUAL GANG

between the two boards to prevent any shorts occuring between the two boards. We also installed cardboard under each of the power amplifier boards similarly to protect them.

Coaxial cable was used to connect the inputs from the potentiometers to the main amplifiers but only twisted pairs from the crossover boards to the potentiometers. Coaxial cable could have been used here but was found to be not necessary as these leads are a long way from the power transformer.

Finally, a word about the power transformer. We have only used a single power transformer, as used in the 422 amplifier, to power the two complete 422 amplifier boards. But remember that the frequency spectrum is split up between the high and low channels and hence each amplifier, although called upon to provide the same peak power, only has to handle half the average power. The transformer is thus quite capable of handling the total load as the system is still nominally 50 watts per channel.

PARTS LIST —
CROSSOVER AMPLIFIER

Two complete sets of components as detailed for the 422 power amplifier module except that only one transformer and rectifier bridge is required for domestic use — especially if the crossover is above 2 kHz.

Two ETI 433A boards with the following exceptions. The transformers, D1 to D4, C11 and C12 are not required for either, and C13, C14, R19, R20, Q1, Q2, ZD1 and ZD2 are not required on the second board. The value of R19 and R20 on the first board should be 8.2 k.

Switch SW1, if required, should be a double pole switch and RV1 and RV2 should be dual gang linear potentiometers.

Chassis.

Input and output sockets as required.

Fig. 3. Artwork for the level control panel. Full size 73 x 50 mm.

World Radio History

BOOSTER AMPLIFIER

The booster amplifier (cover removed).

eti

PROJECT 422B

Increase the output from your existing amplifier to 50 watts per channel.

AFTER many years of faithful service you have finally decided to update your old Hi-Fi system with a new pair of speakers. Upon evaluation however, you find that the modern speakers you have chosen are much less efficient than those you presently have. This means that not only do you have to get new speakers, but you also have to replace an otherwise perfectly good amplifier because its five-to-fifteen watts output is no longer anywhere near enough. A pity, because there may be nothing wrong with the preamplifier and you may have to pay out $200 or more just to get that additional power.

An obvious solution is to retain your existing amplifier, which has all the facilities that you require, and obtain the extra power required by means of a booster amplifier. Unfortunately commercial booster amplifiers are very rare, if available at all. The ETI 422B is designed to fulfill this need and thus save the person updating his system a considerable number of dollars that need not be spent in replacing the preamplifier.

The ETI 422B is designed to be used as a main amplifier, driven from the existing preamplifier, or as a booster amplifier driven directly from the speaker output of the existing power

---

MEASURED PERFORMANCE OF THE PROTOTYPE

POWER OUTPUT
Both channels driven
into 8 ohm load 50 watts RMS

FREQUENCY RESPONSE.
20 Hz – 20 kHz ± 0.5 dB

CHANNEL SEPARATION
at rated output and 1 kHz 80 dB

HUM AND NOISE
With respect to rated output –100 dB

SENSITIVITY
For 50 watts output 500 mV

DISTORTION	100 Hz	1 kHz	6.3 kHz
1 watt	0.14%	0.11%	0.12%
5 watts	0.17%	0.13%	0.15%
10 watts	0.16%	0.11%	0.13%
50 watts	0.27%	0.38%	0.60%

DAMPING FACTOR > 70

Fig. 1. Interconnections of the booster amplifier (heatsink not shown).

amplifier. It provides an output of up to 50 watts into 8 ohm speakers with a distortion that is typically around 0.2%.

It must be noted however that the distortion and noise cannot be less than that available from the existing amplifier and you must ensure that this amplifier is of good quality if this add-on technique is to be successful.

HOW IT WORKS

The amplifier is constructed around the power module from the ETI 422 basic amplifier described on page 40. The only additional circuitry required is that for the input attenuator or for a direct input depending on whether a booster or main amplifier approach is being used. We have used 33 ohm resistors in the earthy side of each input to prevent the damage which may occur to some amplifiers if the leads to the booster amplifier are inadvertently connected the wrong way around.

CONSTRUCTION

Assemble the main amplifier printed-circuit board and the heatsink assemblies in accordance with the component overlays and drawings for the 422.

We mounted our prototype into the same size box, undrilled, as was used for the ETI 440 amplifier (July 1975). However any conveniently sized box would be suitable. To minimize hum pickup the transformer was mounted centrally to keep it as far away from the input circuits as possible. If a larger box is used put the transformer as far away as is possible from both inputs. Chassis mounting fuses were used as they are less expensive than the rear-panel mounting types, and only need to be changed on the very rare occasions when the speakers leads are accidently shorted.

The heatsinks used are the Mullard 35D type which are smaller than those originally used in the 422 amplifier. For domestic applications the larger heatsinks have been found to be unnecessary.

A power outlet socket was fitted to the amplifier so that the existing amplifier may be powered from it if required. The individual constructor may include or omit this socket as required. The interwiring details (except for the heatsinks) are given in Fig. 1. For the values of resistors required in the divider networks reference should be made to Table 1 as these will vary depending on the power output of the existing amplifier. If required these may be made adjustable by substituting a potentiometer (10 k) for the series resistor.

Most modern amplifiers can work into a high impedance without trouble. However some older types, especially those with an output transformer need to be terminated into the correct load. The resistors shown across the inputs are for this purpose and should be made equal in value to the nominal output impedance of the existing amplifier. The rating of these resistors should be about two watts. ●

TABLE 1

AMPLIFIER POWER (8 ohms)	VALUE OF SERIES RESISTOR
2W	2.7 k
5W	4.7 k
10W	6.8 k
15W	8.2 k
20W	10 k

eti
PROJECT 422
50 WATT POWER MODULE

Details of the basic amplifier used in the Booster and Crossover amplifier.

Fig. 1. Circuit diagram of the 50 watt module.
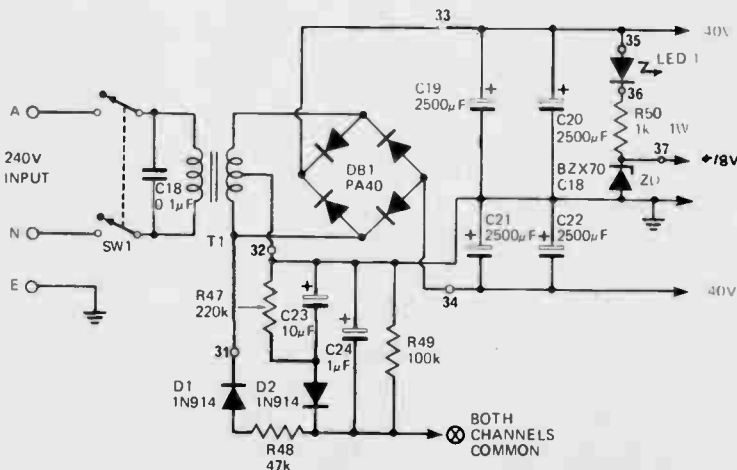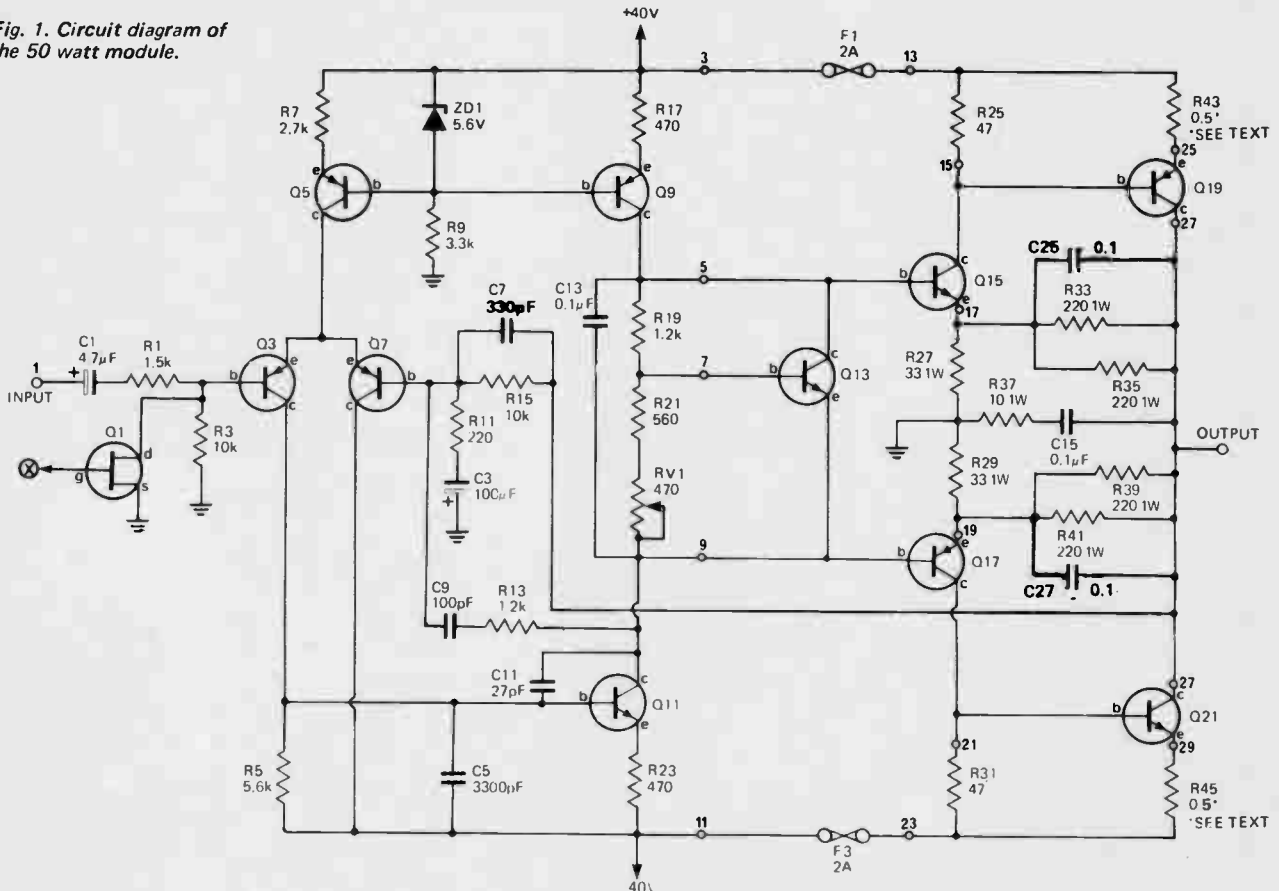
NOTES
Q1 2N5485
Q3,5,7 BC557,BC177
Q9,17 BD140
Q11,15 BD139
Q13 PN3643
Q19 MJ2955
Q21 2N3055

RIGHT CHANNEL ONLY SHOWN
LEFT CHANNEL IS IDENTICAL
EXCEPT COMPONENT NUMBERS
ARE THE EVEN NUMBERS
ie, R 16 IS THE SAME AS R15

COMPONENTS D1,2 Q1,2
R47,48,49, C23,24 ARE
ARE FOR THE DETHUMP CIRCUITRY
AND MAY NOT BE REQUIRED

LED 1, R50 AND ZD3 ARE
USED ONLY IF THE 422
PREAMPLIFIER IS USED

DETAILS for the construction of this power module were first published as part of the International 422 amplifier, described in the May 1974 issue of Electronics Today. Both the add-on power-booster and crossover amplifiers described in the preceding articles use this power amplifier.

Most of the electronics is mounted on either the printed circuit-board or on the heatsinks. The board may be assembled in accordance with the component overlay diagram given. Note that capacitors C25, 26, 27 and 28 do not have holes provided for them and they are therefore mounted directly across resistors R33, 34, 41 and 42 respectively.

The heatsink should be assembled as shown in the photograph and the drawing. The transistors Q13 and 14 should each be epoxied into a hole in one of the heatsinks to ensure good thermal contact. Also secure all leads to the heatsink with epoxy. The interconnections between the printed circuit board and the heatsink should be carried out in accordance with the wire numbering on the diagrams. Final wiring details are given in the respective separate projects.

HOW IT WORKS – MAIN AMPLIFIER

The input signal is fed via C1 and R1 to the base of Q3 which, with Q7, forms a differential pair. Transistor Q5 is a constant current source where the current is [5.6 V (ZD1) – 0.6 (Q5)]/2700 (R7) – that is about 2 mA. This current is shared by Q3 and Q7. Transistor Q9 is also a constant current source supplying about 10 mA which, if no input signal exists, flows through Q13 and Q11. The differential pair controls Q11 and thus the voltage at its collector.

The resistors R19 and R21, together with potentiometer RV1, control the voltage across Q13 and maintain it at about 1.9 volts. But as Q13 is mounted on the heatsink, this voltage will vary with heatsink temperature. Assuming that the voltage at points 5 and 9 is equally spaced about zero volts (ie ± 0.95 volts), the current will be set at about 12 mA through Q15 and Q17. The voltage drop across the 47 ohm resistors (R25 and R31) will be enough to bias the output transistors, Q19 and Q20, on slightly to give about 10 mA quiescent current. This quiescent current is adjustable by means of potentiometer RV1.

Local feedback is applied to the output stage by the network R33, R35, R39 and R41, giving the output stage a voltage gain of about four. The overall feedback resistor, R15, gives the required gain control.

Protection to the amplifier, against shorted output leads, is provided by fuses in the positive and negative supply rails to both amplifiers.

Temperature stability is obtained by mounting Q13 on the heatsink. Q13 will thus automatically adjust the bias voltage. Frequency stability is ensured by C9/R13, C5, C7, C11, C25 and C27.

Although the power amplifier itself does not produce a thump in the loudspeakers on switch on, the preamplifier used may. To reduce any thump to an acceptable level, Q1 is used to short the input for about two seconds on switch-on and immediately after switch-off.

The power supply is a conventional full-wave bridge with centre tap, providing + 40 volts and –40 volts. Diode D1 is used to rectify a second negative supply which is used to control the FETs. Due to the resistance in series with the diode, the charge of C24 is slow. In addition, during the charge period, C23 is also being charged increasing the delay. On switch off, however, C23 cannot assist the voltage on C24 and the off-timing is much shorter than the on-timing.

Fig.3. Component overlay.
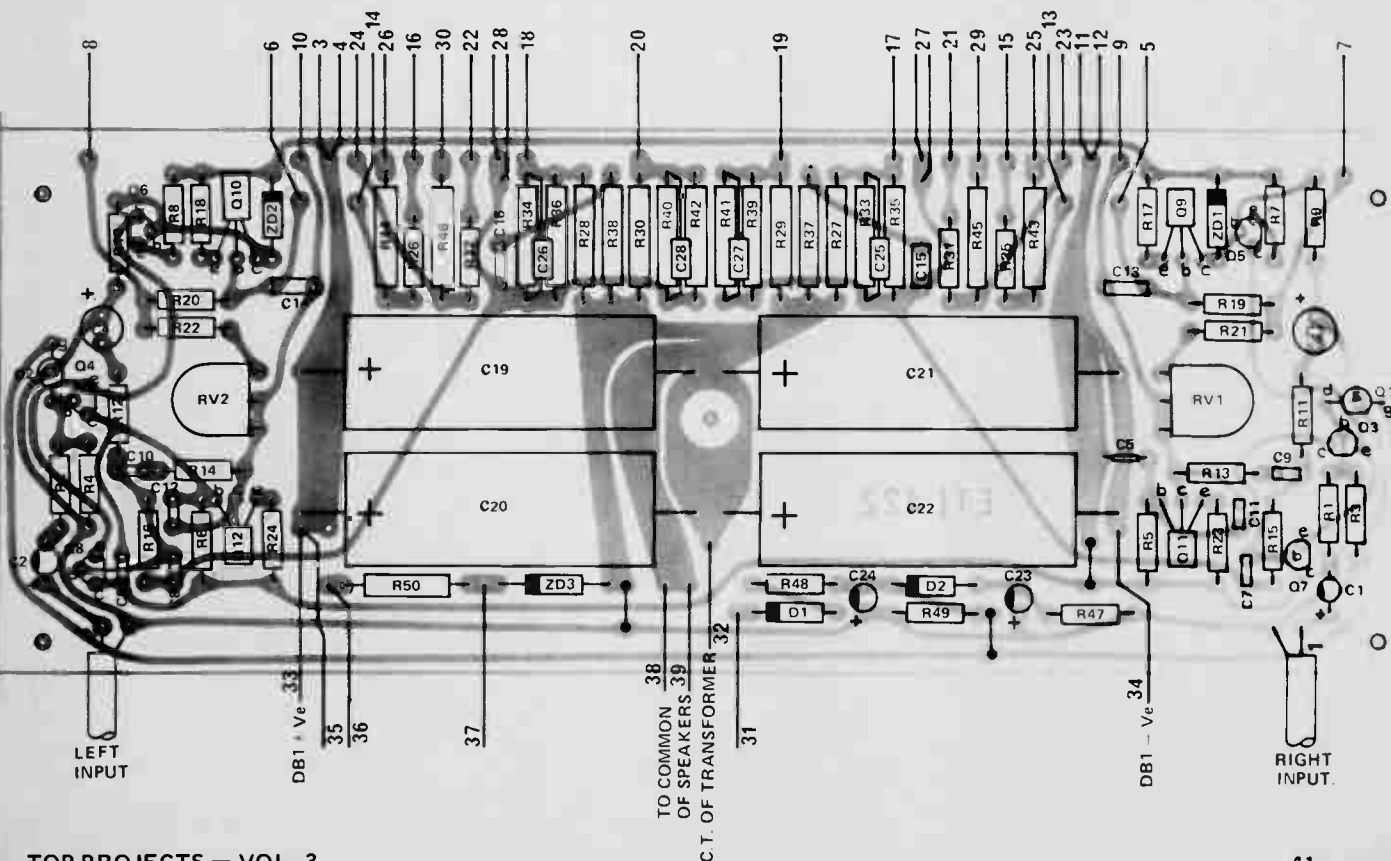
50 WATT POWER MODULE
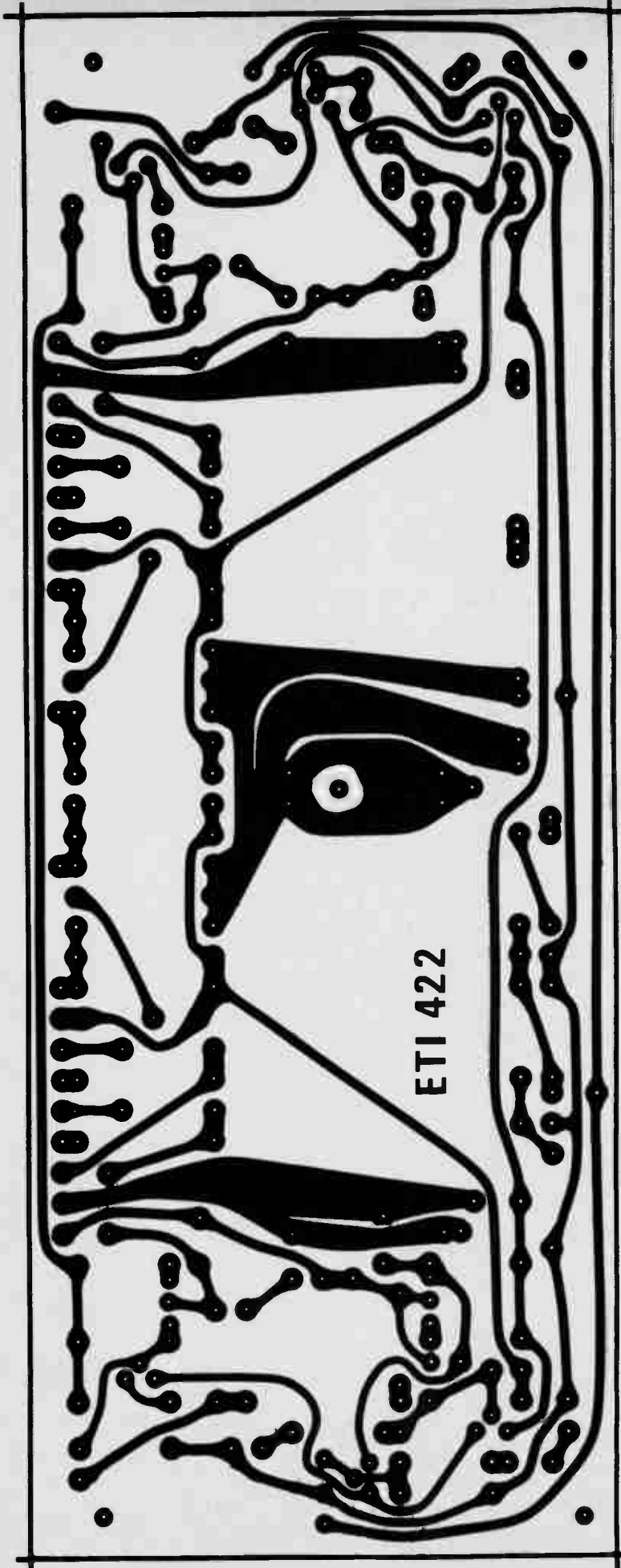
ETI 422

Fig. 4. Printed circuit layout for the amplifier. Full size 255 x 97 mm.

PARTS LIST
ETI 422 MAIN AMPLIFIER

R43,44,45,46	Resistor 0.5 ohm	2W*	
R37,38	" 10	" 1W	5%
R27,28,29,30	" 33	" "	"
R25,26,31,32	" 47	" ½W	"
R11,12	" 220	" "	"
R33,34,35,36	" 220	" 1W	"
R39,40,41,42	" 220	" "	"
R17,18,23,24	" 470	" ½W	"
R21,22	" 560	" "	"
R13,14,19,20	" 1 k2	" "	"
R1,2	" 1 k5	" "	"
R7,8	" 2 k7	" "	"
R9,10	" 3 k3	" "	"
R5,6	" 5 k6	" "	"
R3,4,15,16	" 10 k	" "	"

*If difficult to obtain, these resistors may be fabricated from a short length of electric jug element — about 90 mm is sufficient for each. Wind securely around a 1 watt resistor (100 ohms or higher) and solder into place.

RV1,2 Potentiometer 470 ohm Trim

C11,12	Capacitor	27 pF	ceramic
C9,10	"	100 pF	ceramic
C7,8	"	330 pF	ceramic
C5,6	"	0.0033 μF	polyester
C13,14,15,16	"	0.1 μF	"
C25,26,27,28	"	0.1 μF	"
C18	"	0.1 μF 250 Vac	
C1,2	"	4.7 μF 10V	Electro
C3,4	"	100 μF 10V	"
C19,20,21,22	"	2500 μF 50V	"

Q3,4,5,6,7,8	Transistor	BC177, 2N3645
Q9,10,17,18	"	BD140
Q11,12,15,16	"	BD139
Q13,14	"	PN3643
Q19,20	"	MJ2955*
Q21,22	"	2N3055*

*with mounting hardware

ZD1,2 Zener diode 5.6V 400mW

DB1 Diode bridge PA40

PC Board ETI-422
F1-F4 Chassis mounting Fuse holders and 2 Amp. Fuses.
T1 Transformer 56V CT PF3577 or similar
Heatsinks 2off 75mm of 35D (Philips)

If the dethump circuitry is required add the following components.

R47 Resistor 220 k

R47	Resistor	220 k	½W	5%
R48	"	47 k	"	"
R49	"	100 k	"	"

D1,2	Diode	1N914
Q1,2	Transistor	2N5485

C23	Capacitor	10μF 25V electro
C24	"	1μF 25V "

2N3055 — MJ2955.

BD 139/140

MICA WASHER

HEAT SINK

MICA WASHER

INSULATION

INSULATION
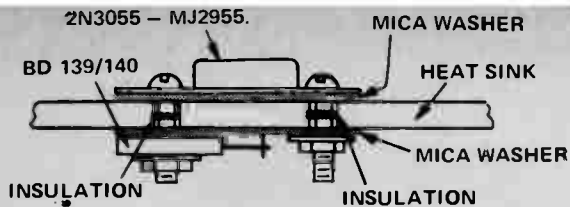
Fig. 2. How the heatsinks are assembled.
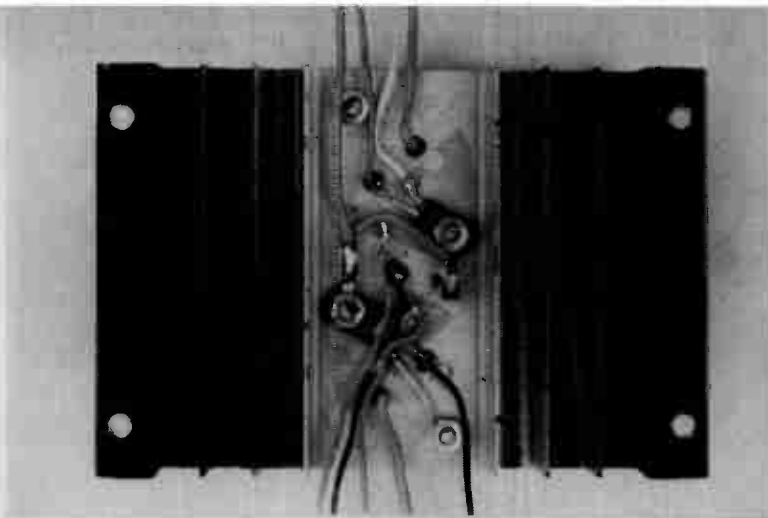
How the completed heatsink assembly appears.

25

e

Q19

b

1

e

c

15

BD139

b

5

b

Q15

c

7

Q13

e

b

9

Q19, Q21, ARE MOUNTED FROM THE OTHERSIDE OF THE HEATSINK

WIRES 5,7,9,17,19 SHOULD BE ANCHORED WITH EPOXY GLUE TO PREVENT MOVEMENT

TO 3 INSULATORS USED ON BOTH SIDES OF HEATSINK

b

BD140

21

Q17

c

e

b

Q21

19

29

e
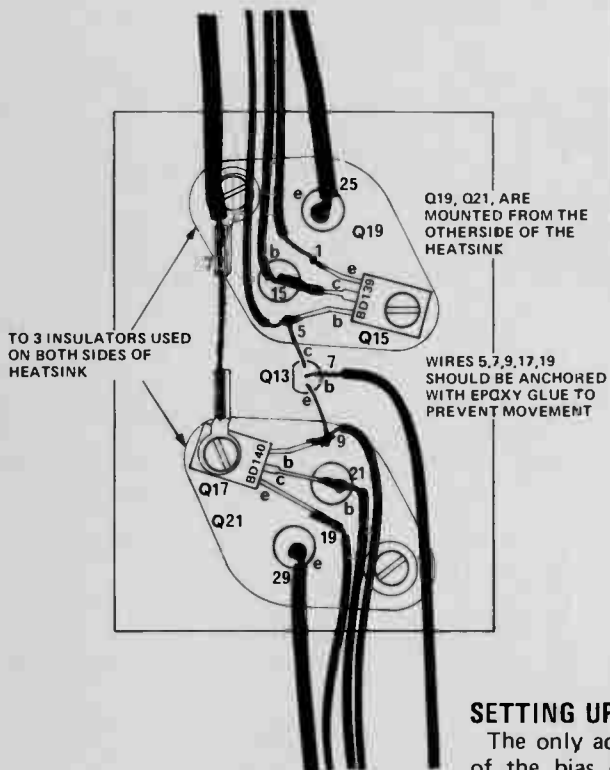
SETTING UP

The only adjustment required is that of the bias current. This is normally done with an ammeter in the power-supply lead to the output stage and, with the speaker disconnected and no signal, RV1 is adjusted to obtain a current of about 20 milliamps. However if a major fault

exists, or occurs, with the above method the meter as well as the output transistors may be damaged.

To obviate this we recommend a different approach as follows. Take out the fuses and temporarily connect a 220 ohm half-watt resistor across the fuse holder. Adjust RV1 to obtain about four volts across these resistors. If a major fault exists these resistors will get hot and possibly burn out. However no other damage will occur to the amplifier as the resistors limit the maximum current that can flow. After bias adjustment these resistors are removed and the fuses replaced.

It may be found that the voltage across the resistor in the positive lead is slightly different from that across the resistor in the negative lead. This is due to a slight offset in the output voltage but as long as the average is about four volts it will be satisfactory.●
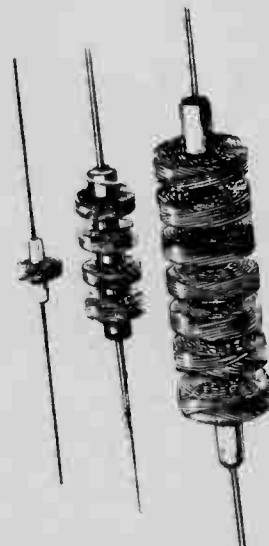
ETI 400 SPEAKER SYSTEM

Acoustic suspension design has big sound.

enclosure before finalising the cross-over network described later in this article.

THE ENCLOSURE

The design of an enclosure for an acoustic suspension speaker system is determined by making compromises on three basic quantities:

(1) The volume of the enclosure.
(2) The efficiency of the system.
(3) The low frequency cutoff.

There is no mandatory volume for an acoustic suspension system but tests over hundreds of different systems have shown that the optimum volume for a 200mm (8 inch) driver lies between 14 litres (0.5 cu ft) and 42 litres (1.5 cu ft). The 14 litre enclosure will sacrifice bass response and efficiency but will handle more power whilst the 42 litre enclosure has extended bass response is more efficient but will handle much less power. We opted for a 20 litre (0.7 cu ft) enclosure as the one which offered reasonable bass response and good power handling with the particular driver being used. (This is in contrast to the recently released kit from Philips using the same drivers that has a volume of 15.6 litres — which in our opinion sacrifices bass response for a smaller albeit cheaper enclosure).

The ETI 400 speaker uses the Philips 203 mm (8") bass driver and the 25 mm (1") dome tweeter.

The dome tweeter is known to be more efficient than the bass driver — in fact our measurements showed that this was of the order of 4 dB. We have therefore included a 4 dB resistive attenuator pad before the tweeter to

EVER since we published our extraordinarily successful Magnavox 8-30 speaker design some three years ago many readers have asked us to design a loudspeaker system that had at least equivalent performance but of smaller overall dimensions.

The design published here will we are sure satisfy the needs of these readers. It is an 'infinite baffle' design based on Philips drive units.

When we first started to investigate this project, we based our prototype on a system described in the Philips Elcoma publication 'High Fidelity Loudspeakers and Enclosure Designs'.

The Elcoma design is simple and effective but the basic cross-over network does not really do justice to the truly excellent design of the drive units specified. It just is not possible to obtain really top-class performance from a multi-speaker enclosure unless a good cross-over network is used. And a good cross-over network cannot be built cheaply.

Initial experiments showed that truly excellent performance was obtainable using a better cross-over. This being so we concentrated on designing the

match it to the woofer. (Philips have specified an 8 dB attenuator for their recently released kit but both measuring and listening tests confirm that 4 dB attenuation is better). The resistor pad has a fortuitous advantage in that it provides extra tweeter damping, considerably improving its sound — especially at the top end where the undamped tweeter (due to crossover impedance) tends to be a little harsh.

The resistive pad and tweeter is fed from C3 and L2 (see Fig. 3) which form a 12 dB per octave high pass filter allowing only frequencies above 2.2 kHz to pass — a 12 dB per octave crossover *must* be used if damage to the tweeter is to be avoided. Some people who built up the Magnavox 8-30 system, previously described in ETI, complained of tweeters burning out. We investigated many of these complaints and found that the problem was caused by using a single capacitor feed to the tweeter rather than the specified network. The Philips tweeter has a pronounced resonance around 900 Hz and if this is not adequately suppressed the tweeter will be damaged by excessive cone excursion at this frequency.

A 12 dB per octave network has also been provided for the woofer and again this should be used if proper mid-range response is to be obtained. Network R1 and C1 provides compensation for the rising impedance of the woofer (with frequency) and effectively keeps the response reasonably level up to the crossover frequency.

Capacitors C2 and C3 should be polyester types — not non-polarized electrolytics! However C1 may be a non-polarized electrolytic if desired.

The coils should be of air wound construction (see winding details) and *not* of the iron cored variety. Iron cored coils tend to saturate at high levels, producing a very nasty kind of distortion similar to amplifier clipping.

Resistors R2 and R3 may be constructed from jug element as follows. Measure out a length of jug element having the required resistance and wind it around the body of a 1 watt resistor (any value above 100 ohms) soldering one end to each of the resistor leads. The wire may be fixed in position on the resistor by a little 5 minute epoxy.

Note that the tweeter is connected out-of-phase. This is necessary due to phase shifts in the crossover. Conventional connection results in a deep hole in the response at about 3 to 4 kHz in addition to a 10 dB peak at around 2 kHz!

The coils may be hand wound, in accordance with Table I, on the former shown in Fig. 4.
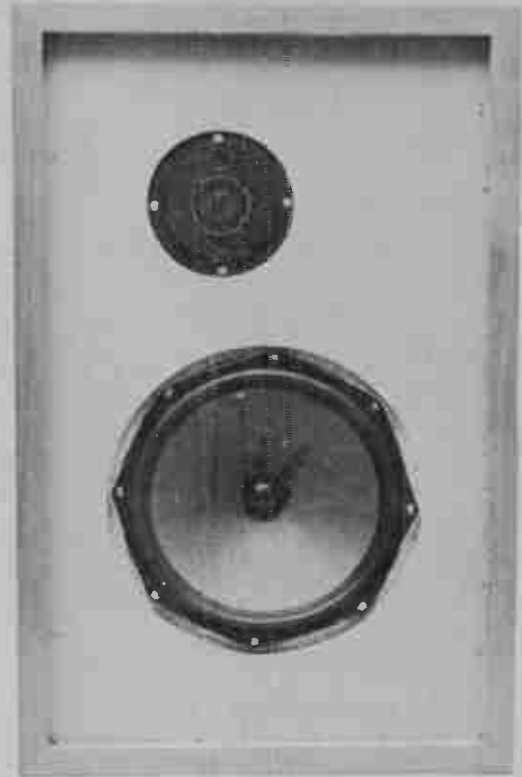
The completed speaker before front panel is painted or grille cloth fitted.

We must emphasize again that the crossover is the heart of any good speaker design. The circuit as described for the ETI 400 *must* be used if good results are to be obtained.

CONSTRUCTION

Dimensions of the enclosure and its assembly are illustrated in Figs. 1 and 2. Note that 19 mm square cleats should be glued into all corners. It is absolutely essential that all joints be airtight, for, if the enclosure leaks at all, the air rushing in and out will produce hissing sounds and the bass response will be seriously degraded.

Note that we used veneered pine board for our prototypes and hence the drawings show mitred joints at the corners. If such joints are beyond your woodworking capability it may be well to use plain, unveneered pineboard and butt joints. The whole box may then be covered with iron-on veneer or with self-adhesive vinyl. Self-adhesive veneer or vinyl does not adhere too well to plain pine-board and tends to lift or bubble after some time. We found that adhesion could be improved by applying one coat of clear lacquer to the pine-board before veneering. This has the effect of
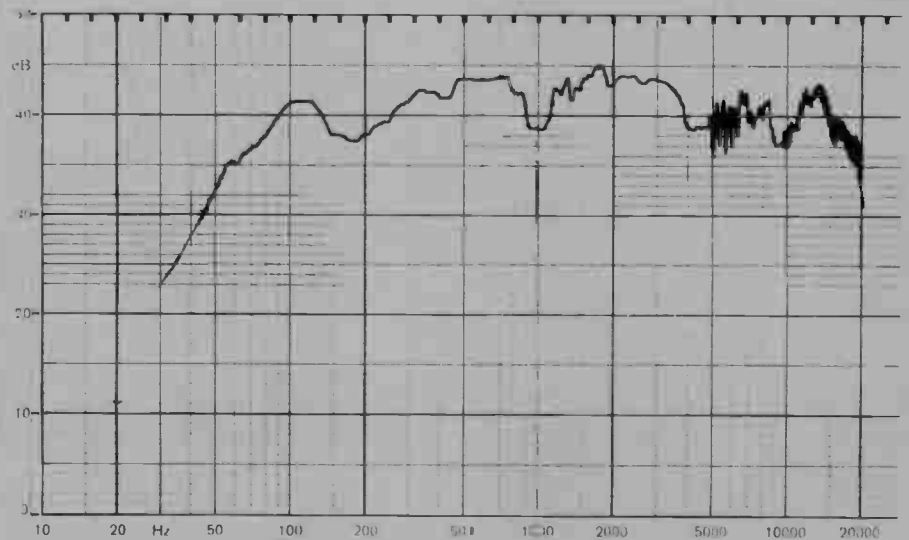
Frequency response of the ETI400 speaker system.

ETI 400 SPEAKER SYSTEM

TABLE 1 CONSTRUCTIONAL DATA

CHOKES 0.8 mH, L1 & L2
170 turns of 0.8 mm (20 B&S) on former shown in Fig.4.

RESISTORS

Resistors can be made from jug element as follows. Standard jug element coils are 300 mm long and have a total resistance of 38 ohms. Therefore a 25 mm length (unstretched) will have a resistance of 3 ohms, and a 120 mm length (unstretched) will have a resistance of 15 ohms. That is use 8 mm of coil per ohm of resistance required.

CUTTING

Two speakers can be cut from one 1800 x 900 mm sheet of veneered pine board (including front and back panels if required).
Alternatively 4 speakers can be cut from one 1800 x 900 mm sheet of veneered pine board if the fronts and backs are cut from a separate sheet of 1800 x 900 mm plain pine board.

CAPACITORS

Any value of polyester capacitor between 5.6 and 6.8µF can be used for C2 and C3 if difficulty is experienced in obtaining the correct value. Both must be the same value. Such change will shift the crossover frequency slightly but will not have other serious effects.

sealing and strengthening the pine-board surface thus preventing veneer lift due to break-up of the pine-board surface.

When the box is completed paint the front panel matt black and finish the veneer surface as desired — a Scandinavian oil finish is easy to apply and very attractive.

Mount the input terminals to the back panel, the crossover network to the inside of the back panel and connect the terminals to the crossover. Attach leads to the crossover for the woofer and tweeter and drape these leads out through the respective driver holes.

Now line the box on all sides (except the front) with 50mm glass wool. Connect the leads to the drivers (watch polarities) and mount the drivers in position using plasticine or sealing putty around the rim of each driver to ensure an airtight fit.

Make the grille-cloth frame from 12mm square timber and attach the grille cloth by stretching it around the frame and then stapling it at the rear. If a stapler is not available the cloth may be glued on.

The speakers will safely handle 40 watts RMS. Although decidedly not recommended, our lab staff fed them with music peaking to 200 watts. Apart from our production department (located next door to the lab) stopping work no difficulty was encountered in handling this level. We therefore consider that the system is entirely safe with amplifiers which deliver 40 watts RMS per channel. ●

SECTION AA
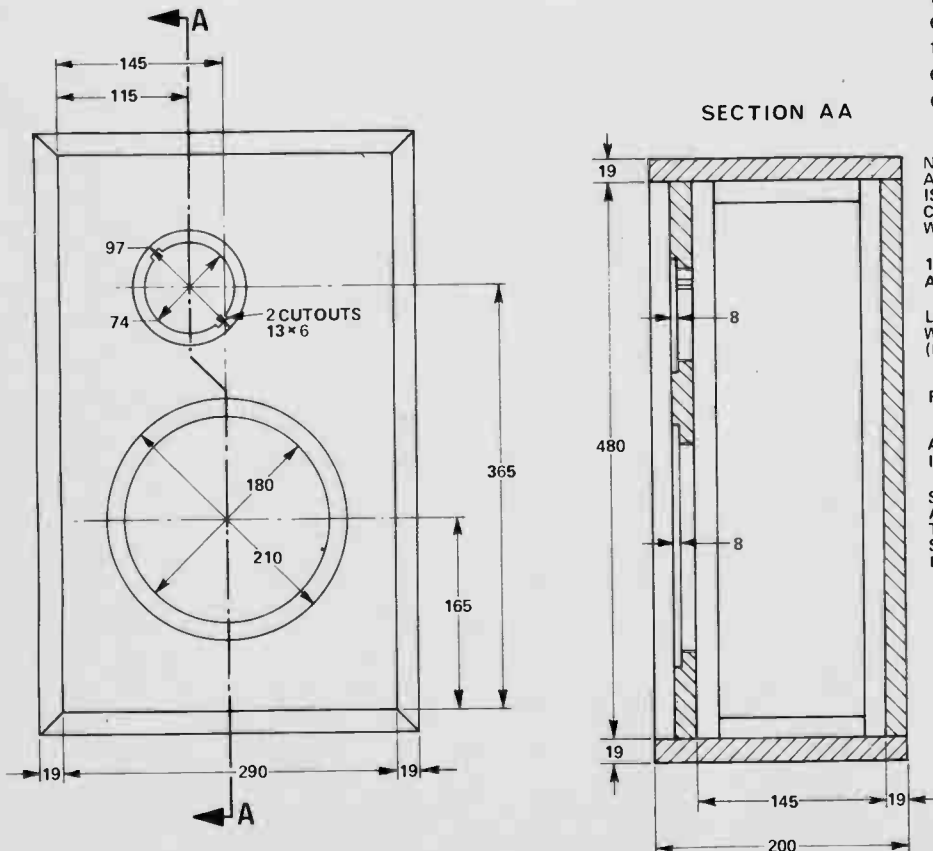
NOTES
ALL OUTSIDE WOODWORK IS 19mm PARTICLEBOARD COVERED WHERE VISIBLE WITH THE DESIRED VENEER

19mm x 19mm CLEATS AROUND ALL EDGES

LINE ALL INSIDE SURFACE WITH 50mm FIBREGLASS (EXCEPT FRONT)

FRONT GRILL NOT SHOWN

ALL DIMENSIONS ARE IN MILLIMETRES

SPEAKERS SHOULD BE MADE AS PAIRS. ONE WITH THE TWEETER ON THE LEFT AS SHOWN AND ONE WITH IT ON THE RIGHT

Fig. 1. Dimensions of the ETI 400 speaker enclosure.
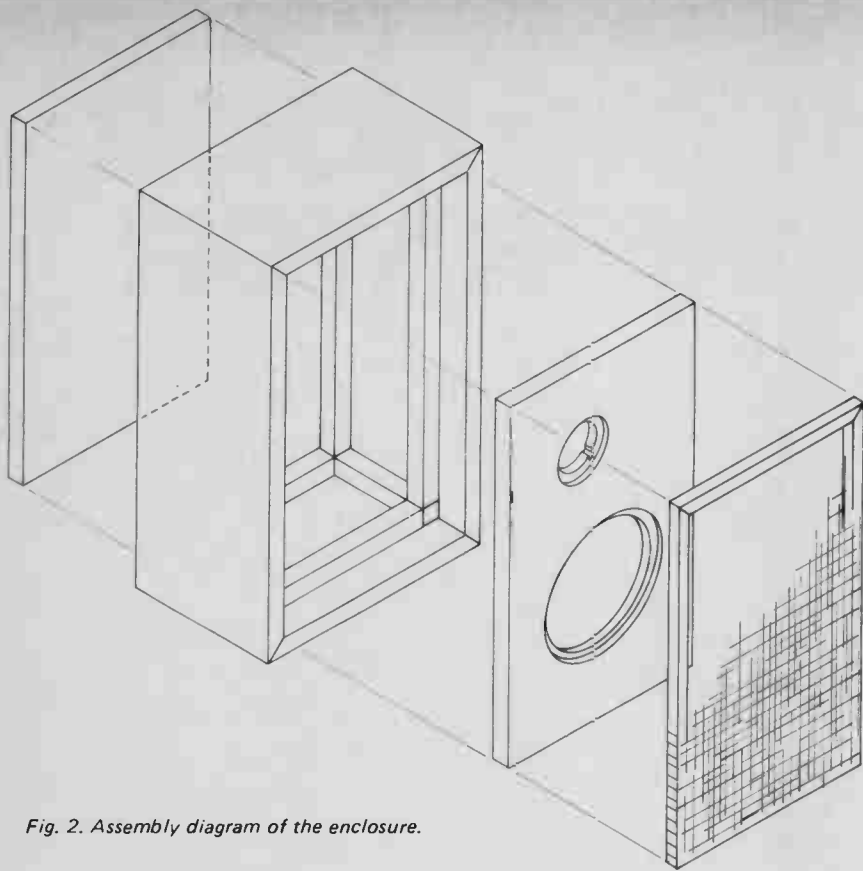
Fig. 2. Assembly diagram of the enclosure.
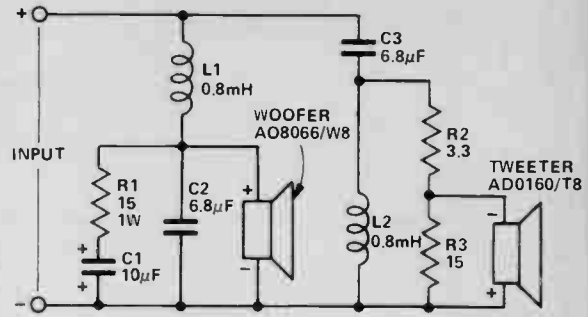
Fig. 3. Circuit diagram of the crossover network. This is the heart of the system and must not be changed if best results are to be obtained.
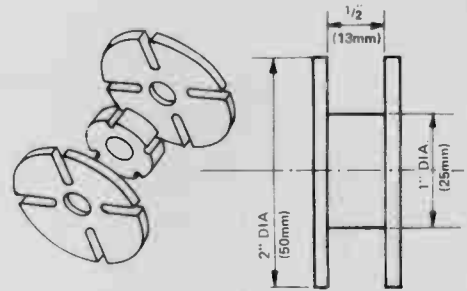
Fig. 4. Former for winding chokes L 1 and L2. Chokes may readily be wound by hand, try and keep wire in uniform layers but a little jumbling will not appreciably affect the final value of inductance.
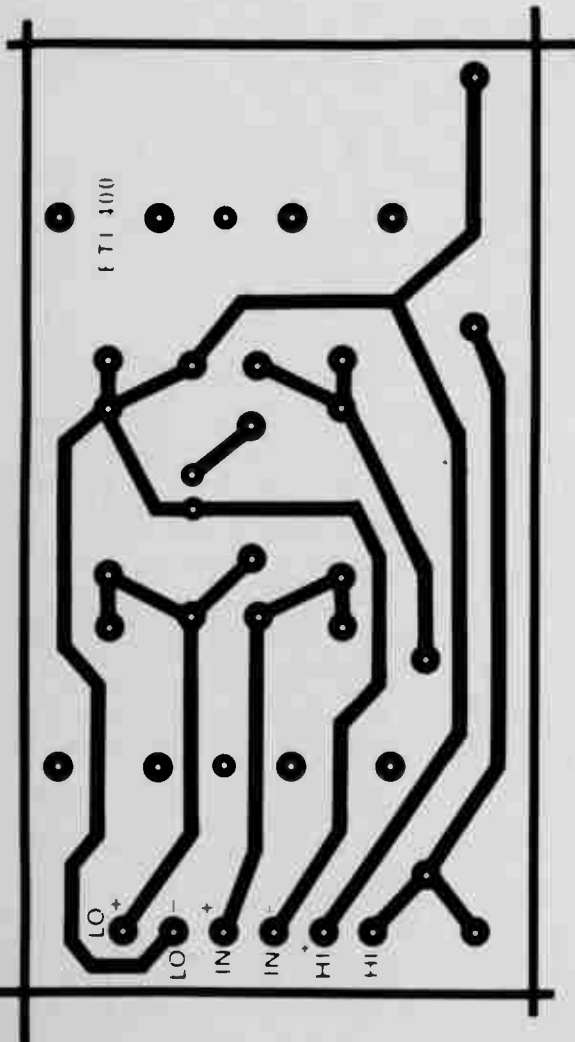
Fig. 5. Printed circuit layout for the crossover network. Full size 145 x 78 mm.
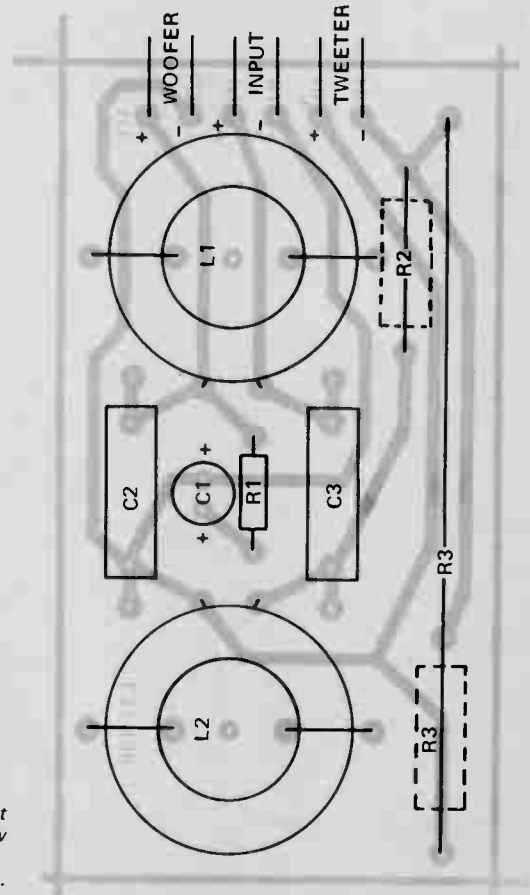
Fig. 6. Component overlay shows how to assemble the crossover network.

AUDIO NOISE GENERATOR

Simple circuit generates both white and pink noise.

NOISE is generally an undesirable phenomena that degrades the performance of many measurement and instrumentation systems. It therefore seems strange that anyone should want to generate noise, but this is often the case.

Noise generators are often used to inject noise into radio-frequency amplifiers in order to evaluate their small signal performance. They are also used to test audio systems, and as random signal sources for wind-like effects in electronic music.

There are two commonly used noise source characteristics, 'pink' and 'white'. White noise is so called because it has equal noise energy in equal bandwidths over the total frequency range of interest. Thus, for example, a white noise source would have equal energy in the band 100 to 200 Hz to that in the band 5000 to 5100 Hz.

Fig. 1. Circuit diagram of the noise generator.

HOW IT WORKS — ETI 441

In the days when vacuum tubes were in common use the most commonly used form of noise generator was a vacuum-tube diode operated in the current saturation mode. Nowadays noise generators may be very complex indeed. Highly complex digital generators which produce psuedo-random digital noise may cost many thousands of dollars. An example of a simpler type of digital noise source may be found in our synthesizer design (see International Music Synthesizer 4600 ETI December 1973). However for audio work of a general nature the most commonly used, and the simplest, method is to use a zener diode as a noise generator.

Transistor Q1 is in fact used as a zener diode. The normal base-emitter junction is reverse-biased and goes into zener break-down at about 7 to 8 volts. The zener noise current from Q1 flows into the base of Q2 such that an output of about 150 millivolts of white noise is available.

The 'zener', besides being the noise source, also biases Q2 correctly, and the noise output of Q2 is fed directly to the White Noise output.

To convert the white noise to pink a filter is required which provides a 3 dB cut per octave as the frequency increases. A conventional RC network is not suitable as a single RC stage gives a cut of 6 dB per octave. Hence a special network of Rs and Cs is required in order to approximate the 3 dB-per-octave slope required. Since such a filter attenuates the noise considerably an amplifier is used to restore the output level. Transistor Q3 is this amplifier and the pink noise filter is connected as a feedback network between collector and base in order to obtain the required characteristic by controlling the gain-versus-frequency of the transistor. The output of transistor Q3 is thus the pink-noise required and is fed to the relevant output socket.

Fig. 2. Component overlay.

Printed circuit layout. Full size 67 x 49 mm.

If white noise is filtered or modified in any way it is referred to as coloured noise or, often more specifically, as 'pink' or 'grey' noise. The term pink noise should be restricted to the noise characteristic that has equal energy per percentage change in bandwidth. For example with true pink noise the energy between 100 Hz and 200 Hz should equal that between 5000 Hz and 10 000 Hz (100% change in both cases).

Pink noise therefore appears to have more bass content than does white noise, and it appears to the ear to have a more uniform output level in audio testing. To change white noise to pink noise a filter is required that reduces the output level by 3 dB per octave (10 dB per decade) as the frequency is increased. The ETI 441 Noise Generator is designed to provide both white and pink noise as required.

CONSTRUCTION

Construction is relatively simple and almost any of the common methods, such as Veroboard or Matrix board, may be used if desired. For neatness and ease of assembly it is hard to beat a proper printed-circuit board and for this reason we have provided details of a suitable board.

Almost any type of NPN transistor will do for the generator provided that the one used for Q3 has a gain of 100 or more. If BC548 type are used watch out for the two different pin connections used by different manufacturers.

For use as a separate instrument in general experimentation the unit will need to be powered by a pair of nine-volt batteries. However if the unit is to be built into some other piece of equipment, as is often the case, any supply within the equipment which has an output of between 15 and 30 volts dc will be suitable.

World Radio History

AUDIO NOISE GENERATOR
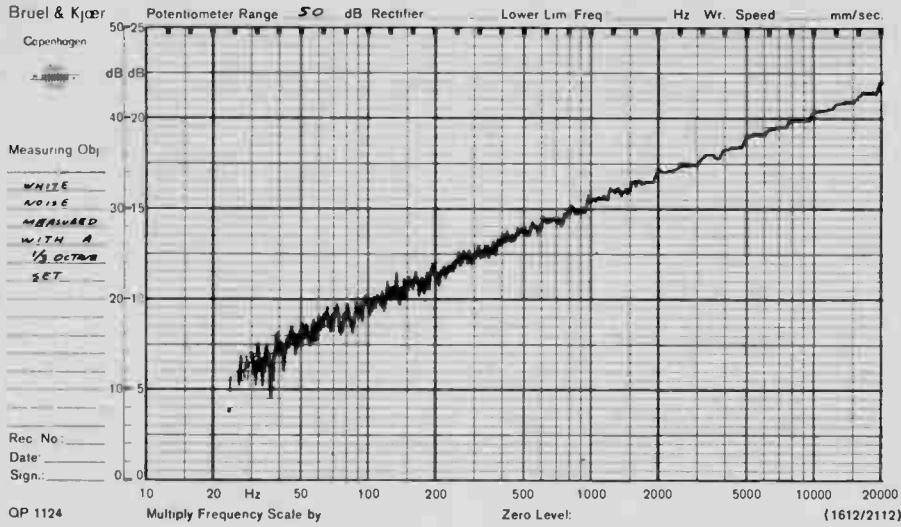
Amplitude of white noise versus frequency as measured with a one-third octave filter set.
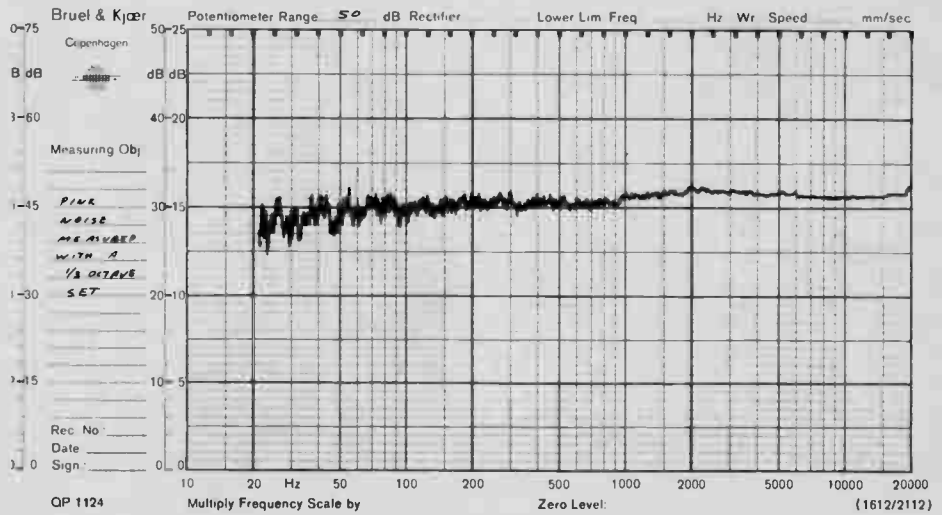
Amplitude of pink noise versus frequency as measured with a one-third octave filter set.
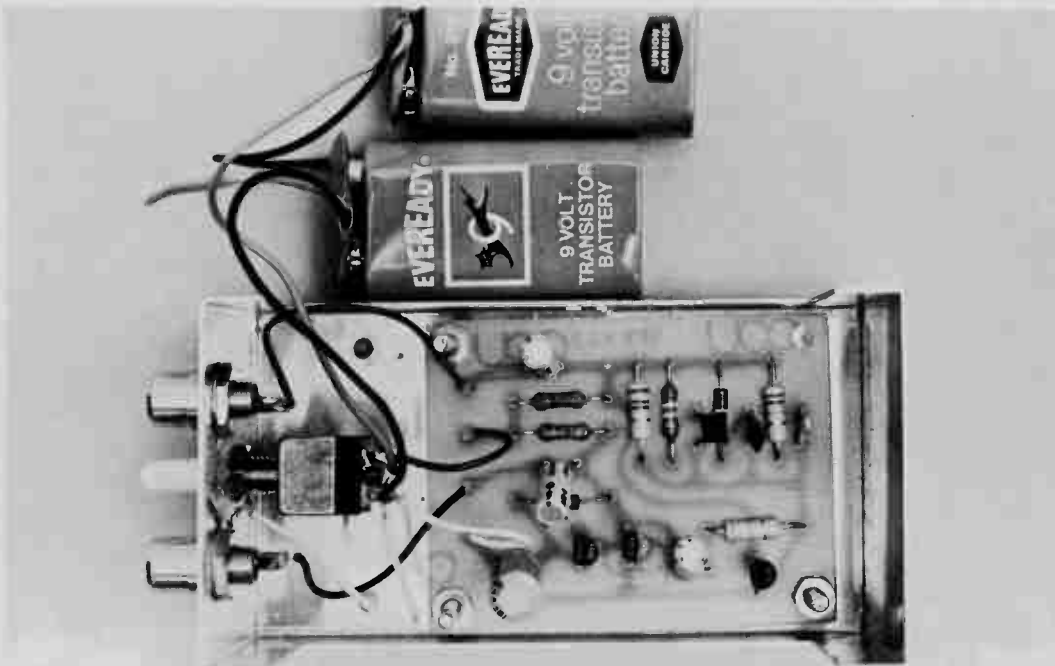
Internal layout of the generator.

PROJECT 704

CROSSHATCH/DOT GENERATOR

Inexpensive unit for converging colour TV set.

THE COLOUR television picture is created in the receiver picture tube by three separate electron guns — one each for red, green and blue. As these guns cannot be in the same physical position they need to be converged into one spot on the screen.

The process of converging at the centre of the screen is called static convergence and is performed by magnets on the yoke assembly.

However, the screen of the picture tube is not everywhere coincident with the deflection plane and this causes errors when the beam is deflected away from centre. These deflection errors are corrected electronically by 12 or more controls and the process is known as dynamic convergence.

An important part of the process is the use of a crosshatch generator to provide horizontal and vertical lines on the screen. Using the generator, the convergence errors are immediately apparent and the controls on the set are usually labelled with the effect each has on a crosshatch pattern.

In addition to setting up convergence the generator pattern may also be used to set up horizontal and vertical linearity and to orientate the deflection yoke coils on both black and white and colour sets.

Most of the inexpensive pattern generators, which are currently available, produce a video waveform, which must be injected into the correct place in the TV, and require a synchronizing signal from the TV set. Such generators are thus fiddly things to use.

The ETI 704 generator produces a combined horizontal and vertical-sync waveform and this, together with the crosshatch video, is modulated onto a carrier frequency operating in VHF channel 6 (175.25 to 180.75 MHz). Thus to use the generator one simply

attaches it to the antenna terminals and selects channel 6.

CONSTRUCTION

Coil L1 should be constructed from 24 gauge B&S enamelled copper wire by winding 6 turns, close spaced, around a former, such as a knitting needle, so that the finished outside diameter of the coil is about 5 mm.

Coil L2 is constructed by winding 4 turns of 24 gauge B&S enamelled copper onto a miniature Neosid former which is fitted with a VHF slug and an aluminium can. Fit links to the board in accordance with Fig. 2 and then the above coils and other components can be assembled to the printed circuit board with the aid of the component overlay. Take particular care with the orientation of ICs and other polarized components. Assemble the CMOS devices to the board last of all and handle them as little as possible. Avoid touching the pins.

Assemble the output socket and switch to the front panel and connect

the output of the module to the socket by means of a short length of 75 ohm coaxial cable. The connections to the switch and battery may then be made with ordinary hookup wire.

SETTING UP

Connect the unit to the antenna terminals of a television receiver and select Channel 6. Adjust the coil L2 to obtain the strongest signal on the screen. (This may be totally out of sync at this stage.)

Now adjust RV2 as you would a normal horizontal sync control to obtain vertical lines and then adjust RV1 for vertical sync. Then readjust L2 for clearest picture and make small adjustments to RV2 and RV1 to obtain the most stable crosshatch.

Finally adjust brightness and contrast of the set to obtain white lines on a black background. These adjustments need only be made on initial set up and henceforth the generator is simply attached to the antenna terminals and switched on.

CROSS HATCH-DOT GENERATOR
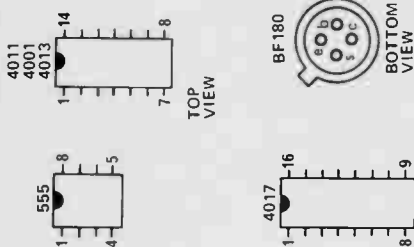
Fig.1. Circuit diagram of the crosshatch/dot generator.
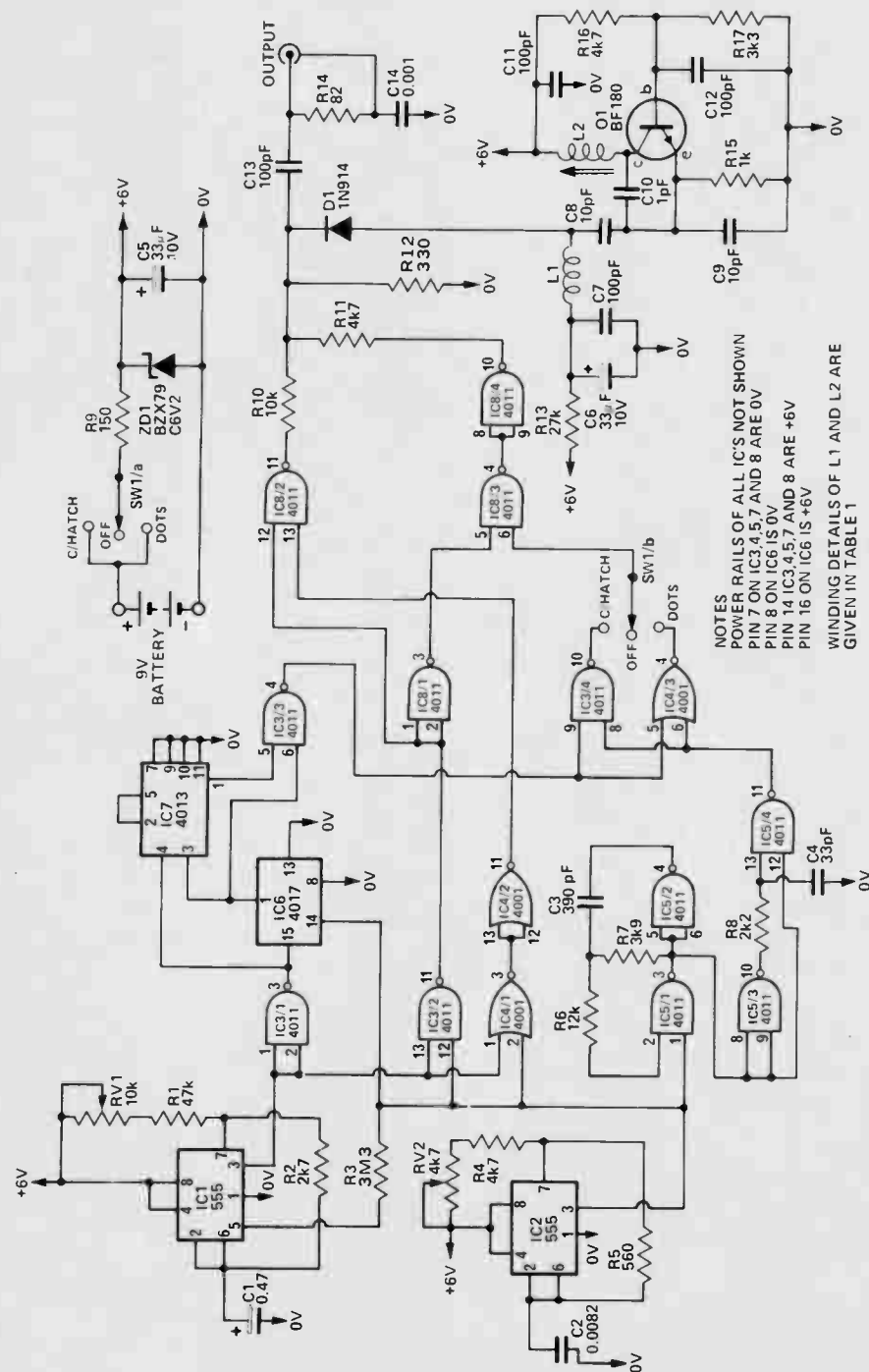
NOTES
POWER RAILS OF ALL IC'S NOT SHOWN
PIN 7 ON IC3,4,5,7 AND 8 ARE 0V
PIN 8 ON IC6 IS 0V
PIN 14 IC3,4,5,7 AND 8 ARE +6V
PIN 16 ON IC6 IS +6V

WINDING DETAILS OF L1 AND L2 ARE
GIVEN IN TABLE 1

HOW IT WORKS — ETI 704

Two 555 timers, IC1 and IC2, are used as the frame and line sync pulse generators respectively. Integrated circuit IC1 generates one millisecond wide pulses at 20 millisecond intervals (50 Hz) and IC2 generates five microsecond wide pulses at 64 microsecond intervals (15625 Hz). Light synchronization of IC1 to IC2 is achieved by means of R3. Thus both oscillators have to be close to the correct frequency before locking will occur.

Gates IC3/2, IC4/1, IC4/2 and IC8/2 form an exclusive-OR function on these two sync-pulse trains to produce a combined sync-pulse train at the output of IC8/2.

At the end of each line-sync pulse an oscillator, formed by IC5/1 and 2 is gated on, and produces a train of pulses at approximately 240 kHz. The leading edge of each of these pulses triggers monostable IC5/3 and IC5/4 such that a 40 nanosecond wide pulse is generated. Thus approximately 14 40 nanosecond wide pulses are generated between successive line sync pulses. These pulses produce the vertical lines of the crosshatch.

At the end of each frame sync pulse decade counter IC6 is enabled. This is a CMOS Johnson decade counter which provides an output at pin 1 every tenth line sync pulse commencing from the 5th pulse after the counter is enabled. This output is divided by two by IC7 and the output of IC3/3 is therefore low for the duration of every twentieth line period. This output is the horizontal lines of the crosshatch.

The vertical and horizontal crosshatch signals are NANDed and NORed by IC3/4 and IC4/3 respectively to provide either crosshatch or dots as selected by SW1/b. These outputs are inhibited during the line and frame sync periods via IC3/2, IC8/1 and IC8/3. The output from IC8/4 is thus the composite crosshatch video signal.

The composite sync from IC8/2 and the composite video from IC8/4 are summed into R12 by R10 and R11 and form a combined sync and video waveform which modulates the RF from oscillator Q1 via diode D1.

Transistor Q1 and its associated components form an oscillator which runs at around 180 MHz. The output from the generator is therefore a modulated RF signal at channel 6 frequency which is adjustable by tuning coil L2.

The unit is powered from a 9 volt battery which is only on when dots or crosshatch are selected. The 9 volts is regulated down to 6 volts by means of R9 and zener diode ZD1.

Fig.3. Component overlay.

Fig.4. Printed circuit board layout.

CROSS HATCH/DOT GENERATOR
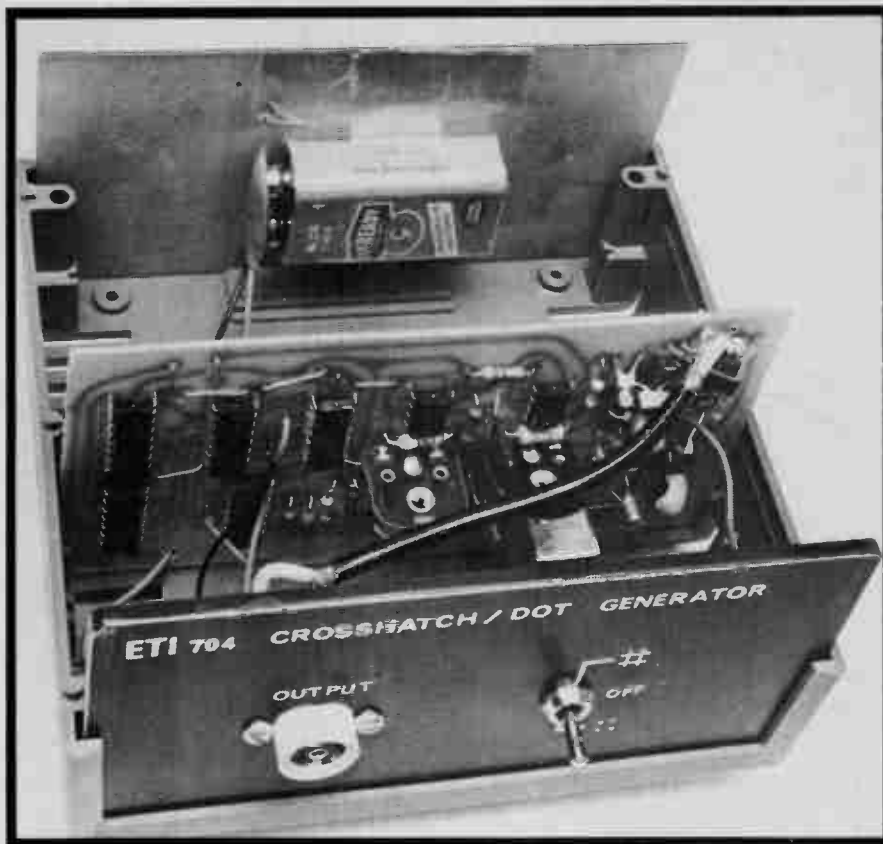
Internal view of the crosshatch generator showing how the board is mounted.

ETI UTILIBOARD

ETI UTILIBOARD

A versatile board for experimenters.

THE CONSTRUCTION of any project is always simplified by the use of a proper printed-circuit board. The neat and tidy appearance of a well made printed-circuit board full of components, gives a professional look and is most satisfying. There are however some drawbacks. Each design requires a different board and you need a reasonable degree of knowhow and time to make your own boards.

Quite often it may be felt that the cost of a ready made printed circuit board, for a simple project, is unwarranted or it is just too much of a hassle to make a trip half-way across a city to obtain one.

There are several alternatives, such as Veroboard and Matrix board, and many people are now using specially designed general purpose boards which are specifically made for versatility in the construction of general circuitry.

This latter approach has several advantages. The finished board looks neat and professional, fairly-complex circuits can be quickly assembled, and the large pads available allow experimental circuits to be debugged with ease. Such boards allow the builder to change the circuit of a particular project to suit his personal needs or, to use physically-larger components (eg junk-box parts) than those specified.

There are many of these boards available but many of them are quite expensive and some are lacking in versatility. Hence we decided to design our own board for use in simple projects. We have in fact used the board for several of our ETI projects.

USING THE UTILIBOARD

On conventional printed-circuit boards the components are always mounted on the non-copper side of the board and all our previous overlays have shown components in this way.

However in experimental circuits it is more convenient to mount the components on the copper side. This allows components to be added, or shifted, without having to continually turn the board over. The code-practice oscillator is in fact built this way.

Note that the board consists of four individual 16-pin dual-in-line IC pad-groups, each pin of which has associated with it a large pad to which several component leads can be soldered without the need for holes.

The broad lines through the centre of the pads, and on either side, are suitable for supply or earth connections. They are continuous so that the group of pads can be used together or the board may be sawn up into single or 2-way sections as required.

The broad line up the centre has indicator marks which point to pin 1 of an IC when it is mounted on the non-copper side of the board and the dot marker on the IC points to indicator-mark end of the board. Note that this central line is broad enough so that individual pads may be connected to it by solder bridging.

Of course any of eight, 14 or 16 pin DIL IC's can be mounted as required, or, discrete transistors may be inserted into appropriate holes. You will find this board extremely versatile and easy to use.   ●
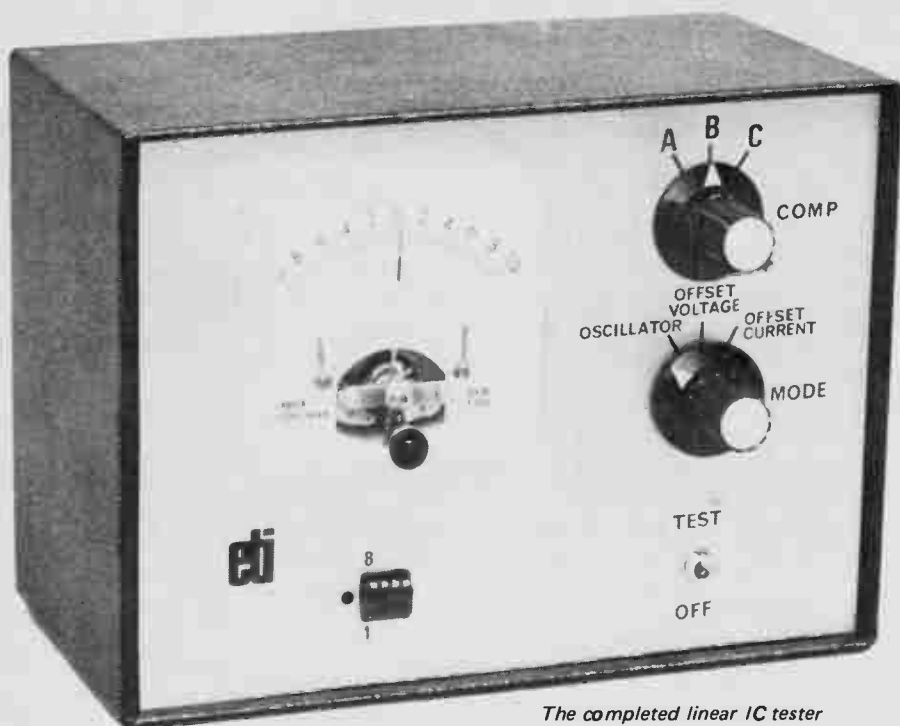
LINEAR IC TESTER

The completed linear IC tester

Test all commonly available operational amplifiers for three vital parameters.

LINEAR integrated circuits are available today at prices little higher than those of discrete transistors. As they offer far better performance parameters, and greater versatility than transistors they are being used in new designs in ever increasing numbers.

Most linear ICs are now built into a standard 8-pin, dual-in-line plastic pack, have the same pin connections and very similar characteristics. Hence as the only real difference is in the associated frequency compensation network, a universal, linear — IC tester is quite a feasible proposition.

The tester, described here provides a

eti PROJECT 115

quick check of vital operating parameters. Checks are provided for offset voltage (max ±10mV), offset current (max ± 1000 nA) and of operation in an actual circuit configuration.

It is a most valuable instrument; saving an experimenter time that would otherwise be spent tracing down faulty ICs.

CONSTRUCTION

We chose to mount our circuitry on a small piece of matrix board, rather than a printed circuit board, as there are relatively few components used.

Make sure that IC1 is orientated correctly (note pins 1, 5 and 8 are not used). The wires from the compensation switch (SW2) should be as short as possible in order to minimise the chance of unstable operation.

The test socket should be glued into place (taking care not to get glue down the pins) and, after the wires to the socket are soldered on, these should also be held to the panel with glue or a metal clamp.

The wires to the socket must be supported in some way, as detailed above, to prevent the rather fragile pins breaking off.

HOW TO USE

The parameters of commonly-available ICs are detailed in Table 1. An IC on test should not exceed these figures. Those that do exceed these values may not operate correctly in some circuits and should be discarded.

To test an IC, plug it into the test socket making sure that it is orientated correctly. Select the appropriate equalization as detailed in column 4 of Table 1 and switch the unit on. Select 'OSCILLATOR' mode and observe that the meter should sweep up and down the scale at about 1 Hz.

Now switch to 'OFFSET VOLTAGE' mode and read the meter which is calibrated at 10 mV full scale deflection.

Next switch to 'OFFSET CURRENT'. In this mode the meter is calibrated at 1000 nA (1 microamp) full scale deflection.

Discard any IC that does not oscillate or has excessive offset current or voltage.
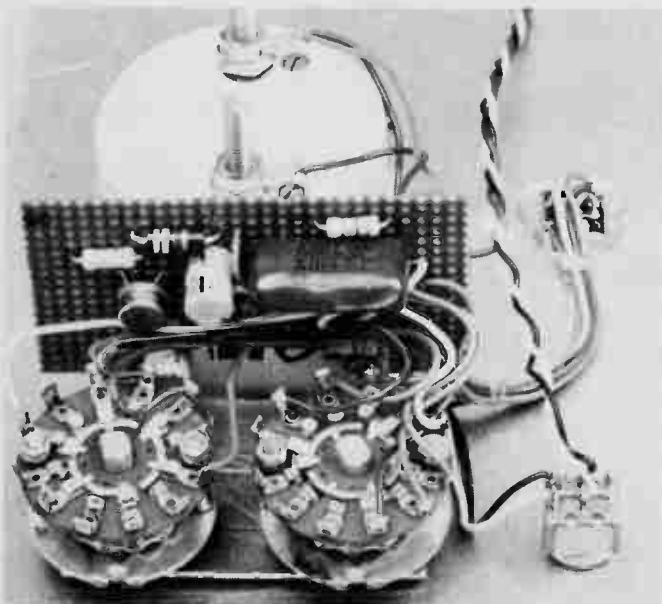
Showing the internal construction of the tester. Note that matrix board holds the majority of the components.

TABLE 1

TYPE	MAX OFFSET CURRENT	MAX OFFSET VOLTAGE	COMPENSATION
301	50 nA	±7.5 mV	C
307	50 nA	±7.5 mV	A
308	1 nA	±7.5 mV	C
709	500 nA	±7.5 mV	B
741	200 nA	±6 mV	A
748	200 nA	±6 mV	C
777	20 nA	±5 mV	C
1456	30 nA	±12 mV	A

PARTS LIST   ETI 115

R1,2	Resistor	100	5% ½W
R3,5	"	2.2M	" "
R4	"	1 M	" "
R6	"	22 k	" "
R7	"	1.5 k	" "
R8	"	3.9 k	" "
R9	"	33 k	" "
R10	"	150 k	" "

C1   Capacitor   1µF polyester
C2   "   0.0047µF polyester
C3   "   33pF   ceramic
C4   "   220pF   "
C5,6   "   10µF 16V electrolytic

IC1   integrated circuit µA741

M1   meter   0.5 mA — 0 — 0.5 mA
Ferrier Instruments model B46 or similar

SW1   Switch   2 pole, 3 position rotary
SW2   "   2 pole, 3 position rotary
SW3   "   2 pole on-off toggle.

Metal box approx. 150 x 180 x 90mm.
(Aust. Trans 70-50-40) or similar.
2 x 9V battery (type 216 or similar).

NOTES:
SW1
POSITION
   A – DYNAMIC TEST
   B – OFFSET VOLTAGE
   C – OFFSET CURRENT
SW2
POSITION
   A – 741, 748 ETC.
   B – 709
   C – 301A, 308 ETC.

Fig. 1. Circuit diagram of linear IC tester.

HOW IT WORKS – ETI 115

Centre-zero meter M1, via resistor R8, indicates the output voltage from the IC under test. The frequency compensation components for the particular IC under test are selected by SW2, and the test mode is selected by SW1.

In position "C", of SW1, a 2.2 megohm resistor is connected from the output (pin 6) of the IC under test to the inverting input (pin 2), and a 2.2 megohm resistor from the non-inverting input (pin 3) to ground. Current is drawn by both pin 2 and pin 3 of the IC and, if these currents are equal, the output voltage will be zero. Any difference in input currents will therefore be indicated as an output voltage on meter M1.

In position B the resistor from pin 6 to pin 2 is reduced to 22k and a 100 ohm resistor, R1, is connected from pin 2 to ground. This results in the IC having a voltage gain of 220. Resistor R2 is also made 100 Ω so that offset current does not affect the operation in this mode. Hence the IC will now amplify any offset voltage between pin 2 and pin3 (that is, it is operating in the linear mode) by 220 and the meter deflection will be proportional to the offset voltage.

If either offset voltage or offset current are excessive the meter will read off scale and the IC should be discarded.

In mode A the IC is connected as a triangular wave oscillator having an operating frequency of 1Hz. Integrated circuit IC1 is connected as a Schmitt trigger where the output of the Schmitt goes high if its input drops below -1.5 volts, and will go low if the input exceeds 1.5 volts. The output of IC1 is taken, via a 1 megohm resistor, to the input of the IC under test and the output of the Test IC becomes the input of the Schmitt trigger. An integrating capacitor, C1, is connected across the IC under test. The effect of this is to cause the output of the test IC to rise at 7 volts per second until +1.5 volts is reached. At this point the Schmitt operates and the output of the test IC now commences to fall at the same rate. When -1.5 volts is reached the direction reverses again and the cycle repeats. Thus we have an oscillator with a frequency low enough to be followed by the output meter as an indication of correct operation.

DUAL BEAM ADAPTOR

Simple unit converts single beam CRO to dual beam operation.
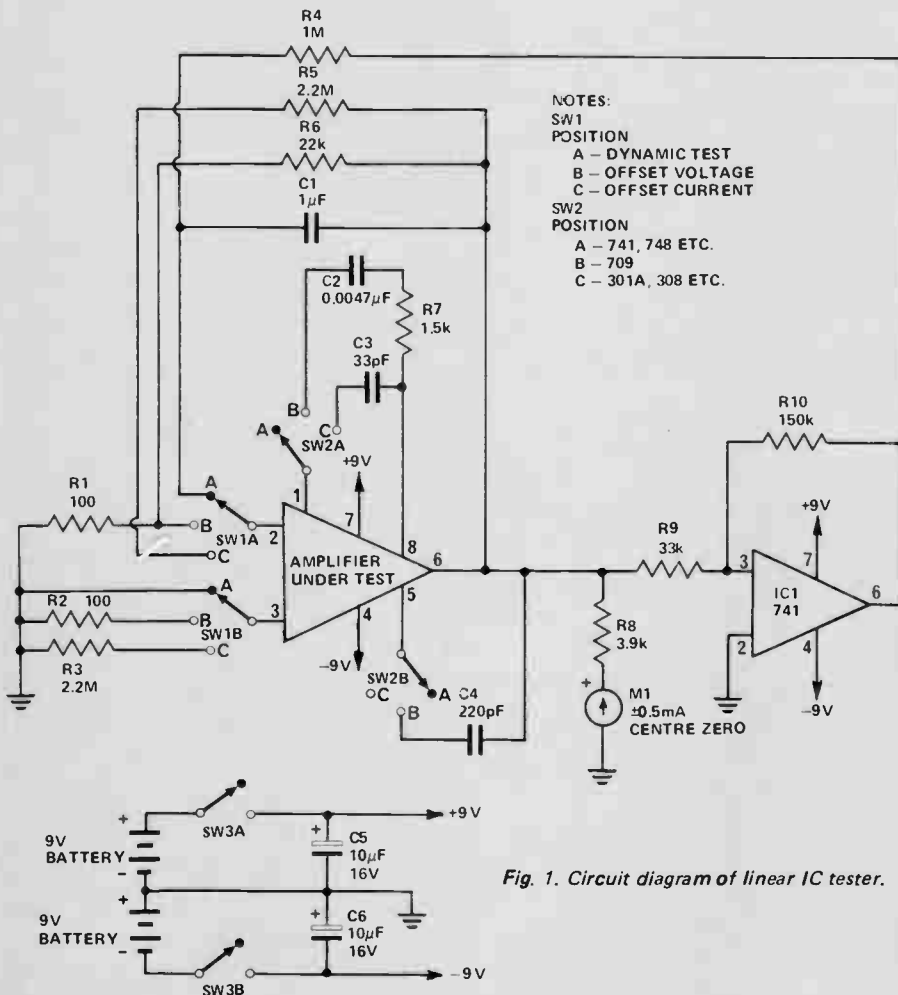
THE oscilloscope, next to the multimeter, is perhaps the most useful test instrument. Indeed, for any serious experimental work an oscilloscope is indispensable. Unfortunately they are expensive beasts, and whilst an experimenter may well afford a simple, low-frequency single-beam type, a dual-beam version (at $300 or more) is usually beyond his means.

Nevertheless a dual-beam facility is most convenient, for it allows comparison of two different signals, for wave-shape or timing, and makes obvious, differences which otherwise would not be discernable.

The simple dual-beam adaptor described here, whilst not providing *all* the capabilities of an expensive dual-beam CRO, will however, cover most experimenter's requirements.

It is a low cost unit which allows two inputs of similar amplitude to be displayed simultaneously on separate traces. Frequency response of the unit is sufficient to allow observation of signals up to about 1 MHz.

CONSTRUCTION

Most of the components are mounted on a printed circuit board. However, if desired matrix or veroboard may be used.

Be careful to orientate the polarised components correctly, as shown on the component overlay. Wiring to the sockets and switches should be as short as possible. Note that C3 and C4 are mounted on the input switches and C5 is mounted on the output socket.

Our prototype was mounted in a small aluminium minibox as illustrated. As individual requirements will vary, details of front panel layout and metalwork only are supplied.

USING THE ADAPTOR

Connect the output of the adaptor to the input of the CRO. The two adaptor inputs now become A and B trace inputs to the CRO. A triggering signal should be applied direct to the trigger input of the CRO as otherwise the CRO will tend to synchronize to the chop frequency and not to either input signal.

It is preferable that the two input signals have approximately the same amplitude as there is no input amplifier or range selection provided
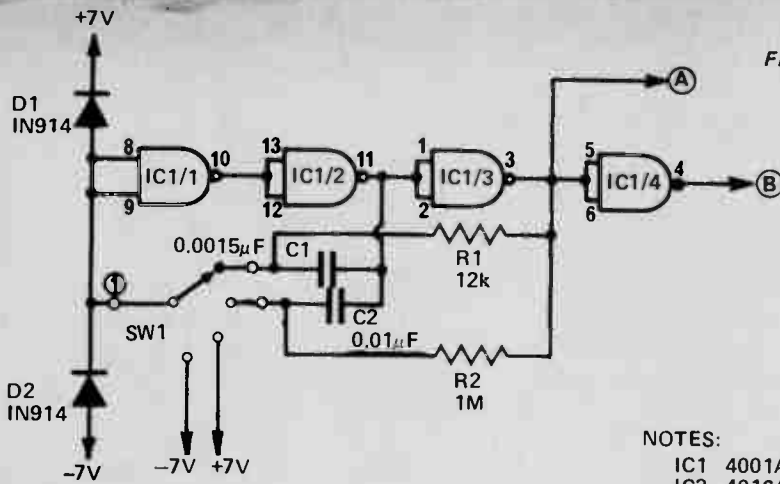
Fig. 1. Circuit diagram of complete unit.

NOTES:
IC1 4001AE CMOS
IC2 4016AE CMOS
C3, C4 ARE MOUNTED ON SW2 AND SW3
C5 IS MOUNTED ON THE OUTPUT SOCKET
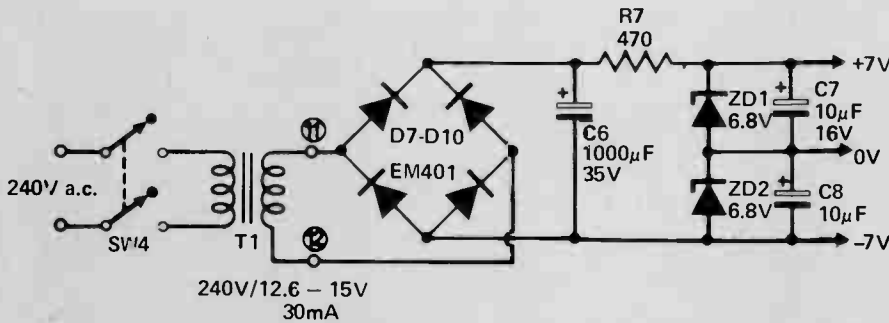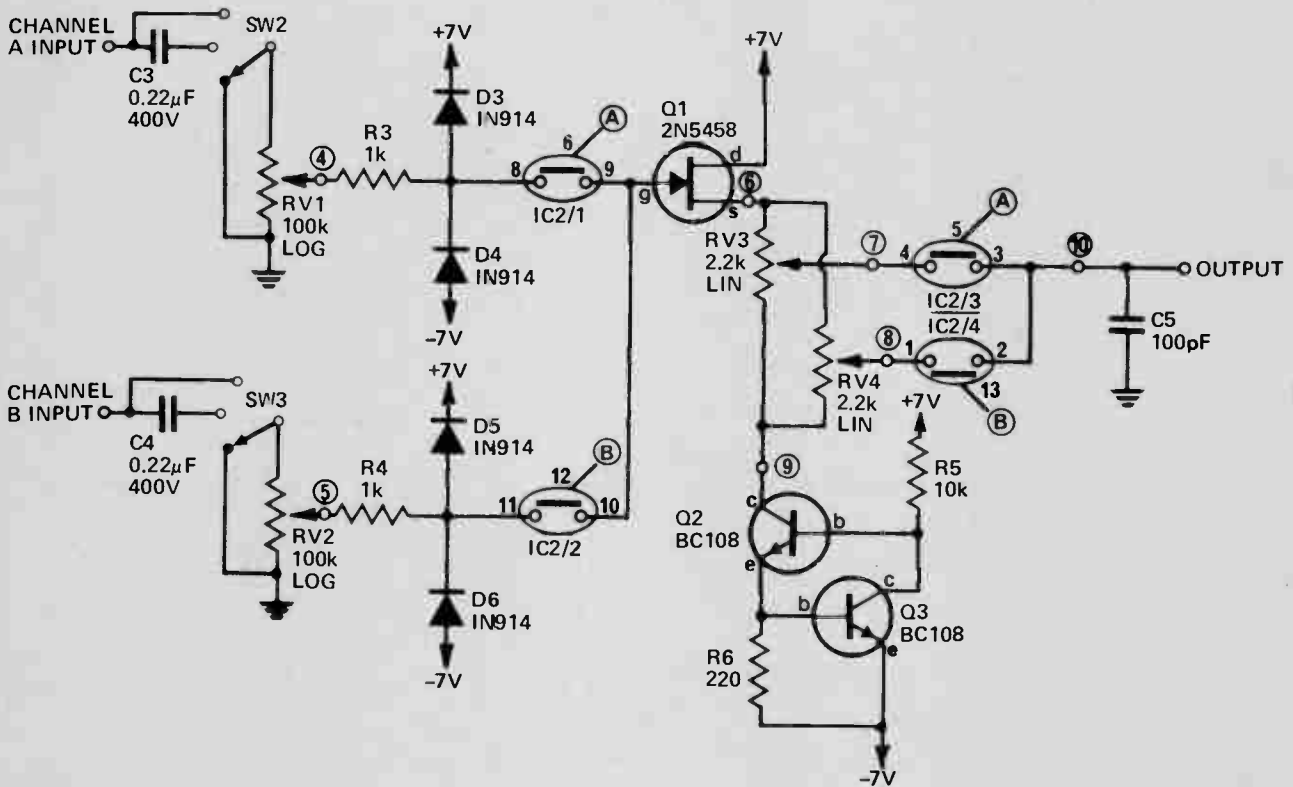
SPECIFICATION

Input Level
dc	± 4 volts max
ac	2 volts RMS max
dc insulation on ac	± 400 volts max
dc level shift	± 1.5 volts

Frequency Response
– 3dB point > 1 MHz

Chopping Frequencies
A	60 Hz
B	35 kHz

Input Impedance
100 k ohm

on the adaptor. However there is an attenuator provided on each input so that some adjustment may be made.

If only one input is to be applied it is best to switch to that input only thus eliminating the second trace and any cross talk which may occur due to the high input impedances.

Two chopping frequencies are used, having widely different frequencies, so that if the input signal is a harmonic of the chopping frequency, (see Fig. 4) choosing the other chop mode will prevent the chop frequency being visible.

Normally CHOP 1 would be used for high frequency inputs, and CHOP 2 for low frequency inputs. An ALTERNATE mode has not been included (entails obtaining an output

DUAL BEAM ADAPTOR

from the CRO of unknown level and availability) as the CHOP 1 mode is similar and almost as effective.

By means of the two shift controls traces A and B may be separated by up to ±1.5 volts.

HOW IT WORKS — ETI 114

Switches SW2 and SW3 select dc or ac coupling, or input shorted, for channel A and channel B inputs respectively. The signals are applied to the sensitivity potentiometers RV1 and RV2 and then passed to IC2/1 and IC2/2 which select one of the signals as an input to source follower Q1.

Transistor Q1 is supplied with a constant current (approximately 2.7 mA) by transistors Q2 and Q3. Hence, there is about 3 volts across RV3 and RV4, and this is unaffected by changes in input signal level. These potentiometers therefore provide a level-shift facility. When channel A is selected by IC2/1, IC2/3 selects RV3, and when channel B is selected by IC2/2, IC2/4 selects RV4. Thus as each signal has an independant level shift the two traces may be separated when chopped.

The CMOS gates of IC2 are driven by the outputs, A and B, the circuitry associated with IC1. The drive circuit mode of operation is selected by SW1, a four position switch, such that channel A only, channel B only, A and B chopped at 60 Hz or, A and B chopped at 35 kHz may be selected. The operation is as follows.

Integrated circuit IC1 forms a multivibrator which can run at 60 Hz or 35 kHz, or be locked in A-high B-low, or A-low B-high output states. For example, if SW1 selects −7 volts, IC1 pin 10 will be at +7, IC1 pin 11 will be at −7, IC1 pin 3 will be at +7 and IC1 pin 4 will be at −7 volts. The CMOS switches of IC2 will be "on" if the control voltage is at +7 volts and "off" if the control voltage is at −7 volts. Thus when −7 volts is selected by SW1, "A" will be at +7 volts, and IC2/1 and IC2/3 will select channel A. Similarly if +7 volts is selected by SW1, IC2/2 and IC2/4 will select channel B.

If C2 and R2 are selected by SW1 the multivibrator will be free to run at 60 Hz and channels A and B will be alternately selected at this frequency. Similarly if C1 and R1 are selected, channels A and B will be alternately selected at 35 kHz.

The power supply is a simple full-wave bridge type which uses two Zeners to provide the +7 and −7 volt supplies required.

Fig.2. Printed circuit board pattern for the adaptor. (Shown fullsize).
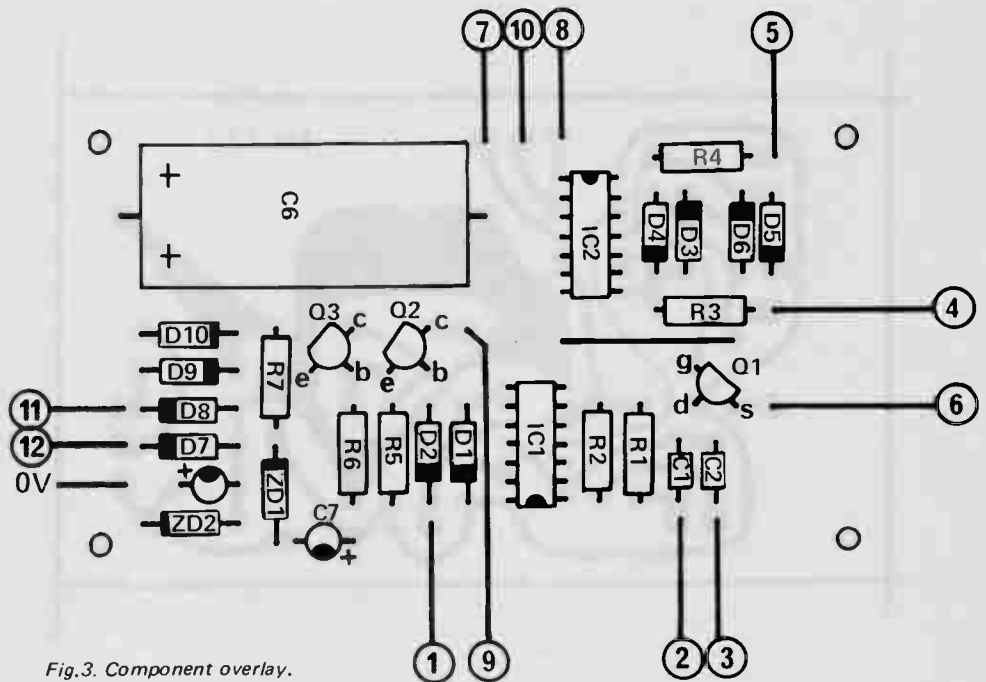
Fig.3. Component overlay.
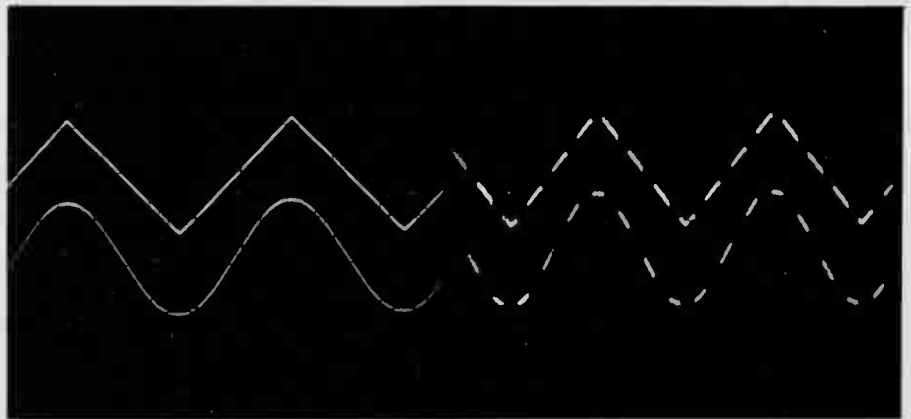
Fig.4a. Two signals, correctly displayed using the dual beam adaptor.

Fig.4b. Use of incorrect chopping frequency for a particular input signal (chop frequency a harmonic of signal) results in above effect. To cure use other chop frequency.

Layouts of components within the unit can be see from this and accompanying photographs.

Fig.5. Artwork for front panel of the adaptor.

World Radio History

World Radio History

IMPEDANCE METER

Measure impedance directly with ETI's new impedance meter — checks capacitance and inductance too!

THIS IS an unusual project — in that we started out designing one thing and finished up developing another!

We had intended to design an RLC bridge which is a very useful instrument and perhaps the next most commonly used after the multimeter, signal generator and scope.

But whilst it is useful to be able to measure the value of an individual component, on many occasions we are more concerned with the magnitude of the impedance than we are with the actual value of C or L.

For example assume that we require to know how the impedance of a speaker varies with frequency. Due to the effects of the crossover network it will not be known whether the speaker is inductive or capacitive in the crossover region. Additionally a speaker goes capacitive below its natural resonant frequency. Hence the use of an RLC bridge to plot impedance would be very tedious indeed. We would have to determine whether the speaker was capacitive or inductive, measure the actual value and then calculate the impedance for each point to be plotted.

With the ETI impedance meter impedance can be read *directly* as a function of frequency as shown in Fig. 7.

This is just one example of the many possible applications. In addition the meter may be used to measure component values by simply referring to a reactance chart or doing a simple calculation as detailed below.

Other applications include measuring the impedances of microphones, filters, transformers and amplifier inputs etc. All can be measured as easily as one would measure a resistor using an ohmmeter. Simply by connecting the device to the input terminals of the meter and making the measurement as detailed in the "How To Use" section.

In most practical applications we require to know the magnitude of the impedance — we do not care whether the device is predominantly inductive or capacitive.

On the rare occasions that we do require to know reactance we can

Fig. 1. Block diagram of the impedance meter shows that it consists of an oscillator an amplifier and a meter circuit.

PROJECT 116
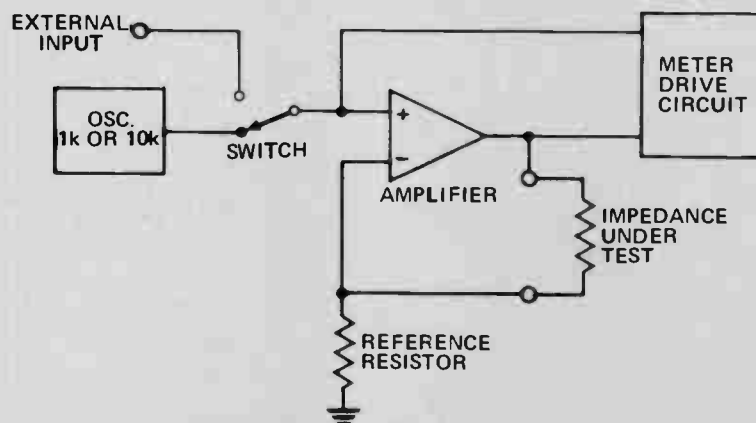
SPECIFICATION

Impedance measuring range	$1\Omega - 1$ Meg Ω	
Frequency of test	20 Hz — 20 kHz	external
	1 kHz or 10 kHz	internal
Range of inductance	$10\mu H - 1000$ H	external
	$20\mu H - 100$ H	internal
Range of capacitance	100 pF — $1000\mu F$	external
	100 pF — $100\mu F$	internal
Accuracy $\pm$ 5%		
Voltage applied to unknown, max 1 V rms		

When measuring items which are connected to the mains earth either the item, or the meter, must have the earth removed.

IMPEDANCE METER
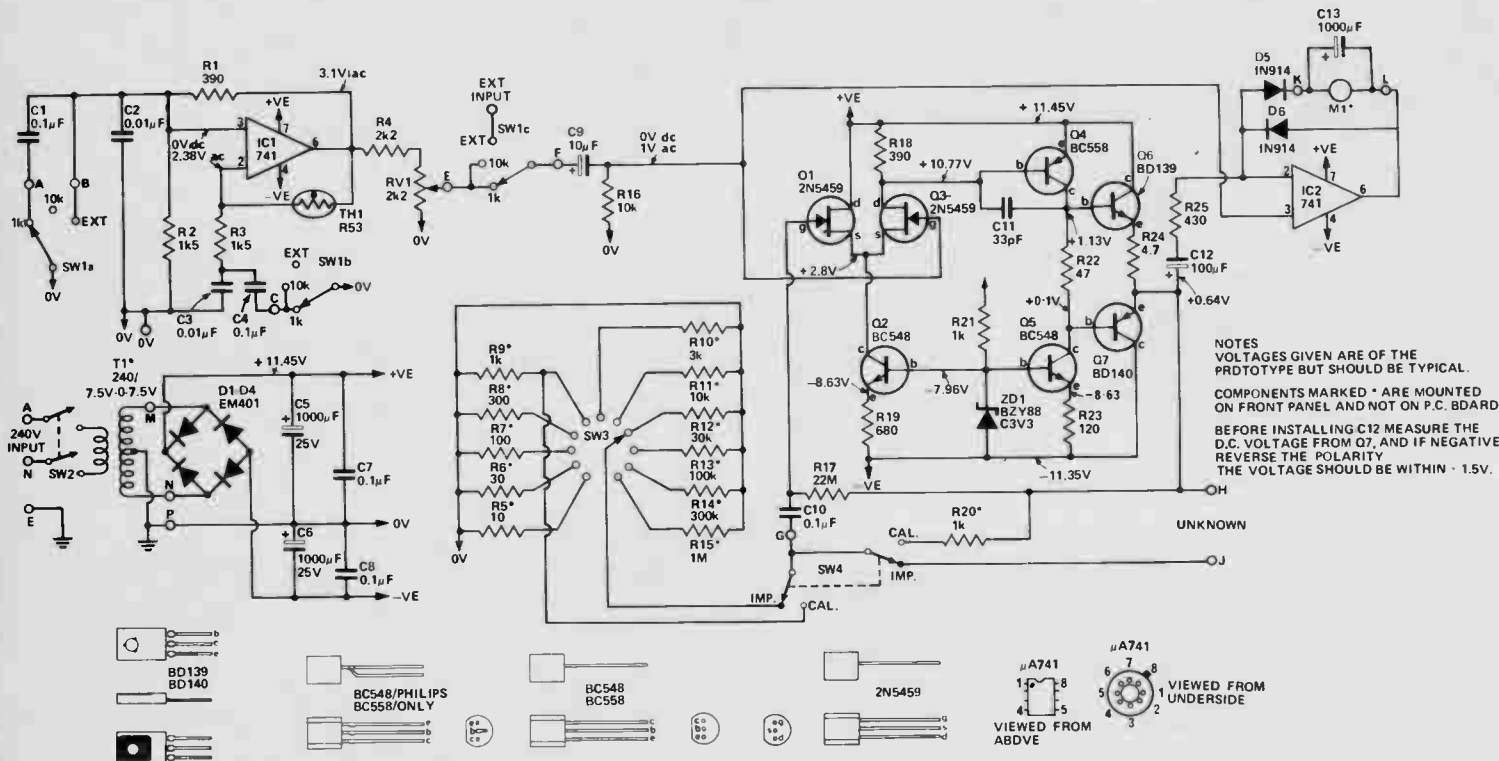
Fig. 2. Circuit diagram of the complete impedance meter.
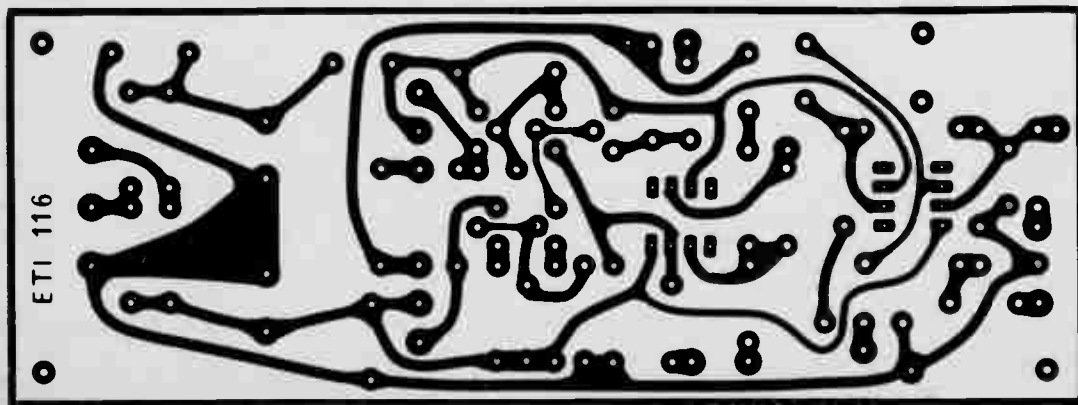
Fig. 3. Printed circuit board layout. Full size. 140 x 62 mm.

measure the dc resistance as well as the impedance and calculate from the formula

$$X = \sqrt{Z^2 - R^2}$$

where X = reactance inductive or capacitive at the frequency used

Z = magnitude of impedance (as measured on impedance meter)

R = dc resistance (as measured by an ohmmeter).

MEASURING CAPACITANCE

The value of an unknown capacitor can easily be determined by measuring the impedance and then using the reactance chart. Or, it may be calculated from the formula

$$C = \frac{1}{2\pi F X_c} \text{ (with capacitors } X_c = Z_c)$$

If the 10 kHz frequency is used this may be simplified to

$$C \text{ in microfarads} = \frac{16}{Z_c} (Z_c \text{ in ohms})$$

and if 1 kHz

$$C\mu F = \frac{160}{Z_c} (Z_c \text{ in ohms})$$

Since the meter can resolve the range 1 ohm to 1 megohm this implies a capacitance range of 16 pF to 160μF. But as explained elsewhere stray capacitance limits the lowest capacitance that can be resolved to about 100pF.

MEASURING INDUCTANCE

To determine the value of an unknown inductance the impedance is again measured and the value read off the reactance chart. Alternately the value may be calculated from

$$L = \frac{X_L}{2\pi F} \quad \text{high Q coils} \quad X_L = Z_L$$

or

$$L = \frac{\sqrt{Z_L^2 - R^2}}{2\pi F} \text{ (low Q coils)}$$
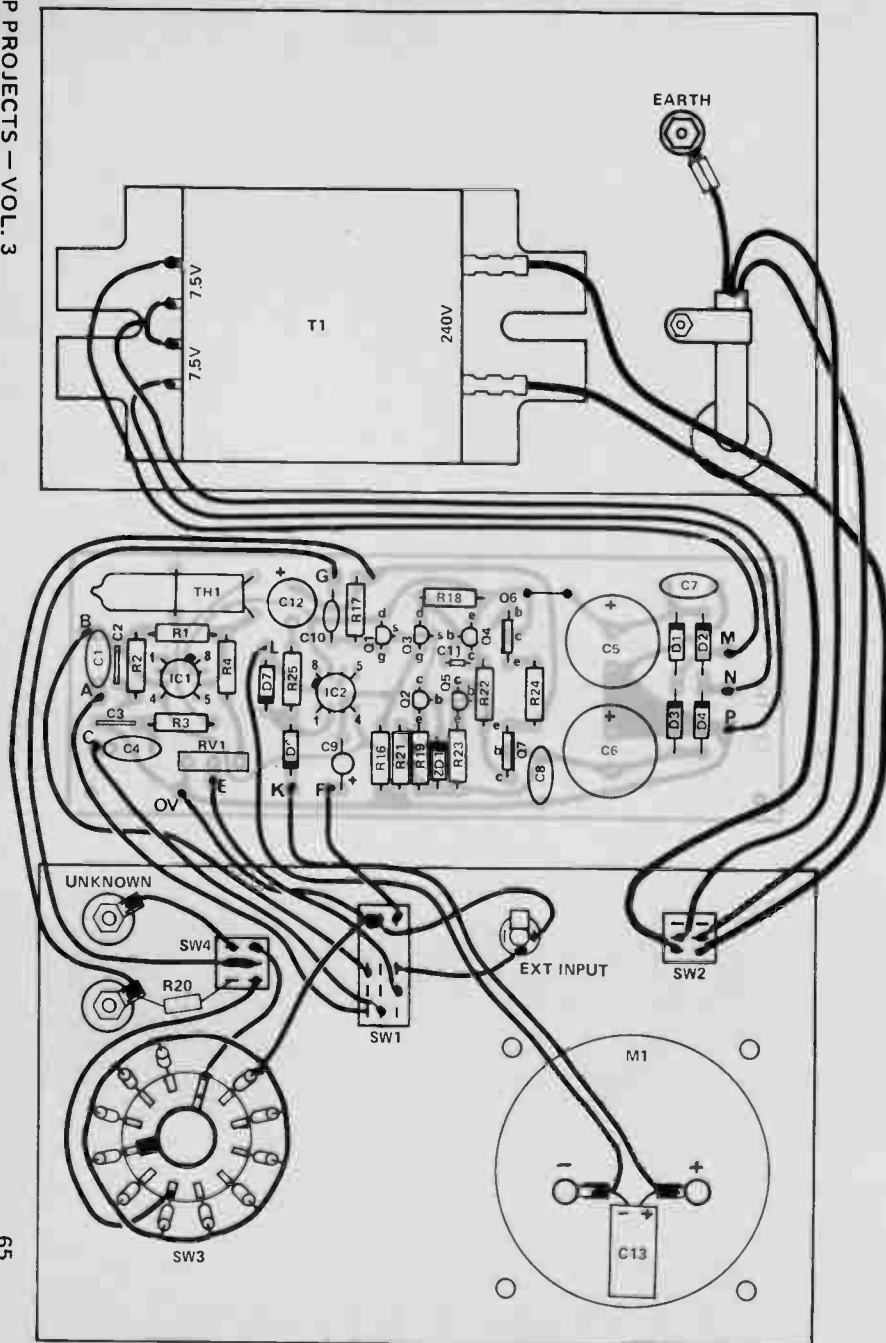
Fig. 4. Component overlay and wiring diagram for the impedance meter.

HOW IT WORKS ETI-116

The basic format of the impedance meter may be seen from the block diagram Fig.1. Firstly, we have an oscillator which may be switched to provide either 1 kHz or 10 kHz. Then we have a differential amplifier with a high input impedance, and lastly a meter drive circuit.

Either output of the oscillator, or an external frequency, as required, is passed to the non-inverting input of the amplifier. The amplifier gain is set by the ratio of the unknown impedance, Z, to the reference resistance, R. Due to feedback, the voltage across R is always equal to the input voltage and, as the amplifier requires no input current, the current through R must also flow through the unknown impedance, Z. The voltage across Z is therefore proportional to its impedance.

The meter circuit measures the output voltage by using the input voltage as a reference. Since the input voltage is equal to the voltage across R, we are effectively measuring the voltage across Z.

Refer now to the main circuit diagram Fig.2. The oscillator is of the Wein bridge type and uses a 741 IC as the amplifier and an R53 thermistor as the stabilizing element. The circuit oscillates at the frequency where the impedance of C2 and C3 is equal to the resistance of R2 and R3 respectively. Therefore, to change frequency, we simply change the values of C2 and C3. The output of the oscillator is attenuated by R4 and RV1 to approximately one volt.

The amplifier has a very high input impedance, can supply about 200 mA into a load, has an open-loop gain of 50 dB and can work into any load including a short circuit (unity gain).

An integrated circuit operational amplifier having the above characteristics (at reasonable cost) is not available, hence, a discrete seven transistor design was used. To obtain the high impedance input a pair of FETs, Q1 and Q3, used as a differential pair, operate with a constant current (4 mA) supplied by Q2. Transistor Q4 is supplied with a constant current of 22 mA by Q5, and Q4, in conjunction with the input pair, supplies the necessary overall gain. Transistors Q6 and Q7 buffer the output of Q4 and Q5 to provide the necessary current drive. The dc bias for the amplifier is provided by R17 such that an output voltage within ±1.5 volts of zero is always obtained.

The meter drive circuitry consists of a 741 IC with a meter, and half wave rectifier in series, connected in the feedback path. A second diode is used to prevent the IC being saturated on the opposite-polarity swing.

The current in the meter is half the current through R25 and, since this is proportional to the difference between input and output voltages of the amplifier, is proportional to the voltage across the unknown impedance. The meter scale is linear and the IC effectively compensates for the diode drop. Capacitor C3 provides the smoothing necessary when working at frequencies less than 40 Hz.

As previously stated the gain of the amplifier is set by the ratio of the unknown impedance 'Z' and the reference resistor 'R', and is equal to

$$\frac{Z + R}{R} \quad \text{(where Z may be complex)}$$

The value of R is switch selectable from 10 ohms to 1 megohm in eleven ranges. In the calibrate mode a 1 k resistor, R20, is substituted for the unknown impedance and the 1 k range selected. This provides a gain of two and thus with one volt in we have two volts out and hence 1 volt into the meter circuitry.

Thus, on calibrate, the output of the oscillator (or the external oscillator level) should be adjusted by RV1 to obtain full scale deflection on the meter. The calibrate position should also be selected before changing the unknown impedance, as an open circuit may damage the meter by driving it well beyond full scale.

IMPEDANCE METER

It should be borne in mind that we are determining impedances by using audio frequencies in this instrument hence components such as RF coils may well have a different impedance at RF frequencies (due to skin effect etc) than they do at audio. Additionally iron-cored coils have an inductance dependant upon the measuring frequency and upon dc current flowing. Hence such coils should be measured under conditions as close as possible to those when in circuit. Further the inductance value, as measured, will only be accurate on coils having a Q greater than 10.

If the dc resistance is greater than one tenth of the measured impedance the second formula should be used.

TURNS RATIO

To measure the turns ratio of an unknown transformer simply load the secondary with a value of resistance, R, which causes the impedance Zp (looking into the primary) to drop by 50% from the unloaded value. The turns ratio may then be calculated from

$$\frac{N_1}{N_2} = \sqrt{\frac{Z_P}{R}} \quad (N = \text{number of turns})$$
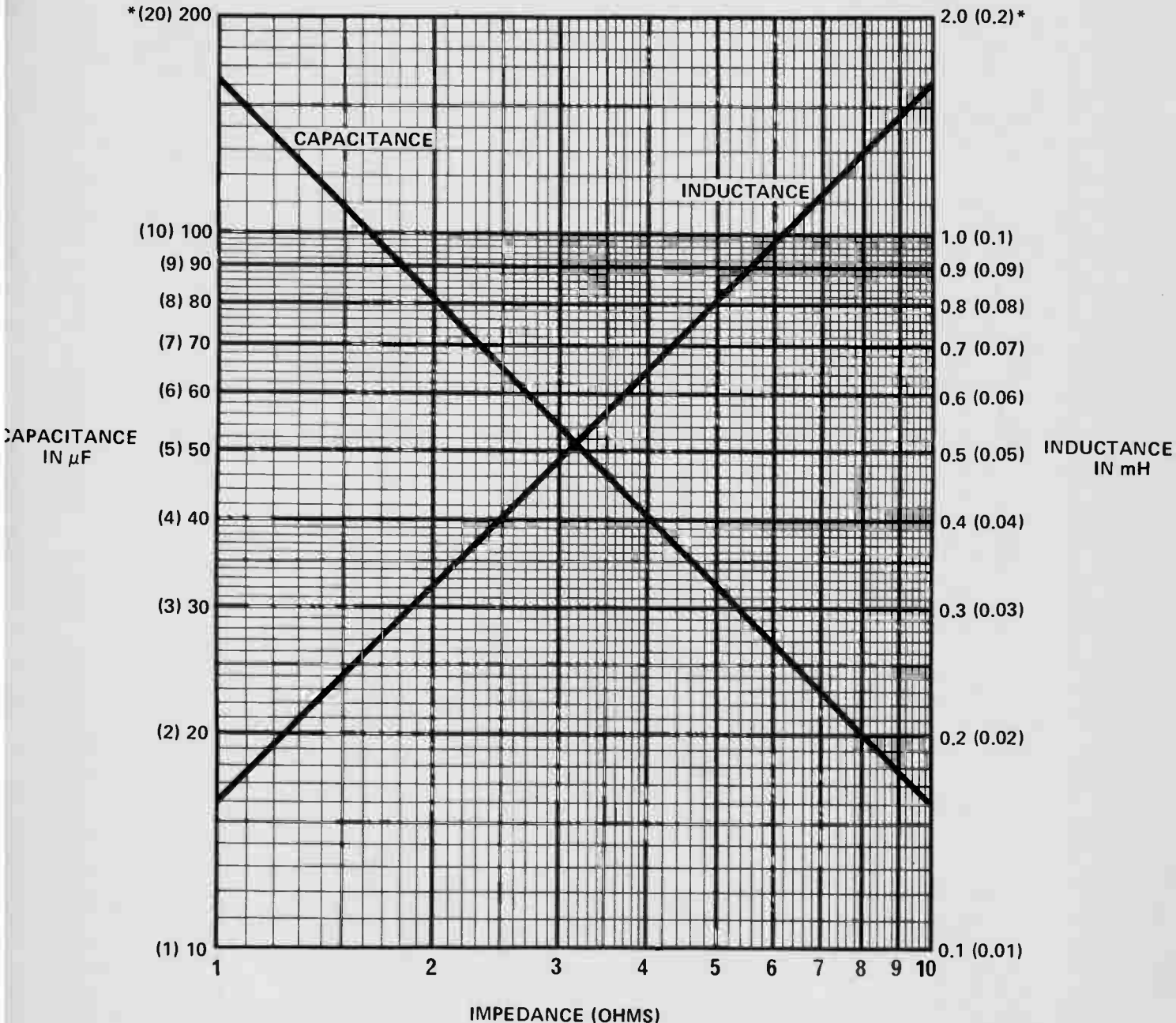
FOR IMPEDANCES GREATER THAN 10Ω DIVIDE CAPACITANCE SCALE BY THE SCALING FACTOR AND MULTIPLY THE INDUCTANCE SCALES BY THIS FACTOR. e.g. A CAPACITOR WHOSE IMPEDANCE IS 6000 OHMS (SCALING FACTOR x 1000) AT 1 kHz VALUE IS 27/1000 = 0.027µF

*FIGURES IN BRACKETS ARE FOR 10 kHz

Fig. 5. Reactance chart for determining values of L or C from measured impedance at 1 kHz (10 kHz in brackets).

This calculation is based on the fact that an impedance in the secondary is transformed to an impedance in the primary that is proportional to the square of the turns ratio.

Many other applications can be devised for an impedance meter and the few mentioned here are indicative of the usefulness of such an instrument.

CONSTRUCTION

Any accepted construction method may be used but the use of a printed circuit board will greatly simplify the procedure.

Components should be assembled onto the printed circuit board, with the aid of the component overlay Fig 4, making sure that all polarized components are orientated correctly. Capacitor C12 should not be fitted initially as the required polarity must be determined as follows.

Temporarily connect the transformer to the otherwize completed board and switch on the power. Measure the voltage from the amplifier at point H. This should be within ± 1.5 volts of zero. If this voltage is negative reverse the polarity of C12 to that shown on the overlay. If the voltage is positive use the polarity shown. This variation of voltage at point H is due to differences in the FET transistors Q1 and Q3.

Attach wires to all output connections of the printed circuit board allowing sufficient length to terminate them in their respective positions. Instal the board in position using 12 mm long spacers and countersunk screws. Countersunk screws are necessary as they will be covered by the lid of the box. Install the power transformer and power lead, on the rear panel, together with the power-cord clamp and earth lug. Mount the slide switch to the front panel using countersunk screws.

Resistors R5 to R14 should be mounted on the rotary switch SW3 before mounting it on the front panel. If the 30, 300, 3k etc resistors are not available they may be replaced by a parallel combination; eg 30 ohms is obtained from 33 ohm and 330 ohms in parallel and 3 k from 3.3 k and 33 k in parallel.

The rest of the front panel components, except the meter, (for ease of wiring) should now be mounted together with the escutcheon. The wiring can now be completed and the meter installed and connected.

USING THE METER

The meter should be used in the following manner:—

1. Switch the cal/impedance switch to cal.

Fig 4. Internal view of the meter shows how the board and other components are positioned.

2. Switch on power.

3. Select the required test frequency. The meter should read full scale, if not, adjust RV1.

4. If an external oscillator is used set the frequency and adjust oscillator output level to obtain full scale reading.

5. Connect the impedance to be measured.

6. Select the one megohm range.

7. Switch the cal/impedance switch to impedance.

8. Reduce the range, if necessary, to obtain a readable deflection. This reading is the required impedance; eg 0.6 on the 10 k range is an impedance of 6 k.

9. If desired the external frequency may be varied to obtain a plot of impedance versus frequency.

10. Switch back to 'Cal' before removing the impedance being measured.

TABLE 1

Error	Resistance (R2/R3)	Capacitor (C1,C4)	Capacitor (C2,C3)
1%	150k	0.001µF	100 pF
2%	68k	0.0022µF	220 pF
3%	47k	0.0033µF	330 pF
4%	39k	0.0039µF	390 pF
5%	27k	0.0056µF	560 pF
6%	22k	0.0068µF	680 pF
7%	18k	0.0082µF	820 pF
8%	18k	0.0082µF	820 pF
9%	15k	0.01µF	1000 pF
10%	13k	0.01µF	1000 pF

PARTS LIST — ETI 116

R24	Resistor	4.7 ohm	½W	5%	
R5	"	10	"	"	"
R6	"	30	"	"	"
R22	"	47	"	"	"
R7	"	100	"	"	"
R23	"	120	"	"	"
R8	"	300	"	"	"
R1,18	"	390	"	"	"
R25	"	430	"	"	"
R19	"	680	"	"	"
R9,20,21	"	1k		"	"
R2,3	"	1k5		"	"
R4	"	2k2		"	"
R10	"	3k		"	"
R11,16	"	10k		"	"
R12	"	30k		"	"
R13	"	100k		"	"
R14	"	300k		"	"
R15	"	1M		"	"
R17	"	22M		"	10%

RV1 Potentiometer 2k2 Trim type
TH1 Thermistor type R53

C11	Capacitor	33pF ceramic	
C2,3	"	0.01µF polyester	
C1,4,7	"	0.1µF	"
C8,10	"	0.1µF	"
C9	"	10µF 16V electrolytic	
C12	"	100µF 6.3V electrolytic	
C13	"	1000µF 6.3V electrolytic	
C5,6	"	1000µF 25V electrolytic	

Q1,3	Transistor	2N5459 or similar
Q2,5	"	BC548 "
Q4	"	BC558 "
Q6	"	BD137, BD139
Q7	"	BD138, BD140

IC1, 2 Integrated Circuit µA741C mini dip or TO5

D1-D4	Diodes	EM401 or similar
D5, 6	"	IN914 "
ZD1	Zener Diode	BZY88 C3V3 or similar

T1 Transformer 240V/7.5-0-7.5V @ 1A
PL 1.5-18/20VA, PL 15/20VA

M1 Meter 0-1ma FSD. 75 x 65 mm

SW1	Switch	three pole three position slide switch
SW2	"	DPDT 240V toggle switch
SW3	"	one pole eleven position rotary switch
SW4	"	DPDT toggle switch

PC board ETI-116, Metal box Dick Smith type LMB 564, Front panel, small phone socket, pointer knob, 3 core flex and plug, rubber grommet and cable clamp, four 12 mm long spacers, two terminals, nuts & bolts etc.

IMPEDANCE METER

FREQUENCY CALIBRATION

The frequency should be within 10% of nominal if specified components are used. However, if a frequency meter is available the network can be trimmed to give the correct readings.

Measure both the 1 kHz and the 10 kHz and calculate the percentage errors. If either or both are low in frequency the resistors R2 and R3 can be paralleled with additional resistors to increase the frequency. Since this will affect both ranges choose the one with the greatest error. Table 1 gives the correct resistance to use.

Re-measure the frequencies. One frequency should now be right and the other high. The capacitors C1 and C4 or C2 and C3 can be paralleled by the appropriate capacitors as selected from Table 1.

LIMITATIONS

Due to stray capacitance, (about 15 pF) associated with the front panel terminals and the switches, the 1 megohm range is useful only up to about 4 kHz. The 300 k range is useful to about 10 kHz.

When measuring series LCR networks (where the impedance rises greatly off resonance) it is usually necessary to parallel a resistor across the network to stabilize it. Once at resonance, the resistor may be removed for the actual impedance measurement. The frequency can now be altered provided that the meter is not allowed to go off scale. The resistor used should be not more than 10 times the value of the network impedance at resonance. ●
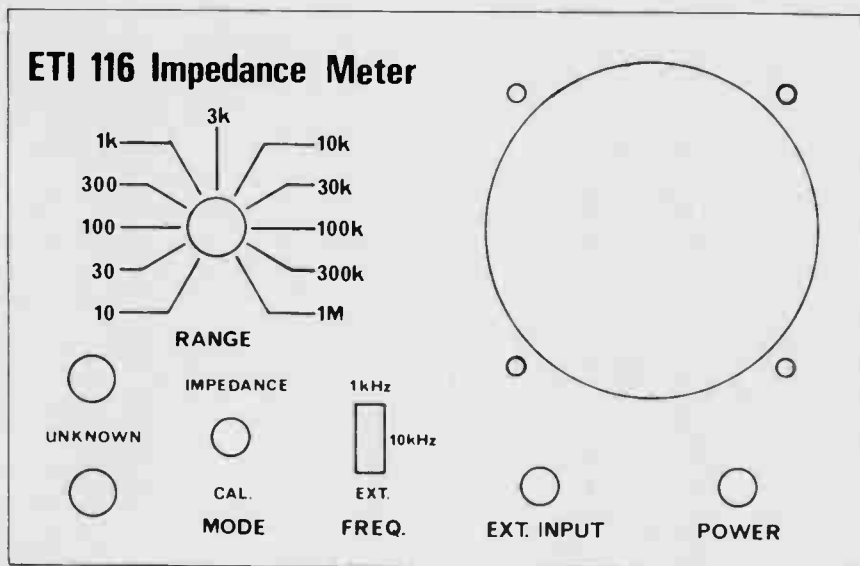
Fig. 6. Layout of front panel. Full size is 152 x 98 mm
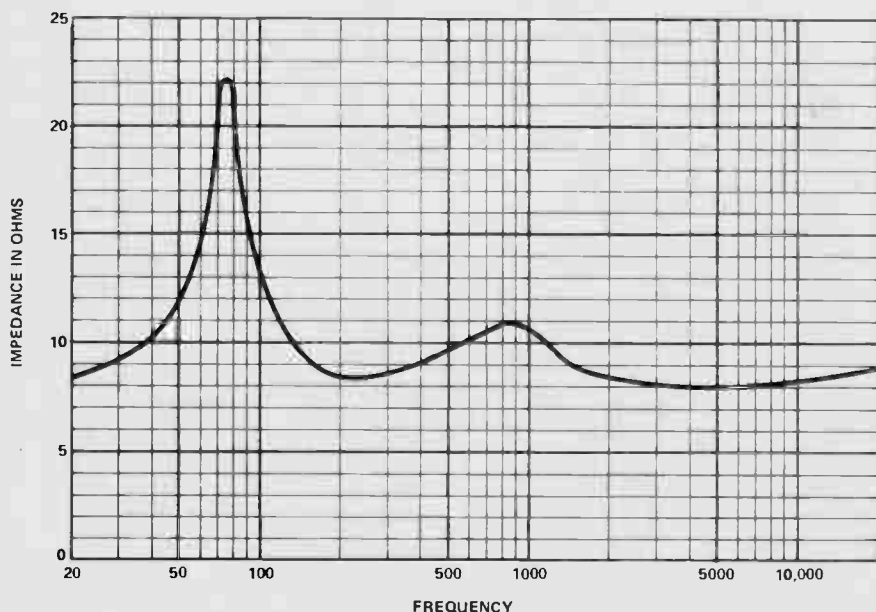
Fig. 7. Impedance-versus-frequency plot for a two-way speaker box. Note the combined speaker/box resonance is 75 Hz. The crossover frequency was 2 kHz. A plot such as this would be extremely difficult to generate using a conventional LCR bridge, but is very simply done using the ETI 116 impedance meter.

CIRCUIT DIAGRAM MARKINGS

ELECTRONICS Today International is adopting British Standard BS1852: 1967 for marking component values on circuit diagrams.

The values of components are given by figures but the decimal point is replaced by a multiplier symbol in accordance with a table of standard prefixes. This procedure greatly reduces the possibility of errors.

Examples

4 k7	equals	4.7 k ohm
47 k	''	47 k ohm
1 M 5	''	1.5M ohm
4n7	''	4.7 nF
6p8	''	6.8 pF

Where a multiplier is not needed, the symbol 'R' is inserted to signify ohms.

Example

4R7 equals 4.7 ohms

Note also that capacitors that were formerly specified as decimal fractions of microfarads (10^{-6}F) are now expressed in nanofarads (10^{-9}F).

Example

0.01μF = 10 nF

Abbreviation	Read as:	Multiplies unit by:
T	tera	10^{12}
G	giga	10^9
M	mega	10^6
k	kilo	10^3
h	hecto	10^2
da	deka	10
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
μ	micro	10^{-6}
n	nano	10^{-9}
p	pico	10^{-12}
f	femto	10^{-15}
a	atto	10^{-18}

Standard prefixes . Multiplier symbols above 1000 are written with capital (upper case) letters, multipliers below 1000 do not use capitals (i.e. they are in lower case).

When spelled out in full, all multipliers start with a lower case letter (except when it is the first letter in a sentence).

Thus   — 10 MW = 10 megawatts
       — 10 mW = 10 milliwatts

TONE BURST testing is a technique which is rapidly gaining acceptance in a wide variety of applications. Typical applications are in testing of hydrophones, signal-to-noise in telephone channels, reverberation chamber testing and in the determination of peak distortion in loudspeakers. With loudspeakers, tone burst testing has the further advantage that the speakers may be tested with their maximum peak power level whilst keeping the average sound output level low enough to not annoy the neighbours — a considerable advantage indeed.

Some time ago our audio consultants, Louis Challis and Associates, asked us to build them a tone-burst generator and the resulting instrument has been used by them ever since with much success. The tone-burst test has been mentioned in several speaker reviews and, as a result, many people have asked for constructional details of this instrument.

DESIGN FEATURES

A tone burst must always be an integral number of cycles. If the burst is switched on or off part way through a cycle then undesirable transients will be produced that will mask the test results. Thus the burst must start and end exactly at the zero-crossing point of the sine wave in the burst.

In the original unit, designed for Louis Challis, preset times can be independently selected for the on and off periods of the burst with the exception that the burst time is automatically modified to give an integral number of cycles. The preselected on/off ratio, however, is independant of the burst frequency. To give the required control range, six switched ranges as well as a variable control are provided for both the on and off periods. Other features of the original unit are the ability to start at any point in the cycle as well as the zero crossing point, a phase-inverting switch to select either the positive or the negative half cycle first and an OFF LEVEL control to set a base tone level which is modified when the tone burst occurs. In addition the dc level of the output can be set and a switch is provided to select burst, pure tone or off as required.

When it came to redesigning the unit as a project we decided that many of the features offered by the original design were unnecessary for the user concerned only with testing speakers. Hence the unit has been redesigned in a greatly simplified form.

Instead of using monostables to generate variable on/off times we now divide the input with a counter to

ei PROJECT 124

TONE BURST GENERATOR

A valuable tool for testing loudspeakers.

MEASURED PERFORMANCE TONE BURST GENERATOR.	
On Time Cycles.	2,4,8 or 16
Off Time Cycles	2,4,8 or 16
Frequency Response 3 Hz — 300 kHz	+0 −3 dB
Distortion 3 V input at 1 kHz	<0.02%
Input Level Maximum Nominal range	3 V RMS 100 mV to 1 V
Input Impedance	47 k
Output Noise Voltage with no input	<25 µV
Power Supply Current	4 mA

TONE BURST GENERATOR

Fig. 1. Circuit diagram.

REVERSE OUTPUT

IC4/3 4016
IC4/4 4016

R6 120Ω

TRIGGER OUTPUT

C1 1µF 25V
INPUT
R1 47k
IC1 301
+6V
−6V
R3 47k
R2 47Ω

IC2/1 4520
SW1
C2 220p
ON TIME

IC2/2 4520
SW2
C3 220p
OFF TIME

R4 47k
+6V

TONE   OFF
SW3/1   SW3/2
+6V   −6V
OFF   TONE

R5 47k
+6V

IC3/1 4001
IC3/2 4001

IC3/3 4001
IC3/4 4001

IC4/1 4016
IC4/2 4016

C4 33p
+6V
IC5 301
−6V
R7 120Ω
OUTPUT
C5 0.047µF
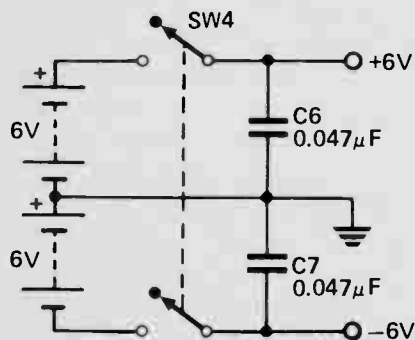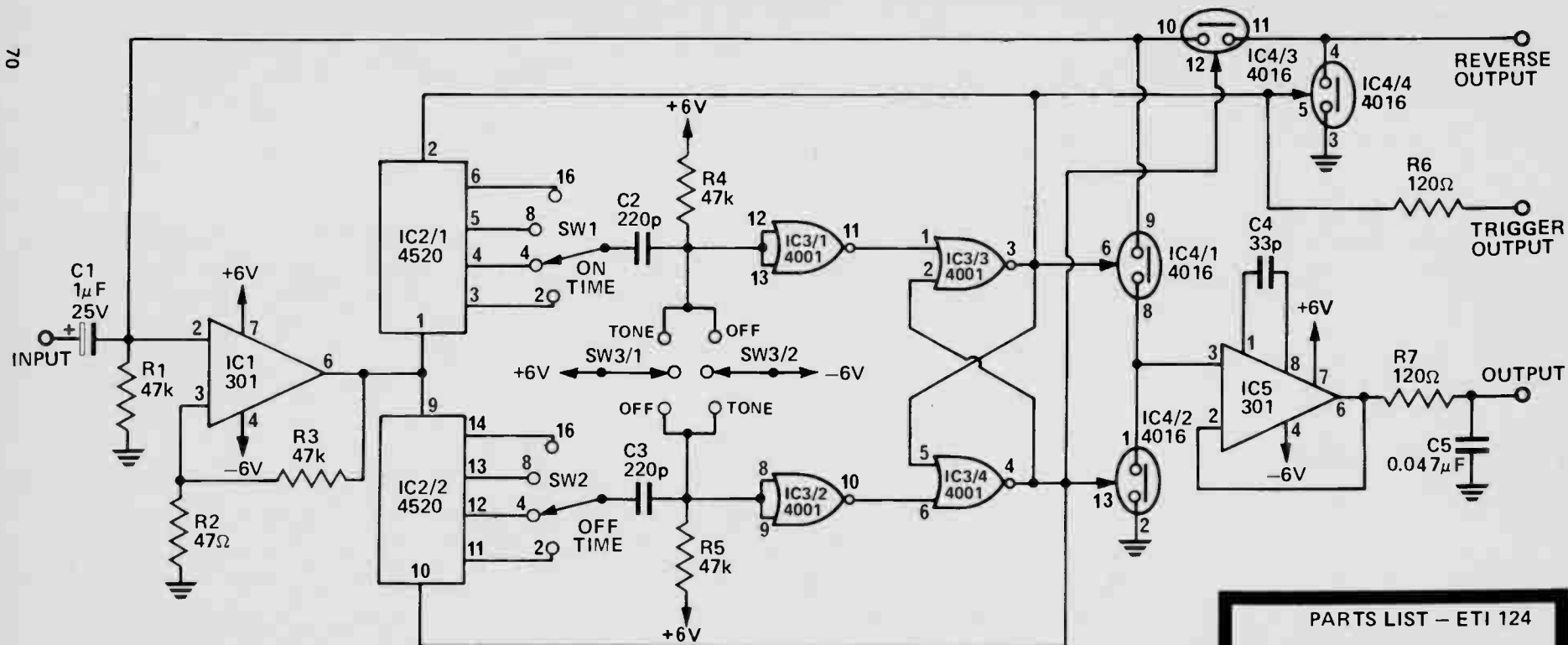
POWER RAILS OF IC2, IC3, AND IC4 NOT SHOWN
PIN 16 OF IC2 IS +6V
PIN 8 OF IC2 IS −6V
PIN 14 OF IC3 AND 4 IS +6V
PIN 7 OF IC3 AND 4 IS −6V
PIN 7 AND 15 OF IC2 ARE RESET PINS AND −6V

SW4
+6V
6V
C6 0.047µF
−6V
6V
C7 0.047µF

Fig. 4. How to add a potentiometer to the generator for burst-on-tone operation. That is the generator gives a continuous tone level with tone bursts of higher amplitude at intervals.

TO PIN 9 ON IC4
47k LIN
TO PINS 2,3 OF IC4 REMOVE LINK TO 0V
TO 0V.
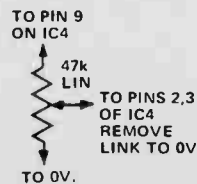
PARTS LIST — ETI 124

R1	Resistor	47	k	¼W	5%
R2	"	47	Ω	¼W	5%
R3	"	47	k	¼W	5%
R4	"	47	k	¼W	5%
R5	"	47	k	¼W	5%
R6	"	120		¼W	5%
R7	"	120		¼W	5%

C1	Capacitor	1 µF 25V electro
C2	"	220 pF ceramic
C3	"	220 pF ceramic
C4	"	33 pF ceramic
C5	"	0.047 µF polyester
C6	"	0.047 µF polyester
C7	"	0.047 µF polyester

IC1	Integrated Circuit	LM 301A
IC2	"	" 4520 (CMOS)
IC3	"	" 4001 (CMOS)
IC4	"	" 4016 (CMOS)
IC5	"	" LM301A

SW1 Switch 1 pole 4 position rotary
SW2 Switch 1 pole 4 position rotary
SW3 Switch DPDT Toggle with centre off
SW4 Switch DPDT Toggle

PC Board ETI 124
8 AA size batteries
2 4-way battery holders and clips
Plastic case
Escutcheon
3 single RCA sockets
2 knobs

14 +Ve
A
1
2 13 CONTROL A
3 12 CONTROL C
B
4 11
C
CONTROL B 5 10
CONTROL D 6 9 D
−Ve 7 8

4016
4066
QUAD ANALOGUE
SWITCH. ON IF
CONTROL IS HIGH
ON RESISTANCE
4016 TYP 280Ω
4066 TYP 80Ω

CLOCK 1 16 +Ve
ENABLE 2 15 RESET
2 3 14 16
4 4 13 8
8 5 12 4
16 6 11 2
RESET 7 10 ENABLE
−Ve 8 9 CLOCK

4520
DUAL 4 BIT
BINARY UP COUNTER
TOGGLE ON POSITIVE
EDGE OF CLOCK
IF ENABLE IS HIGH
AND RESET IS LOW.

14 +Ve
1
2 13
3 12
4 11
5 10
6 9
−Ve 7 8

4001
QUAD 2 INPUT
NOR GATE

INPUTS		OUTPUT
A	B	
0	0	1
0	1	0
1	0	0
1	1	0

Fig. 3. Pin connections of the ICs used in the generator.

4 x 1.5V BATTERY
4 x 1.5V BATTERY
SW4
SW3

INPUT
OUTPUT
C6
C1
R7
C4
IC1 R3 IC5 IC4 IC2 IC3
R2 C7 R6 C2 C3
R1

TRIGGER OUTPUT

11 3
12 4
13 5
14 6
SW2 SW1

Fig. 2. Component overlay
and interconnection diagram.
Note that there are six links on
the board, including two under
IC4, which should be installed
first.

HOW IT WORKS — ETI 124

The input signal is squared by comparator IC1 such that the output of the comparator will be high if the input is above +6 mV, and low if the input signal is below −6 mV. Resistors R2 and R3 provide the necessary positive feedback to cause the IC to act as a comparator. The output of the comparator is connected to both clock lines of IC2. If the enable line is high these counters (IC2) will toggle at the input frequency.

IC3/3 and IC3/4 form an RS flip flop where the output must be in either a high or a low state, that is the flip flop has only two stable states. If the output of IC3/3 is high IC2/1 is allowed to clock and, after the number of input pulses selected by SW1 have been counted, the output from SW1 goes low. This low is coupled to the flip flop by C2 toggling the flip flop, disabling IC2/1 and enabling IC3/2. After the number of cycles, as selected by SW2, have been counted the flip flop is again toggled. IC3/1 and IC3/2 are used to square up the pulses generated by C2 and C3 respectively.

The input signal is also coupled to the output buffer, IC5, by the analogue switch IC4/1. When this switch is closed (control signal high) the output of the buffer will be the same as the input. When switch IC4/1 is open IC4/2 will be closed and the output will be held at zero. Since these switches are controlled by the flip flop the output will be the required tone burst.

A trigger output is taken from the flip flop to synchronize an oscilloscope if required. A second output is also available from pins 4/11 of IC4 which is the reverse of the main output.

Switch SW3 forces the flip flop into either of its two possible states thus allowing continuous tone or no output to be selected as required. In the centre position the normal tone burst is obtained.

TONE BURST GENERATOR
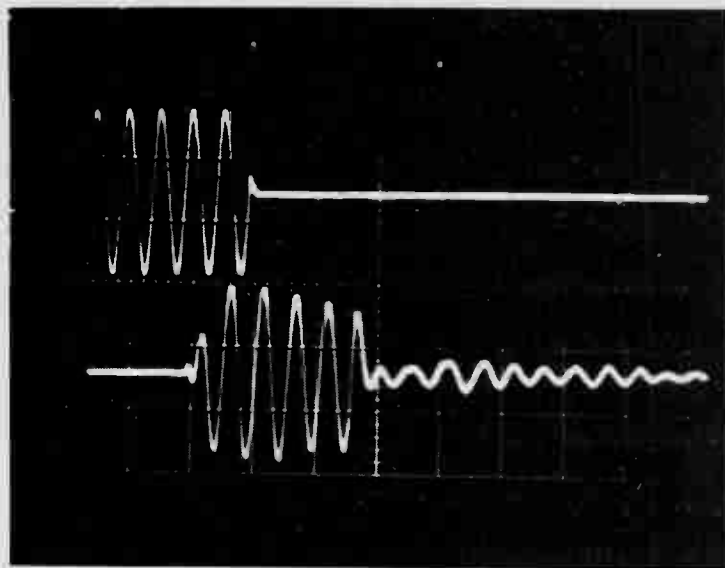
Fig.5 (a) Top trace — the input tone burst of five cycles. (original design).
(b) Bottom trace — the response of a low-cost speaker at 1 kHz. Note the reduced amplitude of the first half cycle and that ringing has added another cycle at the end of the burst. The room reflection can be seen on the trace after the burst.

obtain times that remain in the same ratio regardless of input frequency. We settled for the ability to select 2, 4, 8 and 16 cycles for the duration of either period, as this compromise greatly simplifies the circuitry. We still have the switch to select tone, tone burst or off, but the OFF LEVEL control has been deleted. The latter control may quite easily be added, however, as shown in Fig. 4. . The output dc level control and the starting-point phase change have also been deleted.

Since we only need half of a CMOS 4016 IC, to give the required output, the other half may be used to give an inverse output if required, that is, the reverse output is on when the other is off and vice versa. This output is not buffered or brought out to the front panel. If it is intended to load this output with less than 47 k it is recommended that a 4066 IC be used instead which will handle loads down to 10 k. For loads of lower impedance than this, a buffer such as is on the normal output should be used.
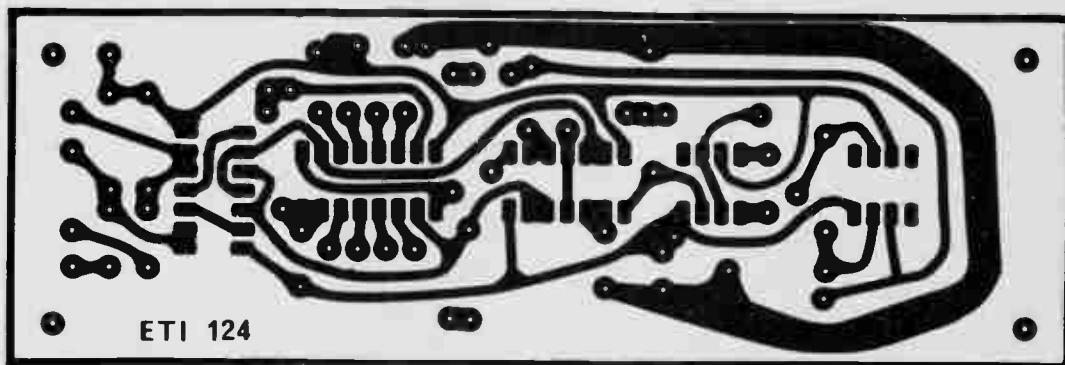
Fig.6. Printed circuit board for the Tone Burst Generator Full size. 142 x 47mm.

ETI 124
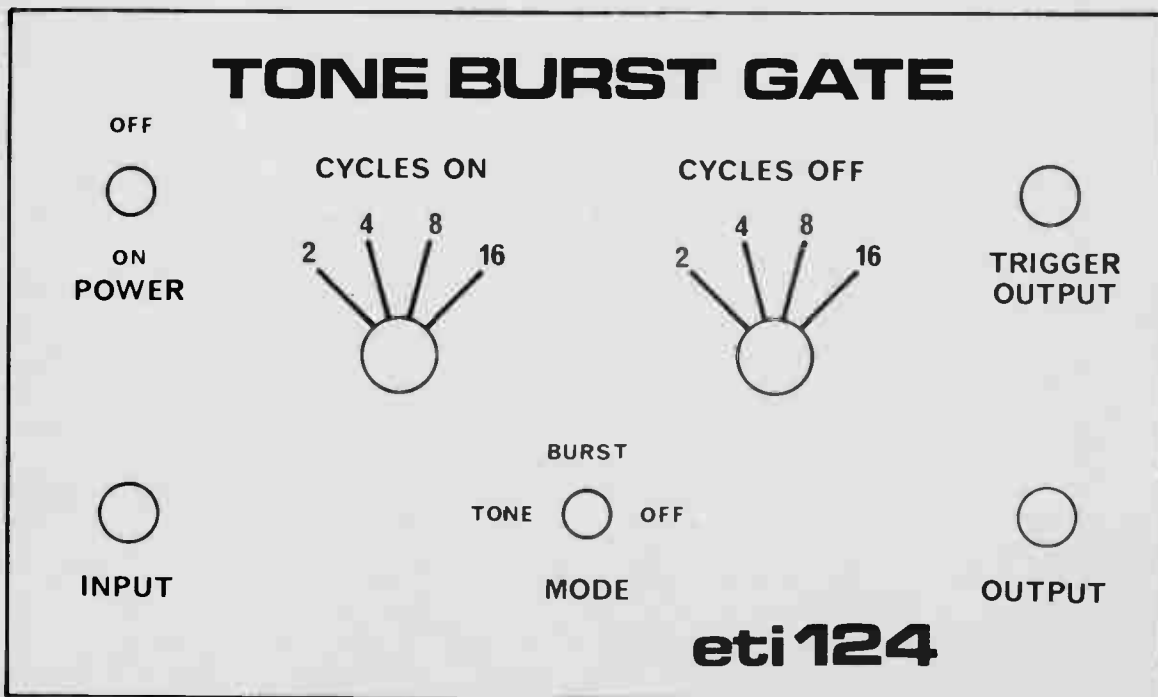
Fig.7. Front panel artwork.

CONSTRUCTION

As with any project construction is greatly simplified if a printed circuit board is used. However the layout of the unit is not critical and any other suitable method, such as Veroboard or Matrix board may be used if desired. We strongly recommend that sockets be used for the CMOS ICs, especially if a printed circuit board is not used, as these devices are quite easily damaged when soldering. The use of IC sockets also facilitates later servicing. Also remember that, unlike TTL, all unused inputs of CMOS must be connected to either the positive or negative supply rail.

The plastic box that we used measured 160 x 95 x 50 mm and is very convenient in that the printed circuit may be held in position by sliding it down behind two of the pillars to which the front panel is screwed. The front-panel overlay on the prototype was made from Scotchcal but, as the amount of lettering required is quite small, this may readily be done directly on the panel by hand or with Letraset.

Shielding of the internal wiring is not required providing that the unit is kept away from strong 50 Hz fields. If operation in the vicinity of strong fields cannot be avoided then the unit should be mounted in a diecast box.

USING THE UNIT

The testing of loudspeakers is very difficult indeed and much effort is still being spent to find test methods which will not only give an accurate understanding of the relative effectiveness of the design, but which will be easy to reproduce.

One of the main problems with speaker testing is that the speaker cannot easily be isolated from its environment. For example, reflections from the walls of a room modify the response, seen by a microphone, no matter where the microphone is placed in the room. If one could eliminate reflections then the situation would be improved considerably, and hence the use of anechoic (echo free) chambers for testing speakers. But such chambers are very expensive to build and consequently not readily accessible to the amateur.

A further problem is in assessing the transient power handling capability of the speaker. Speakers will handle far greater peak transient power than is indicated by their RMS power rating. This is a very important attribute of loudspeakers in handling musical transients. Any attempt to assess this with a sinewave signal may result in the destruction of the speaker due to thermal failure — apart from also being extremely noisy.
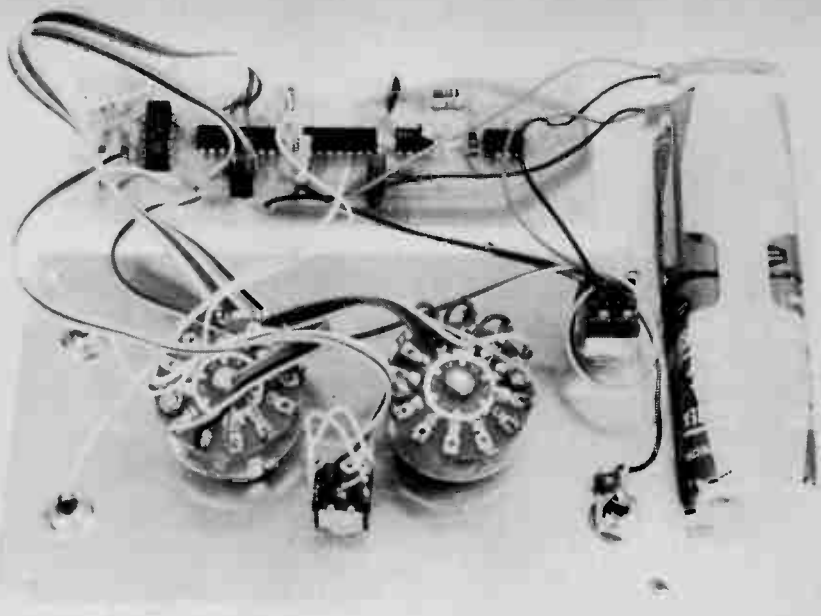
How the unit is assembled.

The use of a tone-burst generator minimizes both these problems. How this is achieved is better understood by examination of Fig.5. This shows on the upper trace a five cycle 1000 Hz burst that is fed to a loudspeaker. The second trace shows the same burst as picked up by a microphone in front of the speaker. We notice that the burst has been changed by the speaker and an examination of these changes can tell us a lot about the speaker. For example we notice that the first half cycle has not reached full amplitude and this indicates that the speaker would have some difficulty in reproducing high frequency transients. Next we notice that instead of five cycles there are now at least five and a half. This could mean one of two things. Either there is a speaker/room resonance or, the speaker itself is continuing to vibrate after the original excitation has ceased. Which is it? We can determine this by changing the position of the speaker to see if any change occurs in the shape of the burst, if not it is caused by the speaker itself, and if it does then it is a speaker/room resonance. A speaker that lengthens the burst unduly will sound muddy in that region. Of course the speaker must be examined over its whole range to gain a thorough assessment of performance.

It is of course possible to eliminate room reflections simply by performing the tests outside. However unless one lives in a very quiet area, background noise will introduce problems — and your neighbours are unlikely to appreciate the noise that you will generate.

By varying the off period we can also select a ratio where the room reflection, the oscillation seen after the cessation of the burst, does not interfere with the first few cycles of the burst and the response versus frequency of the speaker may then be assessed from the amplitude of the first half cycles that are stable in amplitude. Thus it is possible to gain an appreciation of the frequency response, transient performance and quality in terms of ringing of a speaker by careful use of the tone-burst technique.

The transient power handling capability of a speaker may be assessed by selecting a fairly long off to on ratio for the burst and by feeding the burst to the speaker via a high-power amplifier. If for example an off to on ratio of 8:1 is used then the peak power will be eight times the average power. Thus the speaker may safely be driven to a peak level where a predetermined amount of distortion occurs. Take care that the amplifier is capable of providing the peak power required.

Of course a tone-burst generator may be used for a wide range of testing. We have mainly concentrated in this article on its application to the testing of loudspeakers.

The circuitry of the tone-burst generator may easily be modified for use as a 'silent switch' for A/B speaker testing. The modification was described in December 1975, Electronics Today.

eti PROJECT 533
DIGITAL DISPLAY
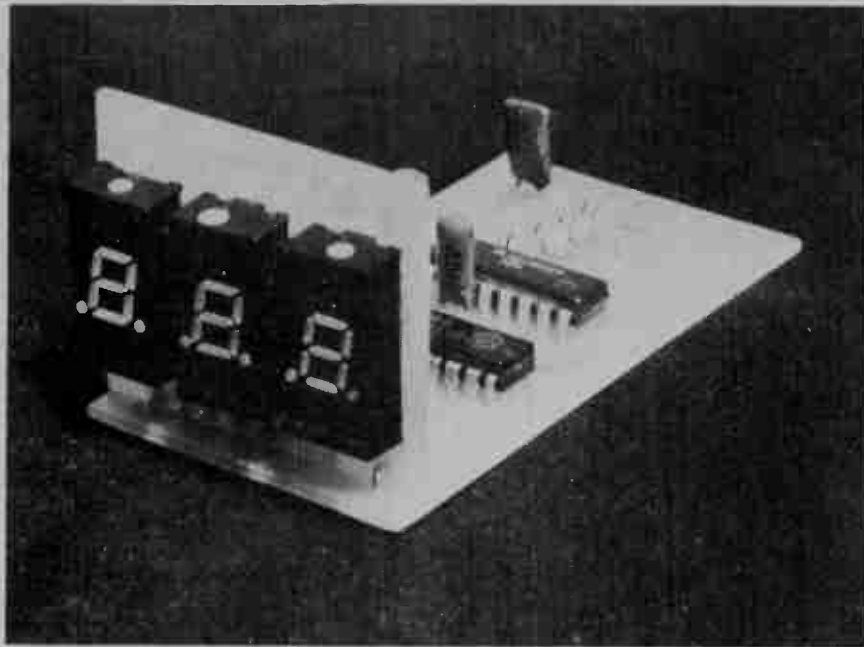
Three digit module for experimenters.

ALL digital instruments have a common assembly in the display system. Again, almost all instruments require decade counters, stores and decoder-drivers for the display.

Normal systems using TTL logic generally have a 7490, a 7475 and a 7447 to drive each 7 segment LED display digit. Hence to build a three-digit display nine ICs are required in addition to three display ICs.

Complex logic functions are available in CMOS which allow a 3 digit display to be built using only two ICs — and such ICs are available at reasonable cost. One of the devices is a three-digit, decade-counter, store and the second is a three-digit decoder-driver. Thus three digit displays can be built which have the following advantages.

1. Small size
2. Low power consumption (120 mA compared to 600 mA in TTL)
3. Wide power supply range (5-15V unregulated).
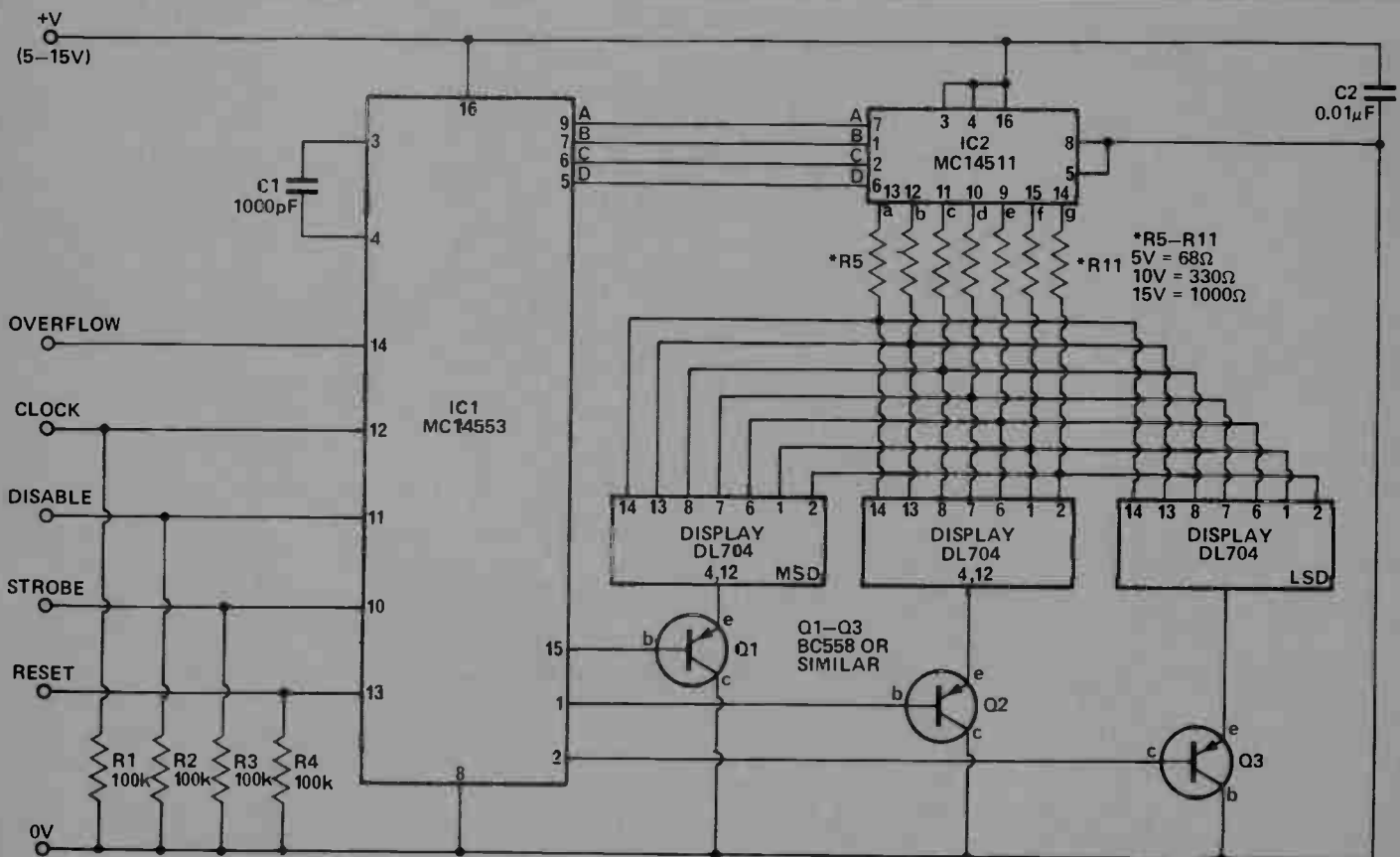
Fig. 1. Circuit diagram of the three digit counter module.

FOR DECIMEL PT. (RIGHT HAND)
ON DISPLAY CONNECT
PIN 9 TO +V VIA RESISTOR
(OF SAME VALUE) AS ABOVE

4. Cost about same as **TTL** but rapidly decreasing.
5. Immunity to noise is greatly improved.

Disadvantages

Maximum frequency about 1 MHz compared to 15 MHz for TTL..

CONSTRUCTION

Construction is quite straightforward especially if the printed circuit boards described are used. Since both ICs are CMOS devices, they can be easily damaged by static charges. Hence they should be handled as little as possible, fitted to the board after all other components and soldered using a minimum of heat.

Using the component overlay assemble the three DL704 displays to the display board (533B). Next solder the links onto the copper-side of the display board and form them so that they are clear of other tracks by at least one millimeter.

Next fix lengths of tinned copper wire to each of the six holes on the bottom of the display board. Allow approximately 10 mm of wire to extend from either end of the holes. Bend each wire so that they lie parallel and flush to the surfaces of the display board — do not solder as yet.

On the main printed-circuit board (533A) fit resistors R7, 8, 9, 12, 3 and 4 and capacitors C1 and C2. Now mate the display board to the main board by inserting each of the previously bent wires into its corresponding pair of holes on the main board.

Apply gentle force to the display

Rear view of the completed module. Note resistors and links at rear of display board.
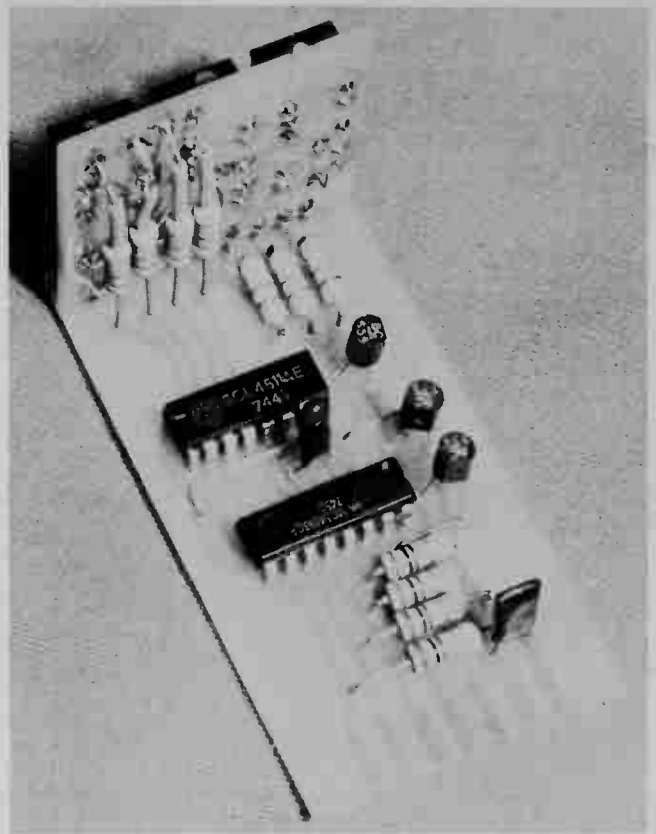
board until its bottom edge fits snugly against the main board. Solder each of the wires to both the supply and main boards to make a sound electrical and mechanical support for the display.

Fit R5, 10 and 11 and, taking care to orientate them correctly, fit Q1, 2 and 3 and IC1 and 2.

Lastly check that all components

have been correctly fitted and all solder joints are good. If possible get someone else to check your final circuit as a final safeguard. ●
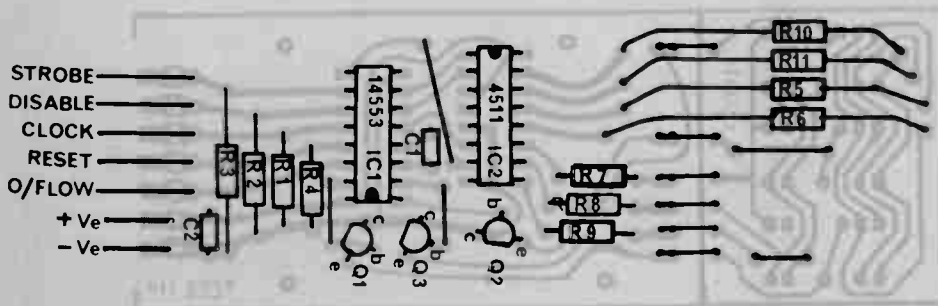
Fig. 2. Component overlay-logic board.
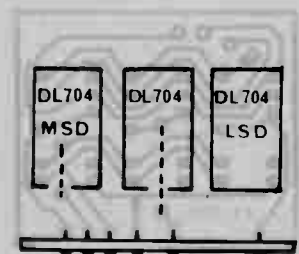
Fig. 3. Component overlay — display board.
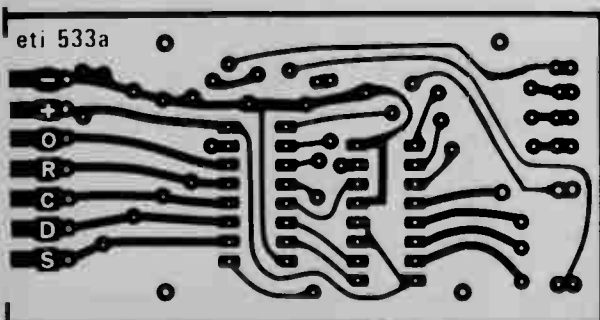
Fig.4. Printed circuit layout for logic board. Full size 80 x 42 mm.
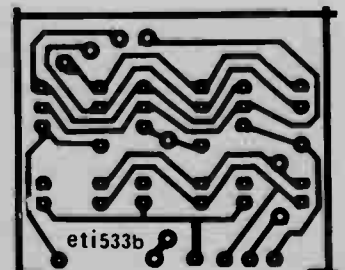
Fig. 5. Printed circuit layout for the display board. Full size 41 x 35 mm.

DIGITAL DISPLAY

PARTS LIST — ETI 533

R1,2,3,4 Resistor   100 k
R5-11   "   see text.

C1 Capacitor 0.001 μF Polyester
C2   "   0.01 μF Polyester

IC1 Integrated Circuit MC 14553 (CMOS)
IC2   "   "   14511 or 4511 (CMOS)

Q1,2,3 Transistor BC 558 or similar
DISPLAYS DL704 or similar three required
PC boards ETI 533A and ETI 533 B

HOW IT WORKS — ETI533

The heart of the counter is IC1, this LSI CMOS chip contains a three-digit decade counter, three sets of latches, and a three-digit multiplexer with an internal oscillator. C1 is used to set the frequency of this oscillator.

The four input lines to IC1 are used to control the operation of the counter. Since IC1 is a CMOS device R1-4 are used to protect its inputs. Pulses to be counted are fed to the clock input and on a negative transition the value in the counter is increased by one. The schmitt-trigger action of the clock input allows any value of transition time of the input pulse.

The counter operates when there is a low at the disable input (pin 11).

To ensure accurate counting the clock should be low when the disable is brought from a high to a low level. The strobe input controls the loading of the latch. When it is low, data can be accepted for display. However the strobe input has no effect on the counter, i.e, even with the strobe input high, the counter can still be incrementing.

A high on the reset input clears the counters (to a 000 state) and stops the internal multiplexing oscillation of IC2, and so — blanks the display. Returning the reset to a low allows the internal oscillator to start up and all zeros to be displayed. This feature could be used in portable equipment to conserve power.

All inputs are standard CMOS inputs and require a minimum voltage change of from 30% to 70% of supply volts. However it is recommended that a swing from 0V to supply be used to give a satisfactory noise margin. Each input can be considered to be 100k shunted by 8-10 pf. Voltage swing below 0V and above supply are also to be avoided.

The one output available is the overflow (pin 14). This goes positive when the counter is 999 and the clock input is high. When the clock input goes low and advances the counter to all zeros the overflow goes low. This is a CMOS output and will swing between supply rails. It is not recommended that the overflow output be used to drive TTL directly.

The internal multiplexer of IC1 allows considerable saving in parts and board space. It allows a three-digit number to be transmitted over a single set of lines and it does this by leaving each digit on the output lines for a short length of time, before replacing it with the next digit. Then after presenting all the digits once, it starts over again and repeats the operation.

IC2 is a CMOS, latch BCD to seven-segment decoder and driver, however for this application the latch is not used. It converts the 4-bit BCD code into the seven-line code necessary to drive the display segments. It also provides sufficient current to drive the display. Although IC2 is coupled to all three displays, only one display is lit up at any one time. Thus when it is the turn of the most significant digit to be displayed IC1 presents that number to IC2 which decodes the number and presents it to the three displays, but only Q1 is turned on, so only the left most display lights.

Note that IC1 controls which number is being presented and which transistor is turned on. This is called multiplexing. The switching between displays occurs so quickly that to our eyes the light appears continous.

Resistors R5 to R11 limit the current to each LED display to a safe level. Three different values have been given for these resistors. Select the value appropriate to the supply voltage that you decide to use. 68 ohms for 5 V, 330 ohms for 10 V and 1k for 15 V. Transistors Q1, Q2 and Q3 also act as current amps since only a limited amount of current can be taken from IC1.

Any voltage from 5 V to 15 V can be used to supply the counter, however, a supply voltage of 15 V allows the counter to operate at its highest speed.

DIGITAL VOLTMETER

THE SIMPLE, three-digit display module described in the preceding article is inexpensive to build and is readily adaptable to a wide range of applications. We now provide details of the first of a series of modules specifically designed to interface with the ETI 533 display module.

The first of these modules is a simple, yet accurate, dc digital voltmeter. Fundamentally we have described it as a single range unit which is economical enough to be mounted within other equipment as a panel meter. However an input switch may be readily added to convert the instrument for use on ranges from one volt dc full scale to 1000 volts dc full scale.

We have not described the mounting of the unit in a cabinet or box as individual requirements will vary widely.

CONSTRUCTION

The display-counter module ETI 533 should be built first using the instructions given on page 75.

Two additional boards are required to complete the voltmeter and the overlays and interconnections are given in Fig. 3. Check that all components, especially the metal case ICs are orientated correctly.

The interconnection wires should be long enough to allow the boards to fold together as shown above. The lower board ETI 533A has the components uppermost, the middle board ETI 117A has the components downwards while the top board ETI 117B again has the components uppermost. It may be necessary to juggle the components slightly on the lower two boards to allow them to fit together closely enough. These two boards are spaced apart with 12mm long spacers while the upper two boards are separated by 6mm insulated spacers. A piece of insulation material should be fitted between the top two boards to prevent the solder joints touching.

Power, 9-15 volts dc, is supplied to the lower board while the input connects to the upper board.

The unit can be either installed in a suitable box or within a piece of equipment. If range switches are required simply change the value of R12 as per Table 1. A suitable box for mounting the unit as a separate instrument is the type PC1 marketed by A & R.

CALIBRATION

Unfortunately to calibrate any voltmeter a known voltage reference

eti PROJECT 117
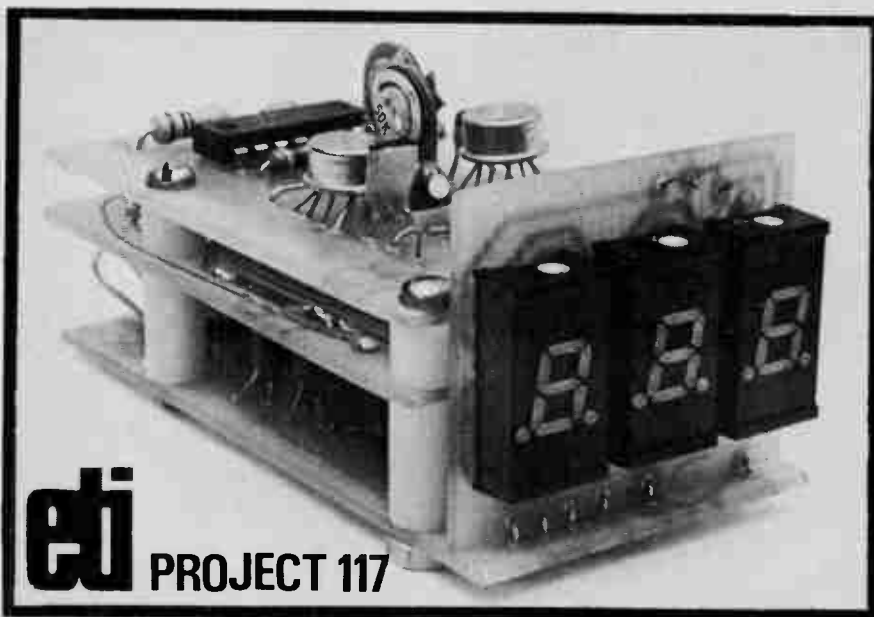
Inexpensive unit uses dual-slope technique

or an accurate voltmeter is required for comparison. Two adjustments are provided, one for calibration and the other to compensate for the offset in the integrator IC. For input voltages of 10 V or more the offset potentiometer is not required as the error is within one digit.

This offset potentiometer should be adjusted first by applying a voltage of about one per cent (10 digits) of full scale and adjusting RV2 to give the

correct reading. The calibration potentiometer RV1 can now be adjusted by applying an accurately known voltage near full scale.

The meter has a large overrange and voltages up to 250 per cent of full scale can be measured except that the first digit is lost and must be assumed, ie, if you are measuring a car battery on a 10 V range and it reads 3.52 V it is obviously 13.52 V.

MEASURED PERFORMANCE OF PROTOTYPE

Number of digits	3	
Overrange	250% (no indication)	
Dual polarity	No	
Ranges	1, 10, 100 and 1000 V dc	
Accuracy	As adjusted	
Linearity	±1 digit	
Power supply	9-15 V dc at 120 mA isolated	
Input impedance	100 k/V	
Overrange Protection		
1 V range	100 V	limited by power
10 V range	500 V	dissipation and
100 V range	500 V	voltage rating of
100 V range	2500 V*	R12
	* input switch permitting	
Reference	5.1 volt zener at constant current.	

DIGITAL VOLTMETER

Fig. 1. Circuit diagram of the dual-slope analogue to digital converter. This circuit is used together with the ETI 533 display to make the complete voltmeter.

NOTES

*RV2 ONLY REQUIRED FOR 1V SENSITIVITY
PIN 14 OF IC3, 6 AND 7 IS +12V
PIN 7 OF IC3, 6 AND 7 IS 0V

POWER SUPPLY MUST BE FLOATING WITH RESPECT TO VOLTAGE BEING MEASURED
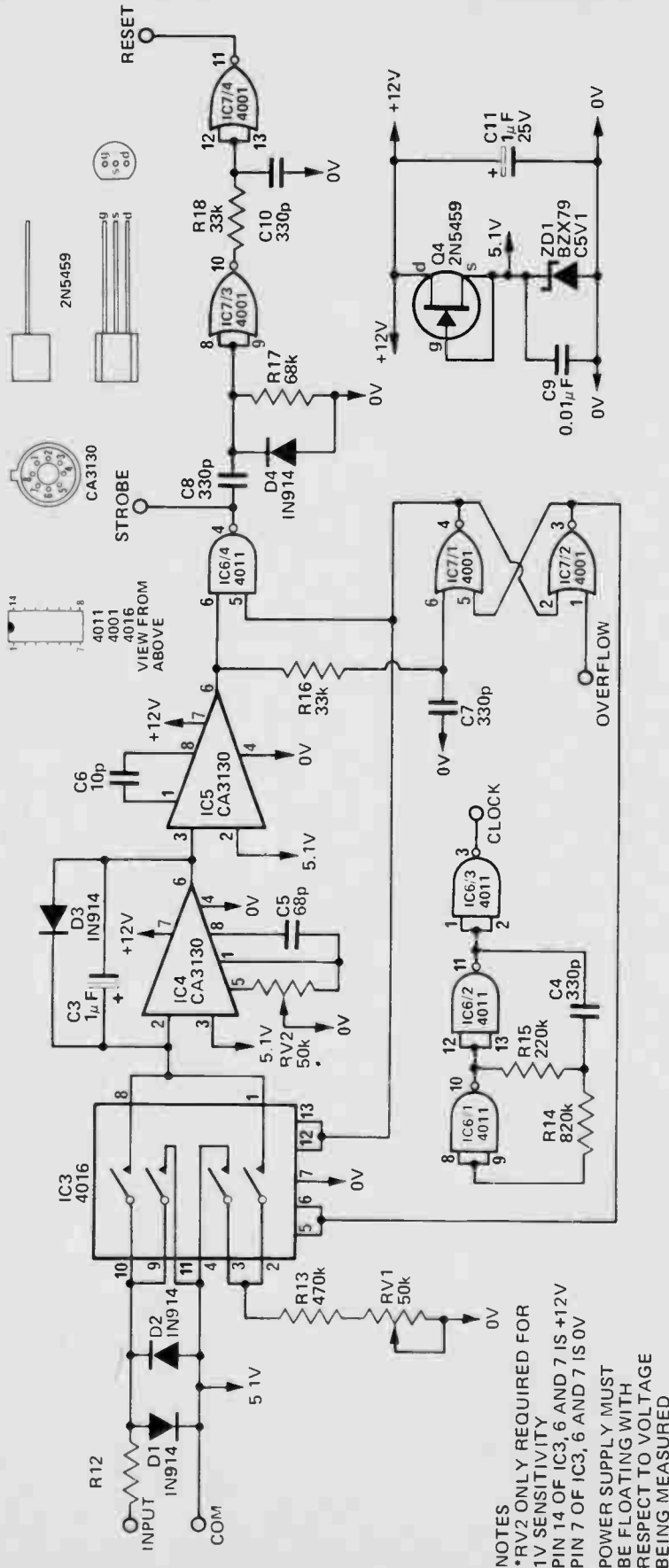
PARTS LIST

R16,18	Resistor	33k ¼w 5%
R17	"	68k " "
R15	"	220k " "
R13	"	470k " "
R14	"	820k " "
R12	"	See text
RV1,2	Potentiometer	50k Trim type
C6	Capacitor	10pF ceramic
C5	"	68 pF "
C4,7,8,10	"	330pF "
C9	"	0.01µF polyester
C3,11	"	1µF 25V Tantalum
D1,2,3	Diode	IN914 or similar
ZD1	Zener diode	BZ x 79 C5 V1
Q1	Transistor	2N5459 or similar
IC3	Integrated circuit	4016 (CMOS)
IC6	" "	4011 (CMOS)
IC7	" "	4001 (CMOS)
IC4,5	" "	CA3130

PC Boards ETI 117A, ETI 117B

Display Board Complete — Project ETI 533 July 1975

is also high). After about 10 μseconds delay, due to R16 and C7, the flip-flop changes state and the output of IC6/4 goes high again Thus a pulse is generated which is used as the strobe to transfer whatever number is in the decade counters into the store, and hence, to the display. The strobe pulse also triggers a 15 microsecond monostable, IC7/3, the output of which is delayed by 10 microseconds and inverted by IC7/4. This new pulse acts as a reset pulse for the counters setting them to zero.

As the flip flop has now reverted to its original state the input voltage is reselected and the integrator commences to ramp down again repeating the cycle.

Whilst the input voltage is selected clock pulses are gated into the counter and after about 200 milliseconds (1000 clock pulses each 0.2 mS) the counter will be full. The overflow thus generated from the display changes the state of the flip flop and the reference voltage is selected. The voltage across the integrator (referenced to 5.1 volts) at this instant will be proportional to the input voltage. With the reference supply connected the output of the integrator will rise at a predetermined rate and on crossing the 5.1 volt reference level the strobe and reset pulses are generated, the flip flop toggled and the process started again.

The time taken to bring the integrator back to the reference level is proportional to the input voltage and hence the number in the decade counter at that instant is the required reading of input voltage.

The only components which are required to have good stability, if accuracy is to be maintained, are R12, R13 and ZD1. All other components, provided their short-term stability is good, can be almost any tolerance. The integrator capacitor, for example, can have any value between 0.5 microfarad and 2.0 microfarads without affecting accuracy. However variations in the value of this capacitor will affect the over-range capability. The clock frequency may likewise be altered without affecting accuracy however, if the time of 1000 clock pulses is a multiple of 20 milliseconds the voltmeter will automatically reject 50 Hz ripple on the voltage being measured. This however was not considered of great enough importance to warrant special adjustment of the clock frequency which is preset by R15 and C4.

The reference supply is a 5.1 volt zener diode and a FET connected as a constant current source. The 5.1 volts is used as the common and hence, the 12 volt supply for the voltmeter must be left floating and must not be connected to ground or to any other equipment.

Due to the simplicity of the circuit there are some features of the instrument which are not desirable but do not greatly affect the operation of the instrument. Firstly there is no over-range indication and thus if 15 volts is applied to the 10 volt range the instrument will read 5 volts. The unit remains accurate (except for the first digit which is lost) until the integrator clips on its negative swing (about 250% of full scale). The other point is that if the input voltage is negative the comparator, IC5, will remain high and no further strobe or reset pulses will be generated. The effect of this is to freeze the display at the last number. This is not normally a problem as the display goes to zero if the input is disconnected.

Fig.2. Circuit boards used for the converter.

ETI 117a

ETI 117b
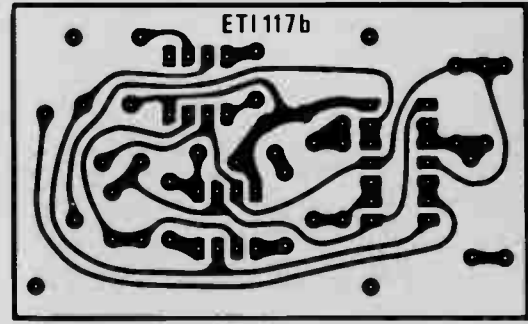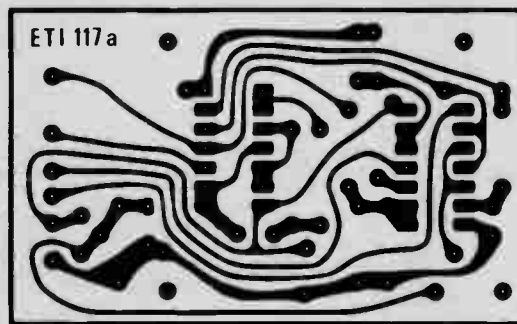
TABLE I

RANGE	VALUE OF R12	
1V	100k	5%*
10V	1M	5%*
100V	10M	5%*
1000V	100M	5%*
	(10 x 10M)	

For multirange meters R12 must be 1% or adjustable.
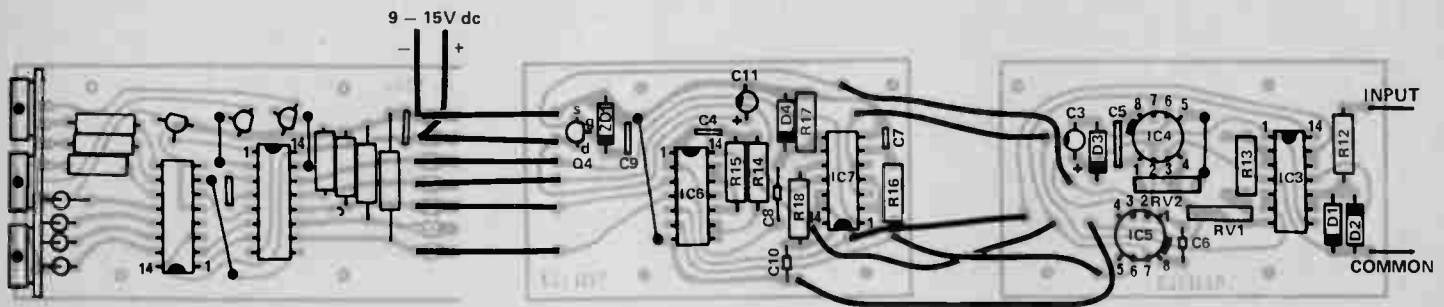
Fig.3. Component overlay of the complete voltmeter.

DIGITAL VOLTMETER
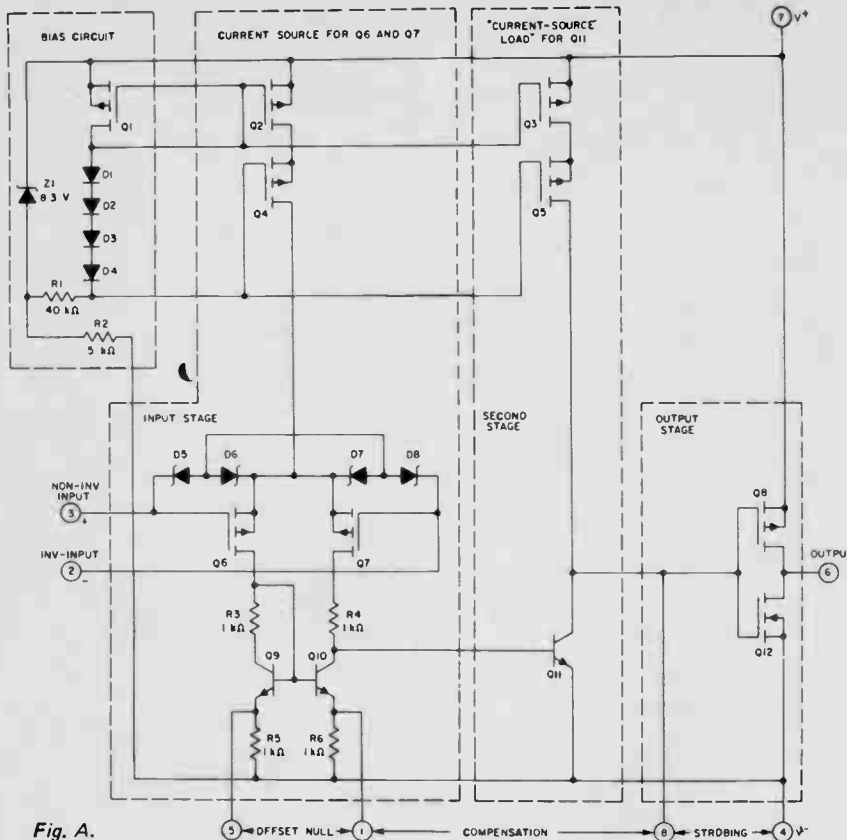
Fig. A.

NOTE
DIODES D5 THROUGH D8 PROVIDE GATE-OXIDE PROTECTION
FOR MOS/FET INPUT STAGE

THE CA3130 OPERATIONAL AMPLIFIER

For those unfamiliar with this IC we have reproduced the internal circuitry in Fig. A. It is an economical FET input operational amplifier. This IC is unusual as it combines a FET input stage with a bipolar amplifier and a CMOS output stage, all on the one chip! It is a pin for pin equivalent for the 301/741 type of IC and needs a 68 pF capacitor between pins one and eight for compensation. The major differences are a maximum voltage of 16 V between the supply rails (± 8 V) and the extremely high input resistance of 1.5 TΩ (1 500 000 MΩ) and low input current of 5 pA.

World Radio History

Inexpensive unit works to 1 MHz.

WE CONTINUE our series of simple units, based on the ETI 533 Display Module, by describing a simple frequency meter. The unit is easy to construct and quite inexpensive.

DESIGN FEATURES

We originally considered that this project would only take a short time to develop — but were we ever wrong! Just about everything that could have gone wrong did so, and we became convinced that Murphy, was not only alive and well but, was living in Rushcutters Bay.

The first problem was to choose suitable timebase circuitry. As the project had to remain fairly economical to build, the use of a crystal timebase was ruled out. We eliminated a mains referenced timebase because it was considered that the possibility of battery powered operation was a definite advantage. Especially as control tones on the mains can cause problems.

An NE555 timer was tried for the 10 second timebase but it soon became apparent that the device just was not stable enough even when the power supply was regulated. The change in frequency due to supply changes was about 1.5%/volt. And even with a regulator the stability was not good enough to allow more than four digit

SIMPLE FREQUENCY COUNTER

readings. The error occurs because the NE555 output stage does not go exactly to the supply rails but only 0.6 V away from them. The same applies to the discharge transistor which has a fixed saturation voltage.

We considered many oscillator designs in an effort to find one with a

stability of better than one part in 10 000 and ultimately chose the one shown in the circuit diagram. This type of oscillator is well known but is not normally considered to have good accuracy and stability. This is because in a conventional op-amp IC there is normally a base-emitter junction at the output, as in the 555. However in the new CA 3130 device this problem has been eliminated as the output stage is CMOS and appears as a resistance (about 500 ohms) and not as a voltage drop. A further advantage of this IC is the extremely high input impedance which eliminates any inaccuracies due to loading effects. On the prototype the frequency change was less than one part in 10 000 with a supply voltage change of from 8 to 16 volts. The main source of error is now due to the temperature coefficient of R10. The expected error, using good quality metal-film resistors would be around 0.01% per degree C.

The CA3130 IC is also ideal for the input stage, because of its high input impedance, and also because it allows a 0 V reference to be used thus eliminating the centre-tap point normally required for conventional operational amplifier circuits.

SPECIFICATION

INPUT IMPEDANCE	470 k // 47 pF
INPUT SENSITIVITY	
10 Hz to 10 kHz	< 50 mV rising to 1 V at 1 MHz
RANGES	99.9 Hz to 999 kHz
DISPLAY	3 digits (no overload indication)
ACCURACY	as calibrated.
STABILITY	0.01% can be expected but depends on resistor stability.
OVERLOAD PROTECTION	
up to 100 kHz	50 Vac.
100 kHz to 1 MHz	dropping from 50 Vac to 10 Vac 50 Vdc.
POWER	240 Vac or 12 Vdc at 100 mA.

SIMPLE FREQUENCY COUNTER
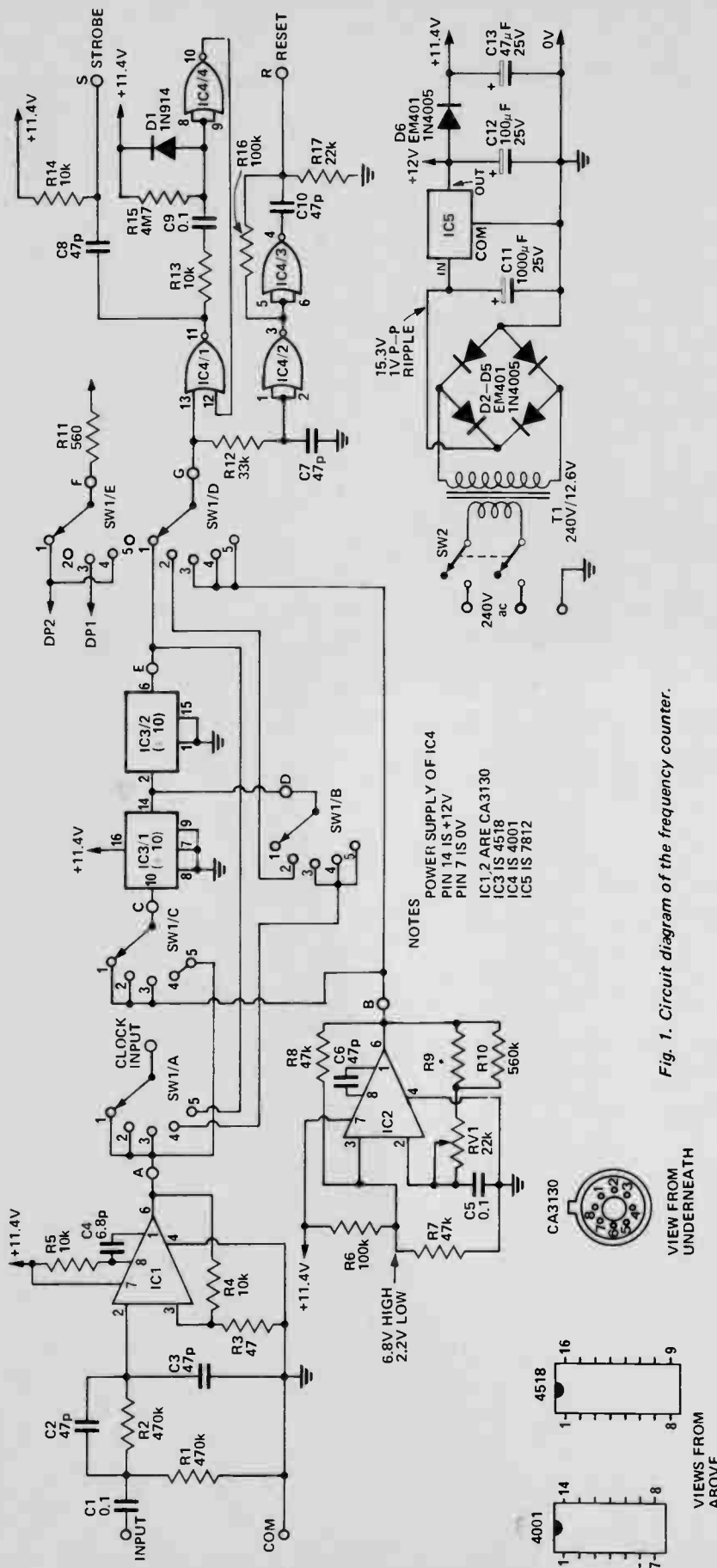
Fig. 1. Circuit diagram of the frequency counter.

PARTS LIST

R3	Resistor	47 ohm	¼W	5%
R11	"	560	¼W	5%
R4,5,13,14	"	10 k	¼W	5%
R17	"	22 k	¼W	5%
R12	"	33 k	¼W	5%
R7,8	"	47 k	¼W	5%
R6,16	"	100 k	¼W	5%
R1,2	"	470 k	¼W	5%
R10	"	560 k	¼W	2%
R15	"	4M7	¼W	5%
R9 (See table 1)				

C4	Capacitor	6.8 pF ceramic	
C2,3,6	"	47 pF ceramic	
C7,8,10	"	47 pf ceramic	
C1,5,9	"	0.1 μF 100v polyester	
C13	"	47 μF 25 V electro	
C12	"	100 μF 25 V electro	
C11	"	1000 μF 25 V electro	

D1 Diode 1N914 or similar
D2-D6 " EM401, 1N4005 or similar
IC1,2 Integrated Circuit CA3130 (AWV)
IC3 " " 4518 (CMOS)
IC4 " " 4001 (CMOS)
IC5 " " 7812 (plastic pack).

SW1 Rotary switch 6 pole 5 position
SW2 toggle switch DPDT (miniature)
T1 transformer 240 V/12.6 V 150 mA

PC Board ETI 118
Case type PC1 (A&R Soanar) or similar
Display Module — ETI 533
Shield as per Fig. 7.
Front panel as per Fig. 5.
3 plain spacers 6.4 mm long insulated
3 plain spacers 19 mm long
3 1/8 whit. spacers 25 mm long
One 8 way tag strip
3 core flex plug, grommet and clamp pc board pins
3 25 mm long 1/8 whit. screws
9 12 mm long 1/8 whit. screws
6 1/8 nuts.
Two input terminals (red-black)

PARTS AVAILABILITY
The CMOS ICs used in this project are distributed by CEMA and TOTAL.

HOW IT WORKS – ETI 118
The frequency counter may be divided into several basic sections.
a. Input amplifier – Schmitt trigger.
b. 10 Hz oscillator.
c. Two divide by 10 networks.
d. Strobe and reset circuitry.
e. Power supply.
f. Display module (ETI 533).

The input amplifier is a CA3130 connected as a Schmitt trigger. Resistors R3 and R4 provide positive feedback whilst resistor R2 provides protection for the input of the IC. The resistor R5 is used to increase the negative slew rate of the amplifier thus increasing the range of operation to one megahertz.

The 10 Hz oscillator is another CA3130 where positive feedback is applied by R8 and negative feedback by R10. When the output is high the voltage at pin 6 is about 6.8 volts. The capacitor C5 charges via R10, and when it reaches 6.8 volts the output goes low. The voltage now set at pin three is 2.2 volts and the output remains low until C5 has discharged to this point at which the output goes high again. Preset RV1 varies the oscillator frequency by
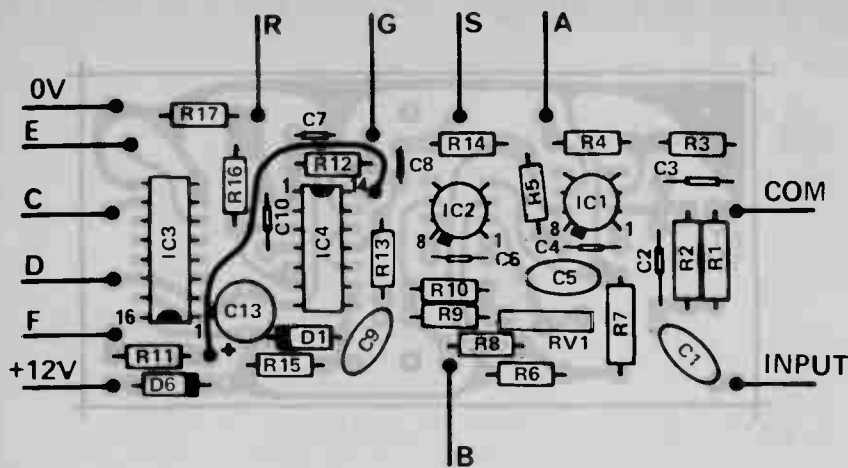
Fig. 2. Component overlay.
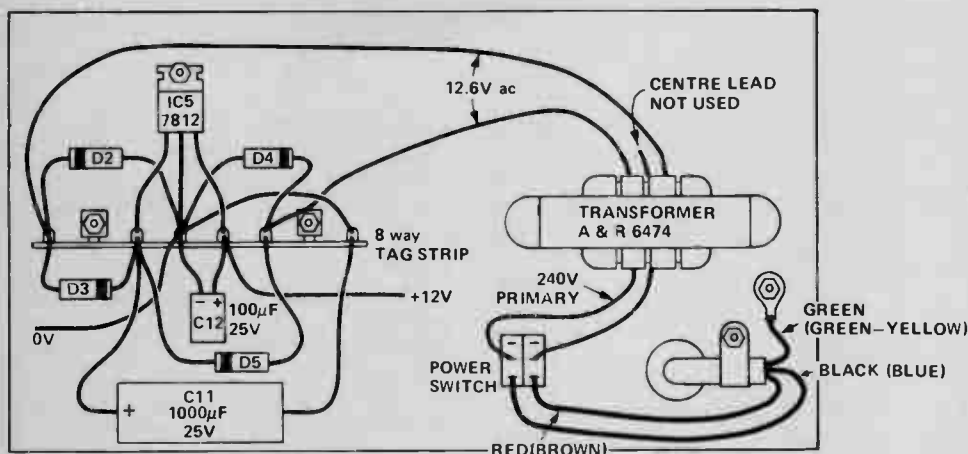
Fig. 4. How the power supply is mounted on the back panel and interconnected.
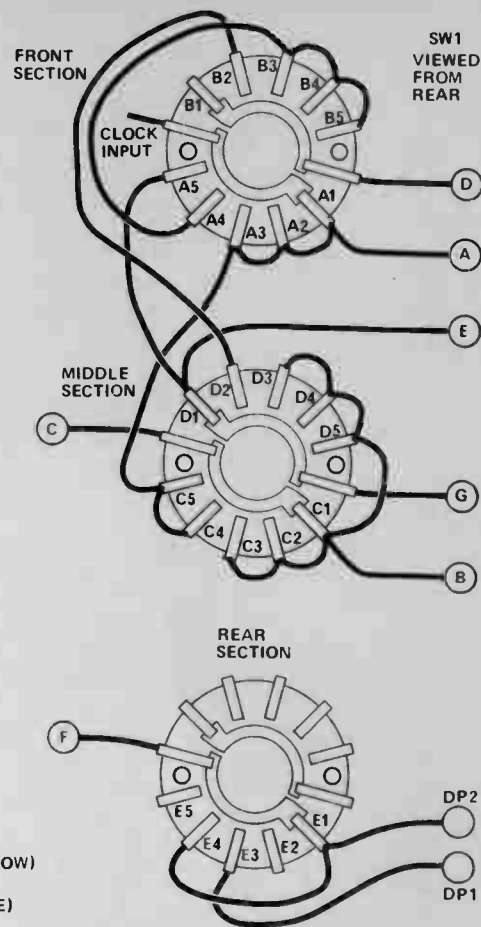
Fig. 3. Wiring of the range switch.

about 4% and a parallel resistor, R9, is required to set it within the required adjustment range. A higher value preset could be used but it becomes difficult to adjust with accuracy.

The divide by ten circuitry is simply a 14518 IC which contains two decade counters. It can be switched to divide the input frequency (100 k, 1 M ranges) or the timebase (100 Hz, 1 kHz ranges) by means of the range switch SW1.

The timebase, be it ten seconds, one second or 0.1 seconds, is coupled by SW1/d to IC4/1 pin 13. When this voltage goes high the output of IC4/1 goes low and C1 couples a short negative going pulse into the strobe terminal of the display module. After a short time, due to R12 and C7, the output of IC4/3 goes high and C10 couples a short positive pulse into the reset terminal of the display module. When the output of IC4/1 goes low the output of IC4/4 goes high and the output of IC4/1 remains low irrespective of what now occurs at pin 13. After about 350 milliseconds C9 recharges via R15 releasing IC4/1 to the control of the timebase. This

procedure removes three out of every four strobe pulses when using the 10 Hz timebase, making the display easier to read.

The resistor R16 is used to raise the steady-state voltage at the reset terminal to about 1.8 volts, thus ensuring that the reset pulse goes high enough to give reliable triggering. The voltage at the strobe terminal sits at about 10.4 volts due to the 100 k input impedance of the display module.

The power supply is a full-wave rectifier and capacitor filter supply which is regulated down to 12 volts by a 7812 regulator IC. The control circuitry is isolated by a diode D6 and capacitor C13 to prevent any ripple appearing on the 12 volts due to the current drawn by the display module.

The display module contains a three decade counter-store-decoder and display as published in the July 75 issue of ETI.

To measure frequency all that is needed is to count the number of pulses occurring over a given period of time. If we count the number of

input pulses over a one second period we can measure to the nearest one cycle, or one hertz. If a three digit display is used then the maximum reading will be 999 Hz. However if the frequency happens to be, say, 156254 Hz the display will read 254 and ignore the 156. To measure a higher frequency, either a shorter timebase must be used, or, the input frequency must be divided down. For the 10 kHz range we simply use an 0.1 second timebase giving 10 Hz resolution. For the 100 kHz we divide the input by 10 and use an 0.1 second timebase, whilst for the one megahertz range the input is divided by one hundred. For the 100 . Hz range a ten second timebase and no division is used.

If we use the one megahertz range to measure our 156254 Hz, we display 156. Switching to 100 kHz we get 563, on 10 kHz we get 625 and finally 254 on the 1000 Hz range, thus the frequency can be read to the nearest hertz but the accuracy depends on the accuracy of the initial setting up and the fact that temperature variations cause an error of one part in 10 000 per degree C.

SIMPLE FREQUENCY COUNTER

Frequency Meter eti 118

INPUT   RANGE   POWER

1000k
100k
10k
1000
100
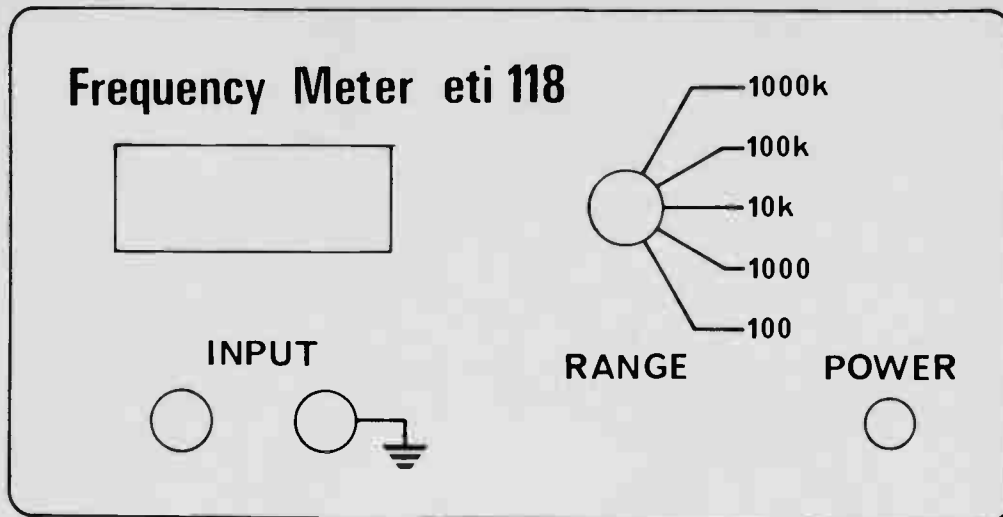
Fig. 5. Front panel of the frequency meter.

Initially the maximum frequency of operation was limited to 200 kHz due to the slow, negative slew-rate of the IC. Looking at the internal circuit of the IC it was decided to increase the bias current in the second stage by adding a resistor between the positive supply and pin 8. This allows the frequency response to be extended to beyond one megahertz. A small compensating capacitor was found to be necessary to eliminate the effects of a small amount of coupling from the 10 Hz oscillator. The resistor to pin 8 also alters the offset voltage but this does not affect the operation of this circuit.

Another problem that occurred was in the strobe and reset pulse network.

Using an 0.1 second timebase the display changes too rapidly for ease of reading. Therefore IC4/4, which is connected as a 350 millisecond monostable, is used to eliminate three out of every four strobe pulses thus making the display more readable. However it was discovered that, when

using this delay, the timebase changed frequency by about four parts in 10 000. Since the power supply to the control circuitry was isolated from the display module, the circuitry is mainly CMOS, and the oscillator rejects supply rail change, none of these factors could be suspected as a cause of the trouble. The problem was due to the fact that IC4/4 works in the linear mode and can draw 10 to 20 mA. This modulates the power supply by up to 20 millivolts. The cure is to power IC4 directly from the 12 volts. This explains the use of the link of the board.

Some coupling between the display board oscillator and the input stage occurred and was cured by adding an aluminium shield between the two boards.

To obtain all five ranges with only two divide-by-ten sections necessitates a more complex switch. This was considered to be justifiable as the alternative was to use a switch with one less wafer but add one more 14518 IC.

CONSTRUCTION

The display module should be constructed as described on page 75. The value of resistors R5 to R11 should be 560 ohms for operation of the 12 volt supply.

The control board should be assembled with the aid of the component overlay Fig. 2. Use printed circuit board pins for all outputs and for R9 as an aid to later assembly. Make sure that the link between +12 volts and pin 14 of IC4 is installed.

Wire switch SW1, in accordance with Fig. 3, and leave the leads long enough to reach the printed circuit board. Assemble the power supply onto the tag strip and the back panel of the box as detailed in Fig. 4. There is no need to insulate the tag of the regulator from the rear panel as it is the common terminal which should be earthed. The rear panel itself is earthed via the mains cable.

The front panel has to be cut and drilled as shown in Fig. 5. It can be either silk screened with the required
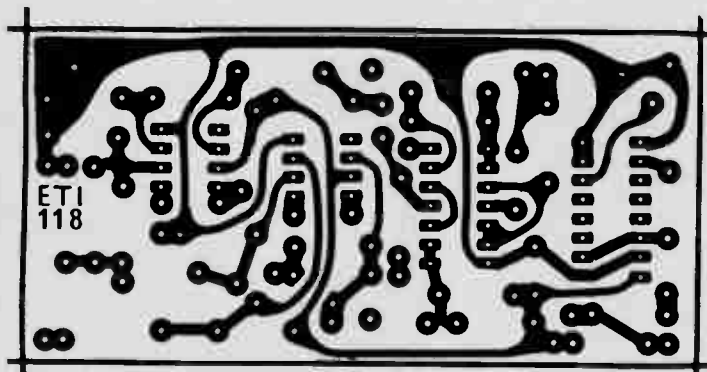
Fig. 6. Printed circuit board for the counter. Full size 90 x 45 mm.

TABLE 1

Frequency with RV1 at minimum 50 Hz input	Value of R9 to allow RV1 to calibrate
48.1 — 50	—
49.8 — 51.8	15 Meg
51.3 — 53.4	8.2 Meg
52.7 — 55.0	5.6 Meg
54.7 — 57.1	3.9 Meg
56.7 — 59.3	3.0 Meg
58.8 — 61.7	2.4 Meg
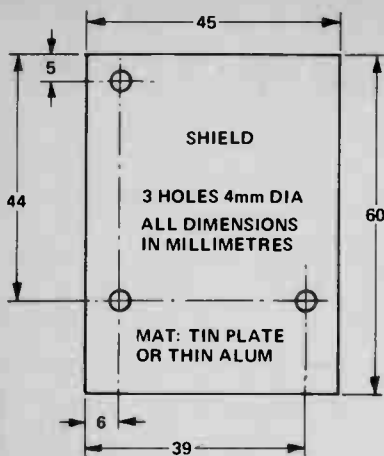
Fig. 7. Drilling details of the shield plate.

range markings etc, or a Scotchcal panel can be used as in our prototype.

Scotchcal panels for this project can be obtained for $2.00 (plus SAE) directly from Electronics Today. A piece of polarized or red plastic can be used to protect the displays. If the A&R box, as specified, is used mounting holes will have to be drilled in the base of the box. These can be marked by temporarily installing the front panel, by fitting the three 25 mm spacers to the control module (the left front mounting hole on the module is not used) and sitting the control module in position. It will be found that the right front spacer interferes with a rib in the base of the box. Cut this rib away with a chisel or similar tool such that the spacer can sit flush with the base. Mark the hole positions, remove the module and drill the holes.

Fit the rear panel in to the box and then mount the input terminals to the front panel (the rear of the screws of the terminals may have to be shortened to clear the display module mounting spacers). The rotary and toggle switches should also now be mounted to the front panel. Connect a short length of coaxial cable to the
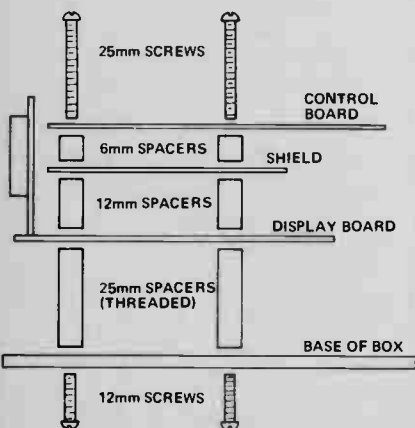
input terminals (about 150 mm) for later connection to the control board. Connect leads to the positive volt, zero volt, strobe, reset and input clock inputs on the display module and assemble the display board, shield and control board as shown in Fig. 8. Make sure that the spacers do not touch the copper tracks on any of the boards, (except for the front spacer on the control board). If any of the spacers are too close to the tracks add a piece of insulation material under the spacer. The whole assembly can now be mounted in to the box.

On the display module the power rails are taken direct to the power supply whilst the 'reset' and 'strobe' go to the control board and the 'control' to the rotary switch. On the control board the power rails also go direct to the power supply whilst all other leads, with the exception of the coaxial cable, go to the rotary switch.

Finally connect the power switch and insulate it with plastic tape to

prevent accidental personal contact.

CALIBRATION

Apply about 6 volts ac at 50 Hz, from the secondary of a power transformer to the input of the counter. Select the 100 Hz range and set the trimpot, RV1, to its minimum resistance position. Wait for the reading to settle (there is about ten seconds between readings) and using this reading look up the corresponding value of R9 from Table 1. Install this resistor and again check the reading, it should now be just under 50 Hz. The trimpot RV1 can now be adjusted to give a reading of exactly 50 Hz. If a more accurate frequency source than the mains is available it can be used instead of the 50 Hz for final calibration. Due to the effect of soldering upon the value of resistors final calibration should be left until several hours after R9 is soldered into position so that the resistor may stabilize. ●

Fig. 8. Assembly of the counter display boards.
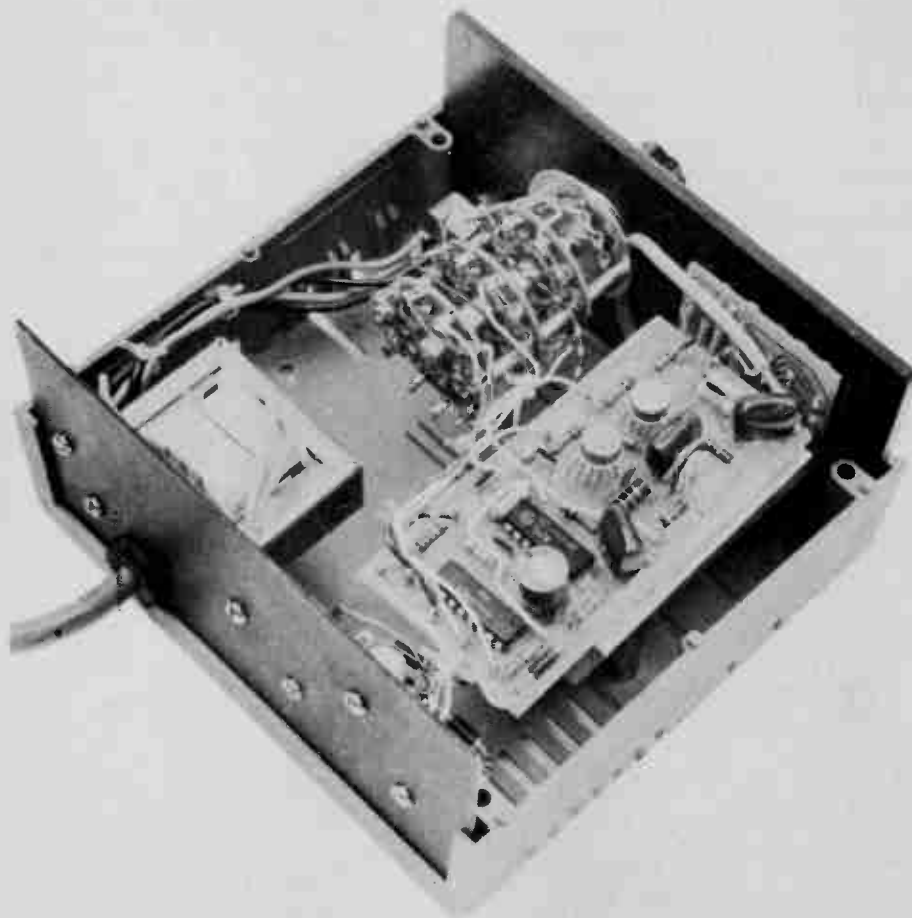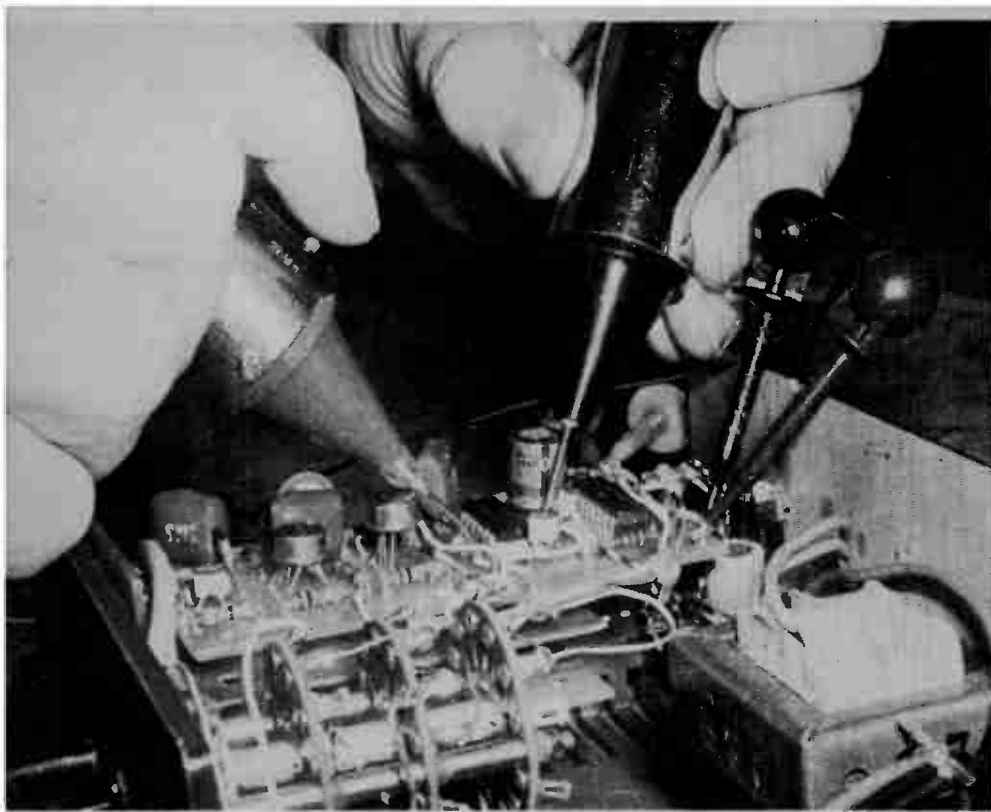
LOGIC PROBE

A basic tool for digital servicing.

THE SERVICING of digital equipment is greatly simplified by the use of a logic pulser and logic probe, for these two instruments enable one to follow circuit operation stage by stage.

THE PROBE

The probe must be capable of detecting pulses as short as 50 nanoseconds (for TTL operation) and

make them visible. It was found that readily available linear ICs were not suitable as they are too slow and required dual supply voltages. Neither could CMOS be used as it also is too slow, for testing TTL gates, and its threshold voltages are not consistent. Further, TTL could not be used as it cannot withstand the voltages used with CMOS logic. This virtually means that the only devices that are suitable are discrete transistors.

The logic probe seen from the rear.
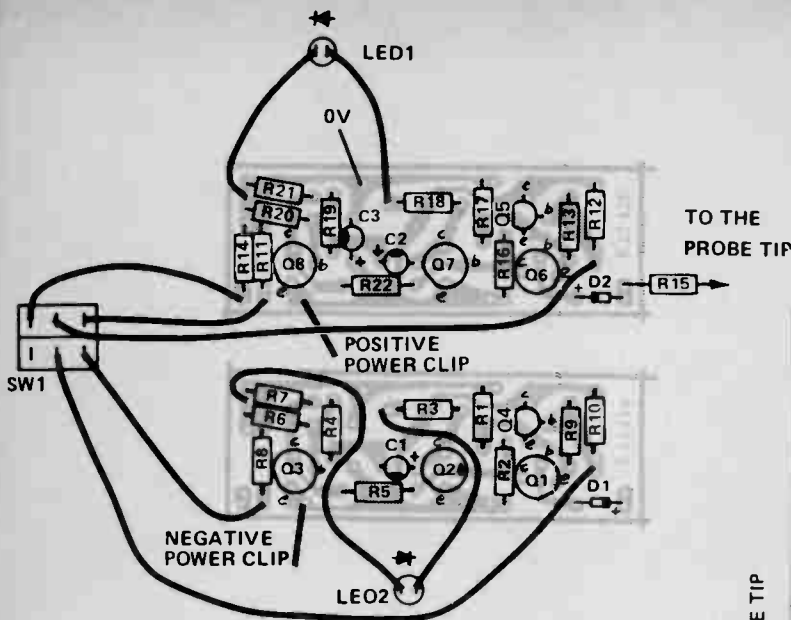
Fig. 3. Component overlays for the two comparators showing interconnection wiring.

PARTS LIST — ETI 120

R3,18	Resistor	680	¼ W	5%
R4,15,19	"	1 k	"	"
R10,13	"	1 k8	"	"
R1,9,12,17	"	2 k7	"	"
R5,14,22	"	3 k3	"	"
R2,16	"	8 k2	"	"
R7,21	"	10 k	"	"
R8,11	"	27 k	"	"
R6,20	"	100 k	"	"
C1,2	Capacitor	0.47 μF	25 V tantalum	
C3	"	10.0 μF	25 V	"
D1,2	Diode	1N914 or similar		
Q1,7,8	Transistor	2N3638, 2N3638A		
Q2,3,6	"	2N3643		
Q4	"	BC179, BC559		
Q5	"	BC109, BC549		
SW1	Switch	Two pole, two position miniature toggle		

PC boards 2 off ETI 120
Probe case (see text)
LED 1, 2 Light emitting diodes 5082 — 4484 or similar
2 Alligator clips or Ezy-hooks

CHARACTERISTICS

PULSER — ETI 121

- Will source, or sink, up to 500 mA.
- Operates on supply voltages from 5 to 15.
- Suitable for both TTL and CMOS.
- Power supply drain less than 15 mA under worst case conditions.
- Press for '1' release for '0'. High impedance at other times (> 1 M).
- Will drive capacitive loads up to 1000 pF.
- Protected against accidental reversal of supply leads.
- Duration of pulse 500 nanoseconds.

PROBE — ETI 120

- Pulses as narrow as 50 nanoseconds will be detected.
- Stretches narrow pulses to 50 milliseconds for ease of detection.
- Operates on supply of 5 to 15 volts.
- Suitable for TTL or CMOS.
- True '1' and '0' level detectors. Neither LED is alight if the circuit is faulty or the probe is not making contact.
- Current drawn from the circuit is less than 20 microamps.
- Current drawn from power supply (one LED alight) 12 mA on 5 volts, 35 mA on 15 volts.
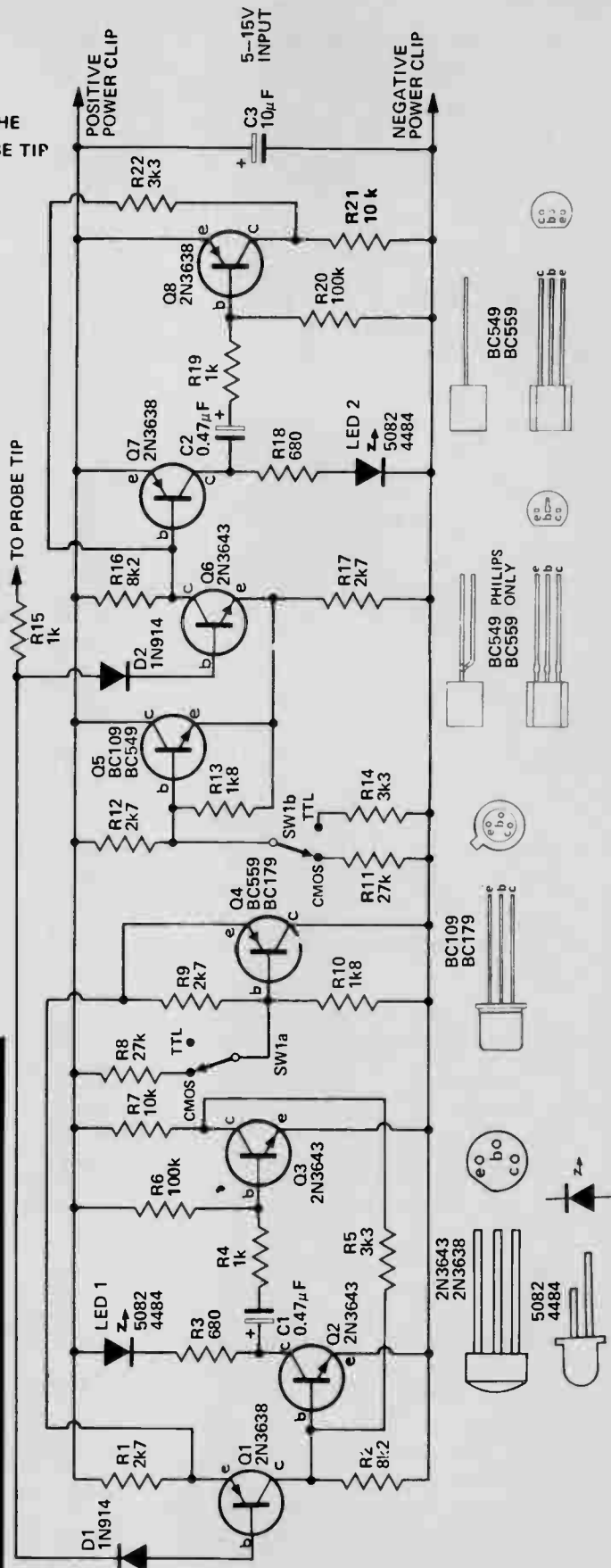
Fig. 1. Circuit diagram of the logic probe

LOGIC PROBE
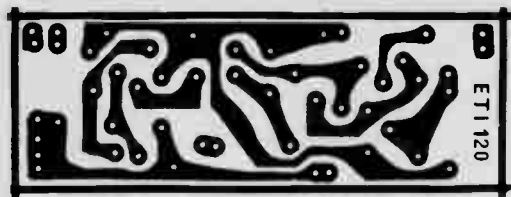
Fig. 2. Printed circuit board for the logic probe (2 required). Full size 23 x 66 mm.
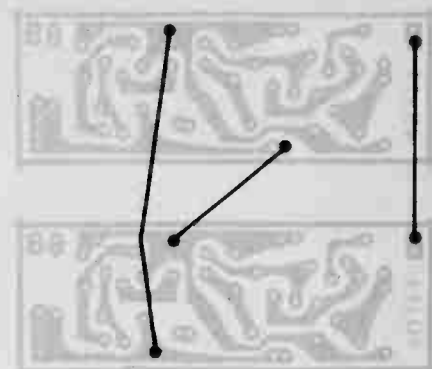
Fig. 4. Linking required between the two boards.

As both high and low logic states must be detected, a discrete transistor voltage-comparator circuit was designed to detect each state separately. These comparators must not load the circuit under test as CMOS is sensitive to current and capacitive loading. In our prototype the current drawn was a maximum of 19.7 microamps for a high, and 10 microamps for a low.

In both comparators the transistors associated with the pulse detector are turned on by an input level that exceeds the comparator threshold.

As transistor turn-on time is much faster than turn-off time, using the transistors in this way ensures the highest possible speed of operation for the particular types of transistors used. Additionally, the delay in turning off assists by lengthening the pulse, thus ensuring more reliable triggering of the monostable on very short pulses.

The input transistors Q1 and Q6 are protected against breakdown, due to excessive base-emitter voltage, by diodes D1 and D2. The diodes are also required to ensure that Q1 and Q6 remain conducting even when the probe tip is taken to the supply voltage.

Transistors Q3 and Q8 are also protected against reverse base-emitter voltages by R4 and R19 respectively.

In operation the probe will light LED 1 if a low level is detected, LED 2 for a high, neither LED if the point being monitored is at ground potential or a poor contact is made with the tip, and both LEDs will light if there is a pulse train present.

A single pulse input will be lengthened, by the monostables, to 50 milliseconds with the pulse polarity being indicated by the LED which is illuminated. Thus even single

pulses as short as 50 nanoseconds may readily be detected.

CONSTRUCTION

We built our probe onto two small printed circuit boards and assembled it into a small, commercially-available probe case. The two printed-circuit boards are identical and care should be taken to use the correct overlay for each board as different transistors are used and some components are reversed on the two boards. Note particularly diodes D1 and D2 and capacitors C1 and C2. Also note how the two boards are linked together and that the supply rails are reversed. No difficulty should be experienced if the printed-circuit boards and the component overlay as specified are used.

The probe case used in our prototype was one manufactured by Jabel. The case has a length of 102 mm and an internal diameter of 23 mm. The probe tip, as fitted, is rather large and awkward. We therefore replaced the tip, with a darning needle, as shown in Fig. 6. The fine point of this tip is much easier to use on micro circuitry and, as it is very sharp, it will penetrate varnish etc to make reliable contact. A needle is a little brittle and for this reason it is recommended that a maximum unsupported length of 12 mm be left protruding. Resistor R15 is mounted within the tip and soldered directly to the needle. The other end of the probe is fitted with a plastic stopper which is used to support SW1 and both LEDs. SW1 is also used to

hold a small name-plate in position as shown in Fig. 6. Two LEDs are mounted into the end plate, together with SW1, and after soldering leads to the LEDs they should be passed through the holes in the plate, and the plastic end-piece, and secured in position with a drop of epoxy cement. Another hole is drilled in the stopper through which is passed the two supply-voltage leads.

Connect the leads from the stopper assembly to the previously assembled boards. Position the boards together, copper side to copper side, with a piece of insulating material between them. Make sure that the board assembly will fit in to the tube without fouling the sides. Cut a piece of cardboard or plastic 75 x 85 mm, roll it into a tube and fit in the probe body. Now fit the board assembly into the tube — it may be necessary to dress the sides of the boards with a file to obtain a neat fit.

The tip may now be connected and both ends screwed into position. Finally, alligator or, better still, Ezy-hooks clips should be fitted to the supply leads.
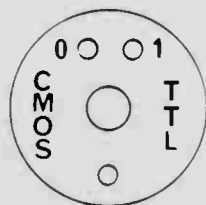
Fig. 5. Artwork for the nameplate on the probe.
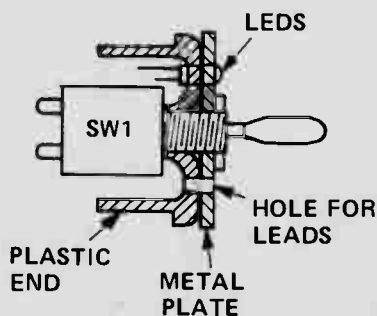
Fig. 6. How the probe ends are constructed.
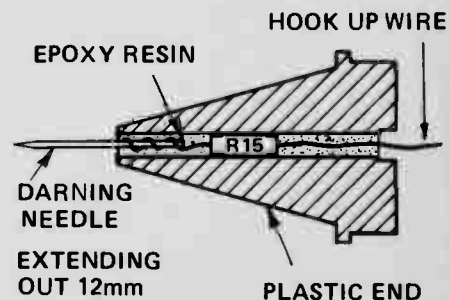
LOGIC PULSER

Companion instrument to the logic probe.

ALTHOUGH the logic probe used alone is a very valuable piece of digital test equipment, it is limited by the fact that it can only observe the logic states that occur naturally within the piece of digital equipment under test.

The logic pulser is a further valuable tool that is used in conjunction with the logic probe. It's function is to override the naturally occurring state at the particular circuit node under test. That is, if the circuit node is normally at the '1' state, the pulser will drive that node to a '0' for a very short period when the microswitch is pressed. If the circuit node is normally at a '0', the probe will drive it to a '1' for a very short period when the microswitch is released. Thus it puts a short pulse into the circuit node regardless of it's normal state when SW1 is pressed and released.

A fairly powerful pulse is required to override the normal logic state of a circuit node and care must be taken to ensure that the devices either driving, or being driven from that node are not damaged. This is achieved by making the pulse of very short duration. In our probe the pulse width is 500 nanoseconds. Thus although the pulse is of high current the energy released is insufficient to damage normal logic devices.

The probe must be suitable for driving either TTL or CMOS that is, it must operate from a supply ranging from 5 to 15 volts, it must be capable of operating into loads having a capacitance as high as 1000 picofarads and must supply a current pulse of around half an amp. All these conditions are fulfilled in the ETI 121 Pulser and the prototype has been tested by causing it to generate several hundred thousand half amp pulses without any problems. The probe is quite capable of pulling two (in parallel) high-power TTL 'zeros' to a '1' level and this is the most severe condition it has to meet.

At the same time as providing high level pulses, the pulser should not draw too much supply current as some CMOS supplies may not have much additional capability. Under worst-case conditions the ETI Pulser drew a maximum of 10 mA.

The probe is capable of overriding a normal logic state but is not capable of overriding a point that is connected to ground or to a supply rail. Thus by pulsing a node and at the same time looking at that point with the logic
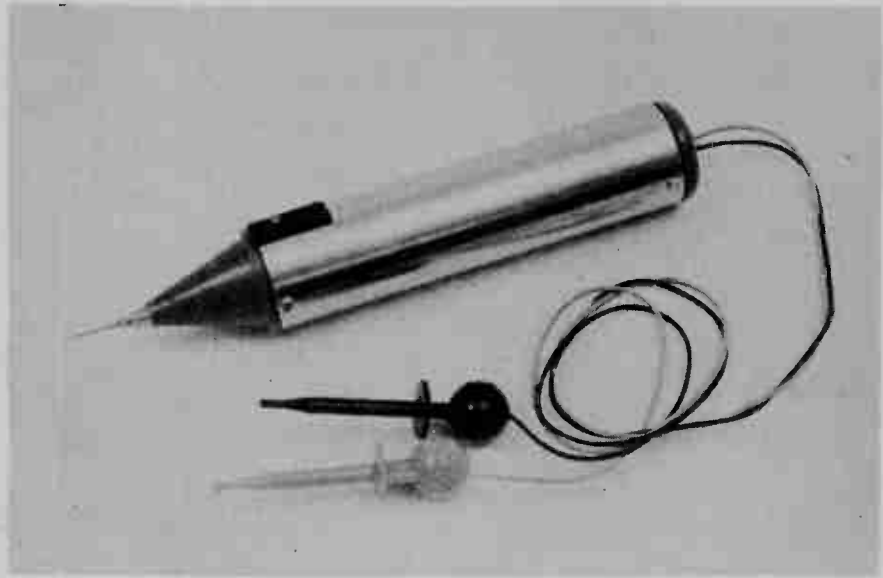
A basic tool for digital servicing.

probe it is possible to tell if that point is shorted to either rail.

The logic pulser combined with the logic probe is thus capable of performing stimulus — and — response testing of both TTL and CMOS logic and of determining the exact nature of a fault at a particular circuit node.

CONSTRUCTION

Construction is greatly simplified if the printed circuit board of Fig. 2, is used. This should have the components assembled to it in accordance with the component overlay. Note particularly the polarity of C1, and the connections of the microswitch such that the normally-closed terminal of the switch is connected to the base of transistor Q1. Also make sure that a red lead is connected to the positive rail of the board, and a black lead to the negative rail, to facilitate later connection.

We used the same probe case for the pulser as for the logic probe. The probe tip is again replaced by a darning needle and the microswitch

SW 1 is mounted into the plastic-section of the tip as follows. First check the switch to determine what the contact arrangement is. Attach colour coded wires to the switch, to aid later identification, and tape the microswitch into position. Epoxy cement may then be used to fix the switch into place permanently. Now cut a slot into the probe case so that the switch and plastic tip assembly can be inserted into the casing.

Connect the probe tip and microswitch leads to the board and, after insulating the inside of the case with cardboard or plastic as previously described, insert the board into the case. Pass the supply leads through the plastic end piece and then fit both end pieces and secure them in position. Lastly attach Ezy-hooks or alligator clips to the supply leads.

Keep the supply leads as short as is reasonably possible as excessively long leads will degrade the performance of the pulser.
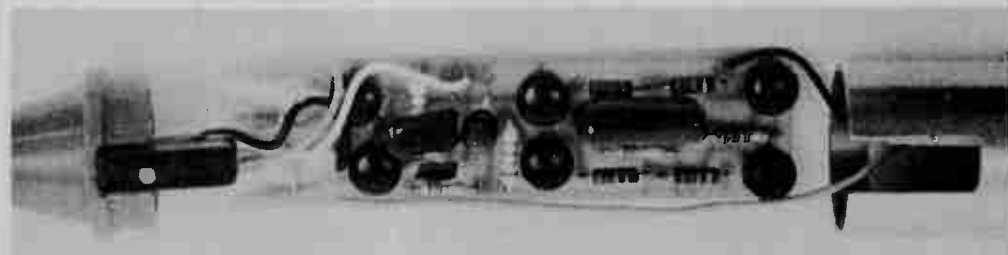
Internal construction of the pulser.
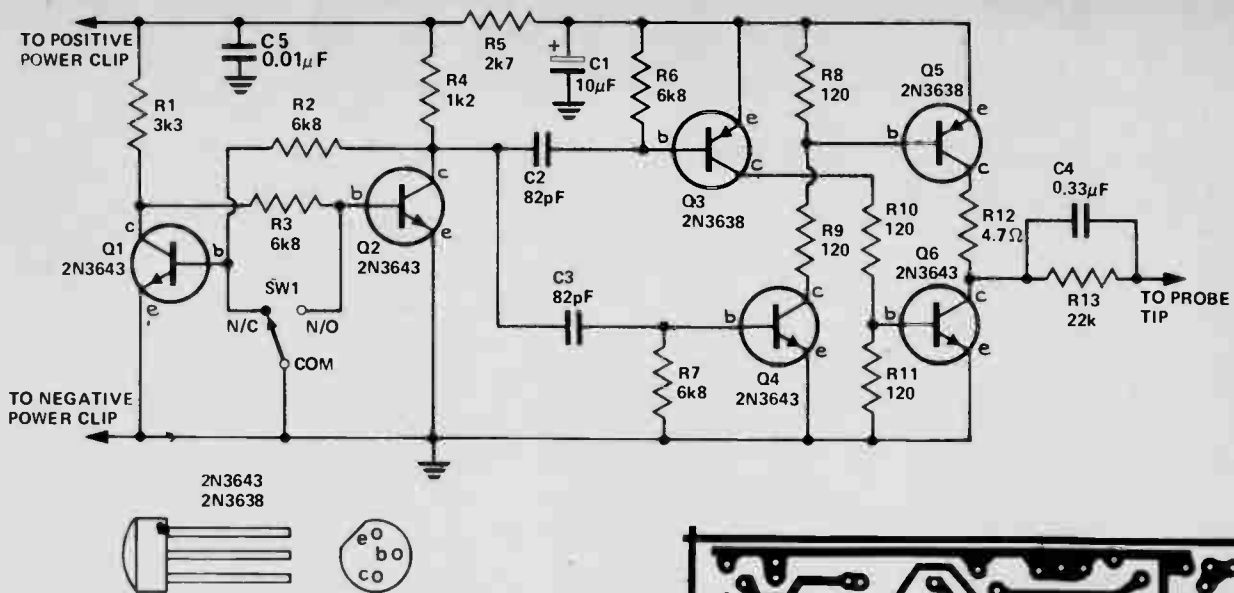
Fig. 1. Circuit diagram of the pulser.
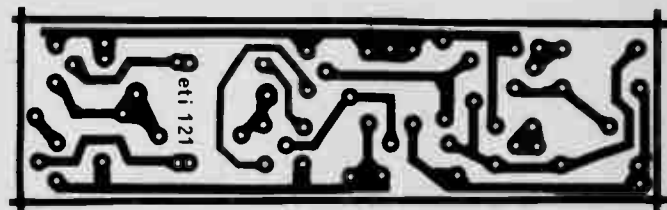
Fig. 2. Printed circuit board for the pulser. Full size 23 x 65 mm.

HOW IT WORKS

The pulser is activated whenever microswitch SW1 is pressed. This switch controls the state of a flip-flop formed by transistors Q1 and Q2. The flip-flop is necessary to prevent contact bounce of the microswitch from having effect.

The output transistors of the probe, Q5 and Q6, which in turn are controlled by Q3 and Q4 are both normally off. However when the microswitch is pressed Q2 turns off and the rising voltage on its collector is coupled, via C3, to the base of Q4 turning it on. This in turn, turns on Q5 pulling the output to the positive rail. This generates a '1' pulse if the point under test was at a '0' level. Resistor R12 provides a current limit of around 500 milliamps. Due to the small value of C3 the pulse output is only about 500 nanoseconds long, short enough so that there is insufficient energy to damage the device under test.

When the switch is released Q2 turns on and the negative-going edge is coupled to Q3 by C2 turning it on. This turns on Q6 causing the output to be pulled to the negative rail. This gives a '0' pulse which, like the '1' pulse, is only 500 nanoseconds long.

The output from the probe is taken via the paralleled combination of R13 and C4 where C4 carries the current and R13 discharges C4 between pulses. This network protects the probe against the condition where the probe is inadvertently connected to a voltage which is above or below the logic supply rails.

Resistor R5 isolates the high current pulse from the power supply, capacitor C1 providing the actual current needed.
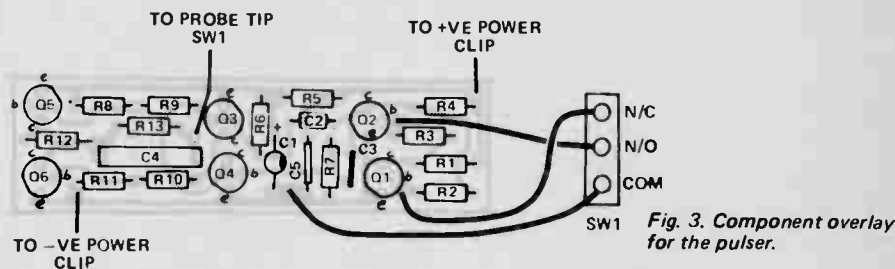
Fig. 3. Component overlay for the pulser.

Fig. 4. Construction of the tip for the pulser probe.
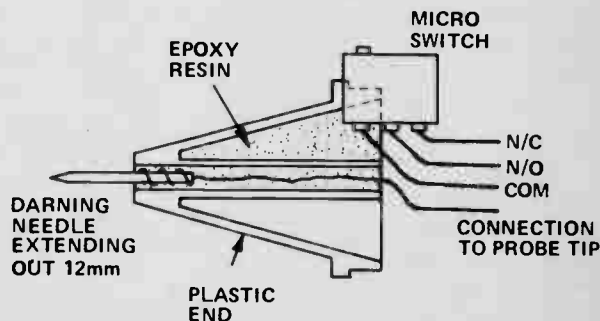
SPECIFICATION
See page 87.

PARTS LIST

R12	Resistor	4.7 ohm	¼W	5%
R,8,9,10,11	"	120 ohm	¼W	5%
R4	"	1k2	¼W	5%
R5	"	2k7	¼W	5%
R1	"	3k3	¼W	5%
R2,3,6,7	"	6k8	¼W	5%
R13	"	22 k	¼W	5%
C2,3	Capacitor	82 pF	ceramic	
C5	"	0.01 μF	polyester	
C4	"	0.33 μF	polyester	
C1	"	10 μF	25 V tantalum	
Q1,2,4,6	Transistor	2N3643 or similar		
Q3,5	"	2N3638, 2N3638A or similar		

1 micro switch miniature McMurdo type 2LM
2 alligator clips or Ezy-hooks
PC board ETI 121
probe case (see text).

SWITCHING REGULATOR SUPPLY

eti

PROJECT 119

Drive those TTL
circuits with
this 5 volt
10 amp (max)
supply.
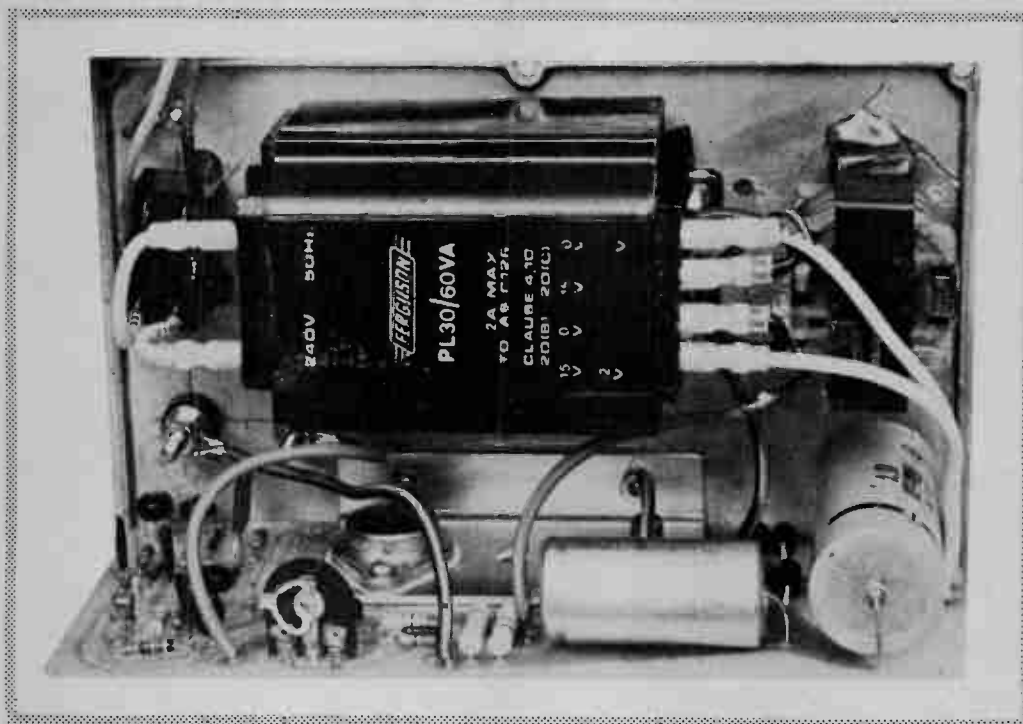
WHILST the introduction of CMOS has lowered the power requirements of digital equipment using it, many large scale systems, because of cost and availability, are still designed around TTL logic. For such systems a five-volt supply having a capability of up to 10 amps is often required.

The choice of power supply for a system depends very much on the output requirements. In very low power applications a shunt regulator consisting of a series resistor and a zener may be entirely adequate. For medium power systems however a series-pass transistor regulator is normally used.

Whilst the series pass regulator is very good with regards to ripple and regulation the specification' of the transformer is critical if the supply efficiency is to be above 50%. In a larger system this can be a very important factor.

With a switching regulator the requirements on the transformer are greatly relaxed and an efficiency of 70% or more can readily be obtained with mains-input variations of from 160 to 260 volts.

A fourth type is the switch-mode supply where the mains voltage is first rectified and filtered. The rectified mains then drives a high-frequency

inverter which employs a ferrite transformer. Regulation is obtained by controlling the inverter and by this means very high efficiencies may be obtained. Nearly all the components in such a system work at mains voltage and hence for safety reasons this approach was not used in our project.

CONSTRUCTION

All components, with the exception of the transformer and the choke are best mounted on a printed-circuit board such as the one specified. The choke should be wound as detailed in

Table 2 with four layers close wound of 14 gauge B&S wire. Due to the dc current in the choke an air gap is necessary to avoid saturation. The easiest method of adjusting this gap for best performance is to run the supply at the maximum current required and adjust the gap by inserting that thickness of insulation between the cores which gives minimum ripple voltage. We found that a 3 mm gap was required at 10 amps for a ripple of 50 mV peak-to-peak.

The prototype was mounted in a ▶

<table>
<tr><td colspan="3">**TABLE 1**
Comparison of typical series and switching regulators</td></tr>
<tr><td></td><td>**SERIES**</td><td>**SWITCHING**</td></tr>
<tr><td>Output Voltage</td><td>5 V</td><td>5 V</td></tr>
<tr><td>Output Current</td><td>10 A</td><td>10 A</td></tr>
<tr><td>Efficiency</td><td></td><td></td></tr>
<tr><td>240 V in</td><td>50%</td><td>70%</td></tr>
<tr><td>260 V in</td><td>40%</td><td>70%</td></tr>
<tr><td>Ripple Voltage</td><td>< 5 mV p-p</td><td>50 mV p-p</td></tr>
<tr><td>Regulation 0-10 A</td><td>< 0.05 V</td><td>0.3 V</td></tr>
<tr><td>Input Voltage</td><td>$240 \pm 10\%$</td><td>160 to 260 V</td></tr>
<tr><td>Transformer Secondary</td><td>8.5 V @ 12 A</td><td>20 to 30 V @ 80 VA</td></tr>
<tr><td>Diodes Required</td><td>10 A</td><td>3 A</td></tr>
<tr><td>Filter Capacitor</td><td>33 000 μF</td><td>2 200 μF</td></tr>
<tr><td>Short Circuit Current</td><td>15 A</td><td>15 A</td></tr>
</table>

SWITCHING REGULATOR SUPPLY

die-cast box which acted as the heatsink as well as a shield to prevent the radiation of RFI generated by the switching action of the supply. If another form of box is used a heatsink must be added to the transistor-diode bracket for cooling.

An external LC filter will reduce the ripple even further if required. For example a series choke of 20 turns of 1.6 mm wire on a 10 mm ferrite rod and a parallel combination of 1000 μF electrolytic and 0.47 polyester capacitors external to the box will provide considerable extra ripple attenuation.

NOTES
R14 IS MADE OUT OF 4 STRANDS JUG ELEMENT WIRE 40 mm LONG

D1–D4 ARE 3 AMP DIODES (1N5408)

R7 CAN BE ADJUSTED TO GIVE MAXIMUM CURRENT REQUIRED.

Fig. 1. Circuit diagram of the regulator.

PARTS LIST — ETI 119

R14	Resistor	0.08 Ω *		
R11,13	"	33 Ω	1W	5%
R12	"	47 Ω	½W	5%
R3,17	"	100 Ω	½W	5%
R15	"	220 Ω	½W	5%
R7,18	"	390 Ω	½W	5%
R6,8,9	"	1k	½W	5%
R10,16	"	1 k	½W	5%
R2,4,5	"	5k6	½W	5%
R1	"	47 k	½W	5%

RV1 Trim Potentiometer 100 Ω

C4	Capacitor	470 pF ceramic
C3,5,6	"	0.001 μF polyester
C2	"	0.1 μF polyester
C1	"	2500 μF 50 V electro
C7	"	5000 μF 6V electro

D1-D4 Diode 3 Amp 100V 1N5408 or similar
D5 " BYX50-200

ZD1 Zener Diode 3.3 V or 3.9 V 400 mV

Q1	Transistor	2N2646 or similar
Q2,3	"	2N3645 or similar
Q4,7	"	2N3642 or similar
Q5	"	BD140 or similar
Q6	"	BDY92 or similar

L1 choke see Table 1.

T1 Transformer 20V — 30V @ 60VA (7.5 Amp output) 75VA (10 Amp output)

SW1 Toggle switch 2 pole 240 V rated.

Heatsink bracket to Fig.3
Diecast Box 6357p
PC Board ETI 119
Insulation kit for Q6 and D5
* R14 is made out of 4 strands of jug element each 40 mm long.

Fig. 2 Component overlay.

−Ve OUT   +Ve OUT

ac INPUT

TO CHOKE

D5 AND Q6 MUST BE INSULATED FROM BRACKET

HOW IT WORKS — ETI 119

IN a conventional series regulator power supply the resistance of a series transistor is controlled in order to maintain the correct output voltage. The series transistor dissipates considerable power and therefore at very high load currents series regulators are quite inefficient. In the switching regulator a series transistor is still used but does not operate in its linear range. Instead it switches ON and OFF at high speed such that the load is alternately connected and disconnected to a supply voltage that is higher than that required across the load. By controlling the ratio of ON to OFF time we effectively control the average voltage as seen by the load. For example if it is on for 25% of the time the average output voltage will be 25% of the input. Thus by controlling the ON/OFF ratio the output voltage may be stabilized whilst dissipation in the series transistor is very greatly reduced.

However since most loads do not like their supply to be in the form of a square wave an LC filter is used before the load to pass only the dc component.

Referring to the main circuit diagram we see that transistors Q5 and Q6 are used as the series switch. L1 and C7 form the output filter. Due to the inductance of the choke a flywheel diode is required, not only to protect the transistor, but to provide proper operation. When the switch is on, the load current flows through the transistor, the choke, and into the capacitor and the load (Fig. A). When the switch is opened the load current must continue to flow through the choke and this is done via the flywheel diode D5 (see Fig. B). The current through the choke will thus rise during the on

period and fall during the off period. The current never falls to zero except at very low load currents and the average is the same as the load current.

The operating frequency is set by the UJT Q1 which runs about 20 kHz; the higher the operating frequency the lower the ripple voltage on the output. However as the operating frequency goes up so also do switching losses in both transistor Q6 and diode D5. The 20 kHz was chosen as a compromise. It is high enough not to be audible but low enough to keep these losses to a minimum. A fast transistor and diode are still required however. For example if an MJ802 transistor is used the power losses increase by 5 to 10 watts at 10 amps output current.

When the UJT fires the pulse generated is coupled into the base of Q4 by C4 turning Q1 on. This, in turn, turns on Q2 and the switch Q5/6. When Q2 turns on Q4 also turns on and both latch on. If the current through Q6 rises above about 12 to 14 amps Q3 will turn on robbing current from the base of Q2 allowing

both it and Q4 to turn off. This also turns off the output switch Q5/6. This is the current protection circuitry.

A voltage proportional to the output is provided by RV1 to Q7 for comparison to the voltage of ZD1. If Q7 is turned on sufficiently it will also turn on Q3 thus unlatching Q2/4 and turning off the output switch. Once the supply has stabilised this action will control the on time of the switch in each cycle of the 20 kHz, such that the output voltage is maintained at a voltage as set by RV1 in a smooth and even manner.

We used a 240 V to 30 V 2 A transformer, which is adequate for supply currents of up to 7.5 amps, however any transformer having an output of 20 to 30 volts and a power rating of 60 VA would do. If up to 10 amps output is required then a transformer with a rating of 75 to 80 VA would be required.

It is also possible to supply the regulator from a dc supply of 10 to 40 volts. If the voltage available is less than 20 volts R2 should be replaced by a link to ensure that the UJT operates correctly.
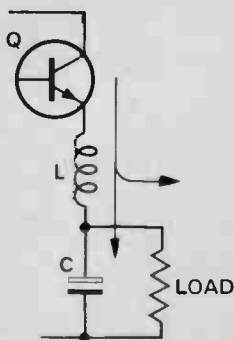
Fig. A. Current paths with switching transistor on.
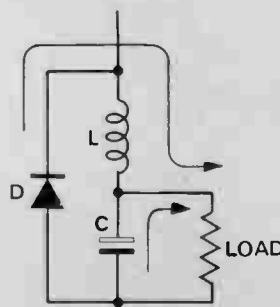
Fig. B. Current paths with switching transistor off.

SWITCHING REGULATOR SUPPLY
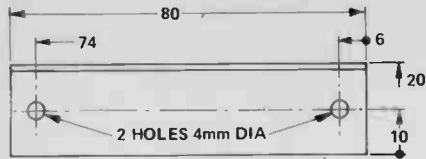
Fig. 3. Transistor/diode mounting bracket.

80
74
6
20
10
2 HOLES 4mm DIA
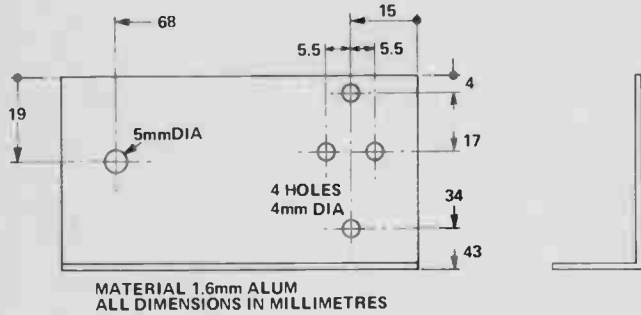
TABLE 2 Choke winding details.
CORE   Philips E core 4322-020-34720 two required
FORMER Philips 4322-021-31830 or 4312-021-23622 one required
Four layers close wound of 1.6 mm wire core gap 3 mm (see text).

68
15
5.5   5.5
4
19
5mmDIA
17
4 HOLES
4mm DIA
34
43

MATERIAL 1.6mm ALUM
ALL DIMENSIONS IN MILLIMETRES

BD140
BDY92

2k7
47

dc INPUT
MAX
40V

2k2
1k
5k1
0.1µF

µA723

8 7
4 6
10
1
3 5 2

47

47

L

+

OUTPUT

1M
+
BYX50
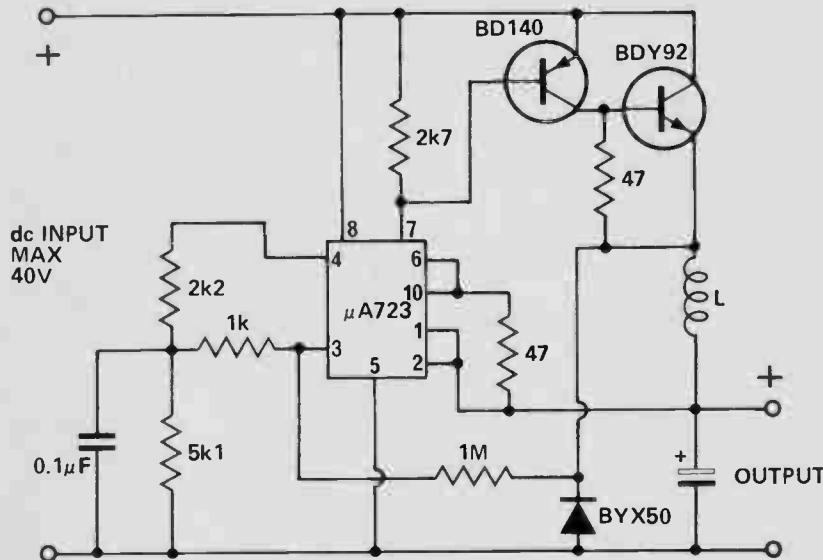
Fig. 4. This circuit recommended by a components supplier is simple but lacks short-circuit protection. Such protection is difficult to add to this circuit.

ETI 119

Fig. 5. Printed circuit-board layout. Full size. 178 x 78 mm.

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TOP PROJECTS — VOL. 3

World Radio History

NICKEL·CADMIUM BATTERY CHARGER

Universal unit will charge practically any nickel-cadmium battery currently in use.

PROJECT 519

THERE is an increasing proliferation of portable equipment, such as flash guns and calculators, which could, or already do, use rechargeable batteries of the nickel-cadmium type.

If the equipment was originally fitted with rechargeable batteries, a charger may well have been provided. But when replacing ordinary dry cells with rechargeable types a charger will be required. Unfortunately, nickel-cadmium battery packs come in a variety of voltages and ampere-hour ratings and a charger supplied for one piece of equipment (eg, an electronic flash) will seldom, if ever, be suitable for other equipment such as an electronic calculator.

The ETI 519 battery charger will charge almost any nickel-cadmium battery in use today. The charging rate is switch-selectable for batteries from 50 mAh to 2500 mAh capacity.

The transformer should be selected for voltage range as detailed in Table 1.

Charging time is approximately 14 hours for a flat battery and proportionally less for one that is partially discharged.

Overcharging at the correct ampere/hour rate will not damage a nickel-cadmium battery. Thus an overnight charge for a partially discharged battery may be safely given. In fact, provided the correct ampere/hour charging rate has been selected no damage will occur if left on charge for 48 hours.

CONSTRUCTION

The circuit is a very simple one. Practically any method of construction may be used provided care is taken with the insulation of 240 Vac wiring.

In our prototype unit we assembled all components on tag strips, with the exception of the range resistors which were mounted directly on the range switch itself.

If only a single range is required, a ▶
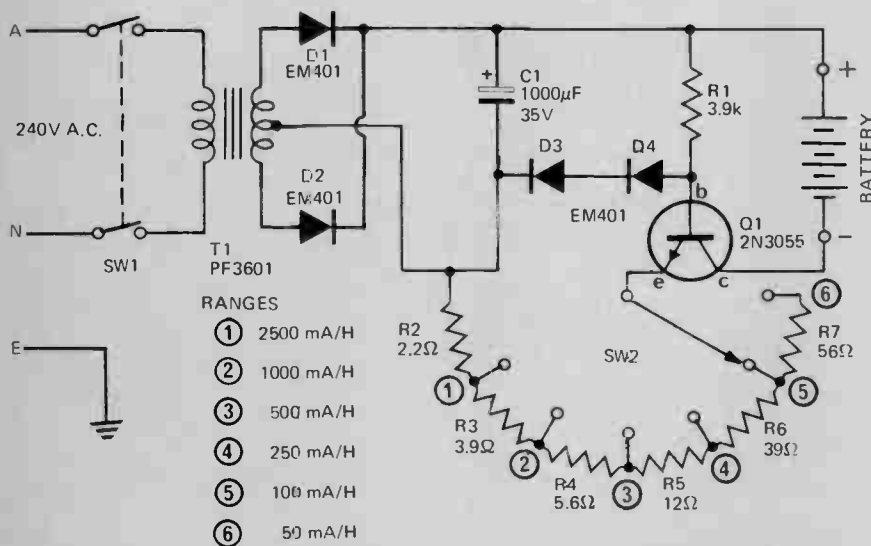
Fig. 1. Circuit diagram of the Nickel-Cadmium Battery Charger.

RANGES

1. 2500 mA/H
2. 1000 mA/H
3. 500 mA/H
4. 250 mA/H
5. 100 mA/H
6. 50 mA/H

TABLE 1

BATTERY VOLTAGE	TRANSFORMER **	R1
1.25 – 3.75	12.6 V CT	1 k
5 – 10	24 V CT	2.2 k
11.25 – 20	40 V CT	3.9 k
21 – 30 *	60 V CT	5.6 k

* Capacitor C1 voltage rating should be 50 V.

** Current rating of the transformer, in mA, should be greater than the maximum mA/h battery rating divided by 10. A single winding transformer of half voltage may be used if a bridge rectifier is employed.

single resistor may be used. Its value in ohms should be 6000 divided by the mA/h rating of the battery. The nearest 5% nominal value to that calculated as above will be adequate.

By virtue of the nature of the constant current supply any battery, or bank of batteries up to 20 volts may be charged. If the 20 volt capability is not required a different transformer may be used as detailed in Table 1.

The transistor dissipates a fair amount of heat and hence should be mounted on a piece of aluminium to act as a heatsink. This piece of aluminium should be insulated from the case, or if not, the transistor should be mounted on the aluminium via a mica washer and insulating bushes. ●

Fig. 2. Layout of components on the tag-strip.

TO BATTERY POSITIVE
TO CENTRE TAP OF TRANSFORMER
TO SWITCH
TO TRANS SECONDARY
TO BASE OF Q1

HOW IT WORKS

Current regulators operate in opposite fashion to voltage regulators. In a current regulator, the current remains constant regardless of changes in load impedance — the output voltage varies to maintain constant load current.

In this circuit, the 240 Vac mains is reduced by T1 to 40 Vac. This is then rectified by D1, D2 and filtered by C1 to provide approximately 28 Vdc.

This dc supply is then regulated by Q1 and its associated components to produce a current level selected by SW2.

Transistor Q1 is biased by D3 and D4 such that there is about 1.2 V between the base of Q1 and the negative side of C1. As there is 0.6 V between base and emitter of Q1, there will be 0.6 V developed across the resistor network R2-R7. Therefore the emitter current of Q1 must be 0.6 V divided by the resistor value selected by SW2.

The emitter current generated as above will produce an approximately equal collector current which charges the battery and remains constant provided there is at least one volt between the collector and emitter of Q1.

Fig. 4. Components in position.
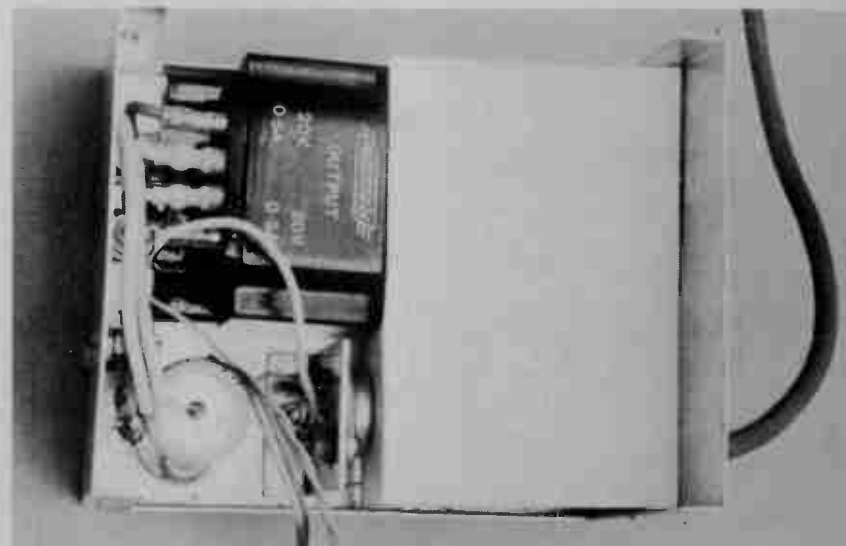
Fig. 5. Constructors are advised to insert an insulating separator as shown in the finished unit above. There is a possible safety hazard in this project. As shown in Fig. 4, the mains power cable is bent around and terminated in a two-way connecting block.

If the cable were to break at the point where it enters the connector there is a possibility of it swinging around and contacting the case of the power transistor Q1.

The separator must be securely fixed in position. Alternatively a metal separator may be used in which case it must be securely earthed.

RADAR INTRUDER ALARM

This microwave unit will detect moving objects at ten metres range.

IN 1963 J B Gunn reported that he had obtained coherent oscillations by applying an electric field to a crystal of gallium arsenide, and that a power of 0.5 watt at a frequency of 1 GHz could be obtained by this means. Since that time a great deal of research and development effort has been devoted to producing a range of solid-state microwave generators with stable and predictable properties.

The Gunn effect oscillator is the first practicable solid-state microwave source. About five times cheaper than an equivalent klystron source (including power supply), the Gunn oscillator, because of its inherent efficiency, reliability and portability is finding wide use in contactless object detection and observation equipment. Applications include intruder detectors in security systems, aids for the blind, automobile anti-collision systems, contactless actuators and speed and rotation measuring equipments.

Microwaves have many advantages over light, infra-red and ultrasonic waves for such duties. Principal among these is the relatively "unpolluted" section of the spectrum in which they operate: few natural phenomena or electrical machines generate incidental microwaves. Additionally, conventional radio-signal processing techniques may be used to improve the signal-to-noise ratio and the immunity to interference.

One of the latest devices to become available, in this field, is the Philips Elcoma CL8963 radar module. This device is intended for short range doppler radar applications.

In essence it transmits a beam of very high frequency radiowaves — virtually anything intercepted by the beam will reflect some energy back to the unit. If the intercepted object is moving then the reflected energy will be at a frequency slightly different from the transmitted frequency (the difference depends on the speed and direction of the moving object).

Tnus if there is a difference between the transmitted and the reflected signal frequencies (i.e. a Doppler shift) then, by definition, a moving object must have caused it.

The CL8963 module consists of a dual cavity and integral aerial assembly. A self-oscillating Gunn diode is mounted in one cavity and a microwave mixer diode in the other.

Hence the unit is self-contained, needing only a power supply and amplifier for the Doppler audio output.

CONSTRUCTION

We did not attempt to miniaturize the unit as ultra-small physical size is unlikely to be required in intruder detection systems. Our prototype was therefore mounted in a 185 x 120 mm diecast box, the side of which makes

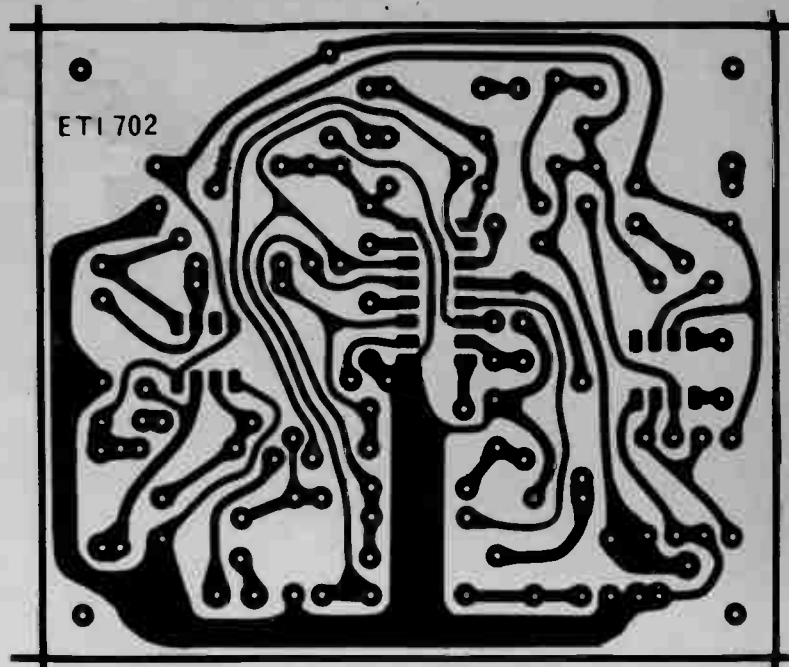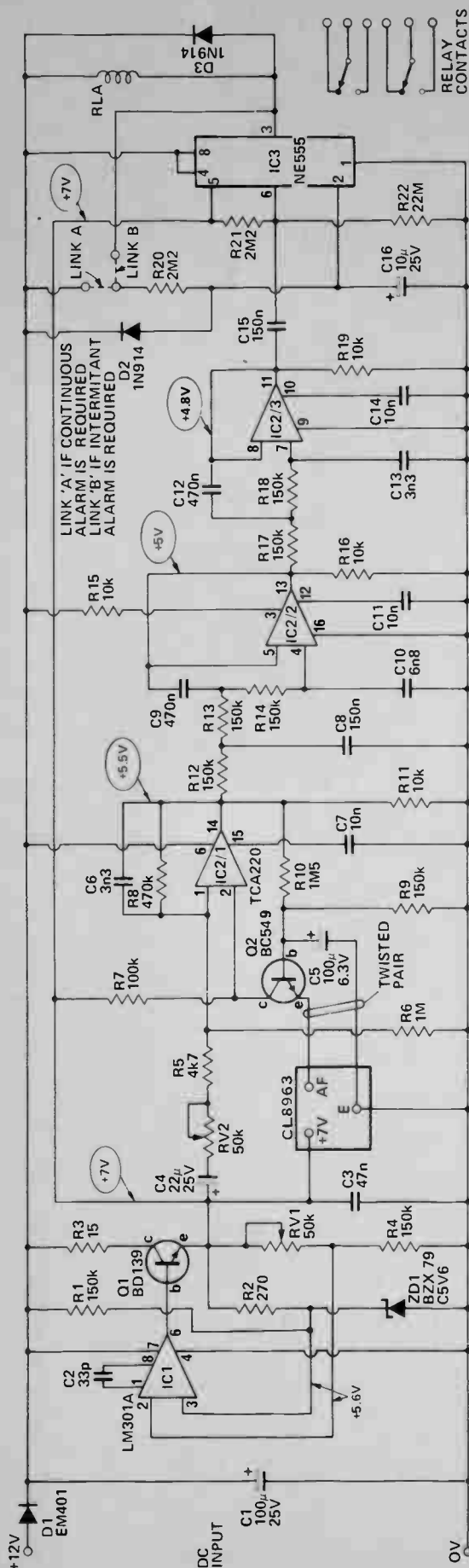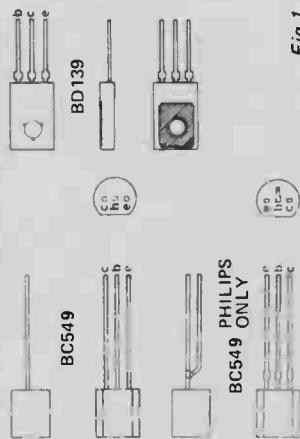| SPECIFICATION	
Frequency	10.525 GHz
Power Output with 7.0V dc supply	8 mW typical
Beam Width free space	approx 60°
Range	up to 10 metres
Sensitivity maximum	50 μV at 10 Hz
Internal Filter	30 Hz, five pole low-pass
Output	by relay — either latching or 20 seconds on plus automatic reset.
Input	10-15 volts dc at 150 — 200 mA.

RADAR INTRUDER ALARM

Fig.1. Circuit diagram of the radar alarm.

Fig. 2. Printed circuit layout.

an ideal rigid support for the radar module.

Assemble the components to the printed circuit board with reference to the circuit diagram and the component overlay. Take particular care with polarization of components and watch for the differing connections of BC549 transistors (see connections at bottom of circuit diagram). The relay may be mounted by simply glueing it to the side of the box.

Do not remove the shorting strap, between the mixer diode and ground, until the module is completely wired into the circuit. The wires from the printed circuit board to the mixer diode should be twisted to minimize pickup — as there is a very low signal level at this point. After these are connected remove the strap by unwinding the end on the mixer diode with the aid of a pair of long-nose pliers and then disconnecting it from the earth terminal.

SETTING UP

The only adjustments required are the setting of the +7 volts supply for the transmitter and setting the sensitivity control.

Initially the transmitter should be left disconnected and a resistor (100 to 1k ohm) inserted from the +7 V line to ground as a simulated load. Switch on and adjust RV1 to obtain exactly 7 volts output. Use some glue or nail polish to secure the potentiometer in this position, switch off, and reconnect the transmitter.

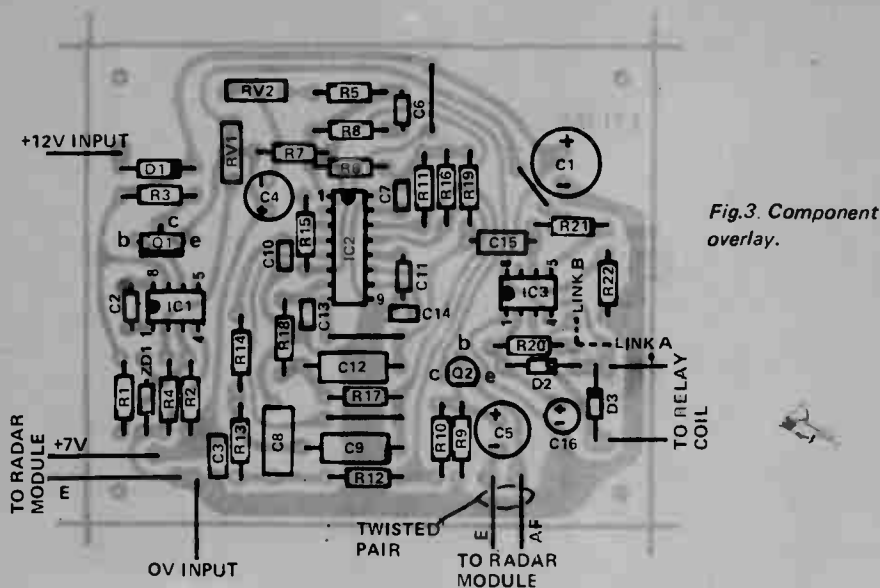To set the sensitivity it is advisable

Fig.3. Component overlay.

Labels in figure: +12V INPUT, RV2, R5, C6, RV1, R8, C1, D1, R7, R3, C4, R9, R11 R16 R19, C7, Q1, C10 R15, IC2, R21, C15, C11, IC3, C14, LINK B, C2, IC1, R18, R13, C12, R20, LINK A, Q2, D2, TO RELAY COIL, R1 R4 R2, ZD1, R14, R17, D3, TO RADAR MODULE +7V E, C3, C8, C9, R10 R9 C5, C16, R12, OV INPUT, TWISTED PAIR, TO RADAR MODULE, b c e (Q1), b c e (Q2), E AF

initially to link the unit for intermittent alarm operation. It may be changed to latching mode later if required. Mount the unit in its normal operating position and adjust the sensitivity such that the desired range is achieved without the unit being over-sensitive. Note that the 10.5 GHz transmitted will pass through timber walls with almost zero attenuation — so movement outside the protected room could set off the alarm if the sensitivity is too high.

This characteristic can be valuable though as it enables the complete alarm to be concealed behind a plastic or wooden screen — or even inside the wall itself if desired.

HOW IT WORKS ETI 702

The intruder alarm consists of four main sections:
1) The Gunn diode assembly and associated power supply.
2) An amplifier for the output of the mixer diode.
3) A 5-pole, low-pass filter.
4) A detector and relay driver.

The transmitter consists of a Gunn diode in a tuned cavity that requires a supply of 7 volts ±0.1V dc at about 140 mA. No other input is required and the diode automatically oscillates at 10.7 GHz. The regulation of this supply is critical as any variation will frequency modulate the Gunn diode. In security applications a 12 volt battery, together with a separate charger, will most commonly be used and the output of such a system will be anywhere between 11 and 15 volts. Hence we have used a series regulator which has a 5.6 volt zener as the reference element. Integrated circuit IC1 compares the zener voltage to the voltage, as set by RV1 and R4, and controls the series transistor Q1 to keep the relationship of output voltage constant with respect to the zener voltage. Thus RV1 controls the output voltage and is set to obtain 7 volts. A diode D1 is used in series with the input to prevent damage due to reversed polarity.

The mixer diode is in a second tuned cavity next to the transmitter and receives two signal sources. The first of these is 'spill' from the transmitter, constituting a local oscillator signal.

The second signal consists of energy reflected from all objects in the target area. If nothing is moving in the area the reflected signal will be of the same frequency as the transmitted frequency — so the output from the mixer will be the transmitted frequency only.

However a moving object in the area will doppler shift the reflected signal. The difference in frequency will be proportional to the objects velocity, in accordance with the following formula.

$$f = 71.3\ V \text{ Hz (V = velocity in metres/sec perpendicular to module)}$$

This doppler frequency is amplified by Q2, connected as a common-base amplifier, and again by IC2/1 providing a maximum gain of some 85 to 90 dB.
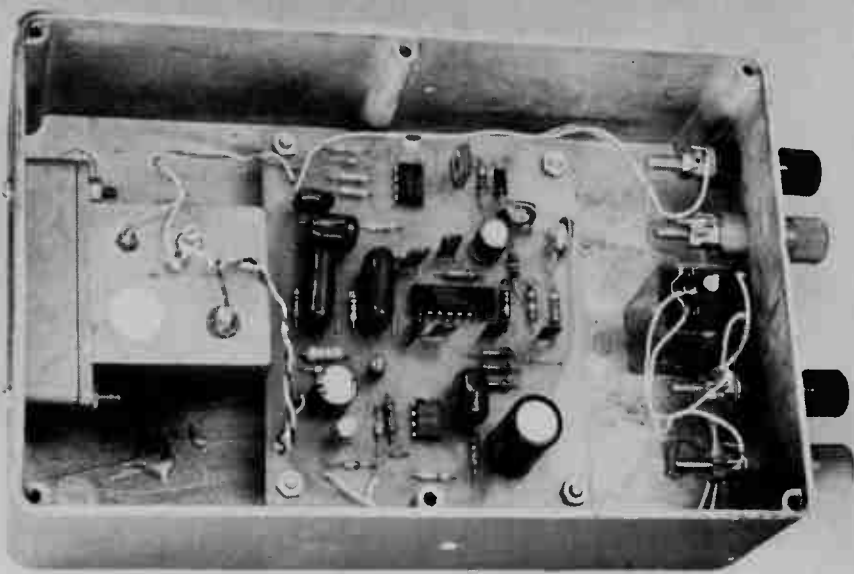
Approximately 20 dB of gain control is provided by RV2. The collector load of Q2 (R1) provides the 35 micro-amp bias required by the mixer diode and R6, 9 and 10 provide the correct dc conditions for the combination.

The filter consists of two active sections, one three-pole and one two-pole, which together make a five-pole Chebyshev filter. The cutoff frequency is about 30 Hz and the attenuation at 50 Hz is more than 40 dB.

An NE555 timer IC is used as a detector. This IC has two level detectors, one at two-thirds of V_s (input A) and one at one third V_s (input B). However, by connecting the control voltage input (pin 5) to +7 volt these levels will be +7 V and +3.5 V respectively. If input B is less than 3.5 V the output will be high irrespective of input A. If input B is above 3.5 V and input A goes above 7 V, the output will go low until input B again goes below 3.5 V. The voltage at input A is normally held at 6.4 V by R21 and 22 and hence about 600 mV increase is needed to reach the trigger point.

On initial switch on, C16 will be discharged causing the output to be high and the relay unenergized. After about 10 seconds C16 charges to 3.5 volts and this allows input A to assume control of IC3. This initial period is required to prevent false alarms whilst the rest of the electronics stabilizes. If the resistor R22 is connected to the output of the IC (link B) the relay will reset itself after about 25 seconds. If it is retriggered within the next two minutes it will re-latch, however the on time will be less than 25 seconds. If link A is used the initial 10 second delay still occurs, however once activated the alarm will remain on until power is removed.

LIMITATIONS

The alarm has a filter which rejects all frequencies above 30 Hz. A person walking towards the unit at a reasonable rate generates frequencies in excess of 100 Hz. However parts of the body will be moving at different rates and there will be frequencies below 30 Hz as well. It may be possible to approach the unit from a distance at a high and uniform rate without setting off the alarm but the alarm will be triggered the moment one stops or changes pace.

Fluorescent lights, when operating, generate 50 Hz and 100 Hz noise. Whilst this is rejected by the filter the alarm may be triggered by the impulses generated when the lights are switched on, especially if switch-start types are used which flick on and off a few times when starting. This is not normally a problem as the lights will be left either on or off whenever the alarm is armed. ●

ABOUT MICROWAVES
Nature and properties

Microwaves, as the name suggests, are high-frequency, short-wavelength electromagnetic waves. Being of short wavelength, their properties lie somewhere between those of normal radio and visible light waves. They can be focussed and directed by comparatively small structures, but being of high frequency they are more easily deflected and attenuated by solid objects. The high quantum energy involved with microwaves means that some precautions are necessary to avoid personal injury.

The microwave region of the electromagnetic spectrum is arbitrarily defined as lying between 1000 MHz (1 GHz) and the far infrared region beginning at 300 GHz. Over this range of frequencies, similar signal generating and processing techniques may be used. The wavelengths involved range from 30 cm to 1 mm, the location of the microwave region of the spectrum.

In most countries, radiation health regulations specify a safe limit of exposure to microwaves of 10 mW/cm^2, however, under normal circumstances a maximum intensity of 1 mW/cm^2 should be regarded as the limit for continuous exposure. The CL8963 output is only 8 mW. There is therefore no danger in using this device.

Guiding and Directing

The high dielectric and skin losses, together with the small wavelengths, rule out the use of normal discrete components and transmission lines. Coaxial lines, if of low loss, may be employed at the low-frequency end of the region, but at frequencies above about 5 GHz wave-guides are usually employed. Where attenuation is unimportant, short lengths of coaxial line fabricated from copper tube and wire can be used. Careful attention should be paid to matching if stable, efficient performance is expected. Discontinuities, such as sharp bends, are undesirable.

Aerials for use at microwave frequencies may be made of high gain in small sizes, a 5 dB gain antenna is supplied with the CL8963 but other higher gain horn antennas are available from Elcoma.

Detection

In low-power industrial practice, microwave signal-frequency amplification is seldom employed. Signals may either be detected directly, or converted to some lower frequency by a diode mixer, or Gunn effect mixer-oscillator.

IMPORTANT

Some **555** ICs do not have the same characteristics as the Signetics NE555 and the alarm may close, or latch, during initial switch on.
This may be cured by adding a 1N914 diode between pin 6 and pin 2 (cathode bar to pin 2) and by changing R20 to one megohm.

USING THE CL8963

1) The Gunn diode will be damaged if the supply voltage is reversed.
2) The mixer diode will be damaged by forward current in excess of 10 mA.
3) The module is despatched with a shorting strap between the mixer a.f. terminal and −E terminal.

The mixer has a low junction capacitance and may be damaged by transients of very short duration. It is recommended that soldering irons be isolated from the mains and that *the shorting strap should not be removed until all wiring is completed.*

4) A 10 nF capacitor should be connected to, and between, the +7 volt terminal and −E terminal to suppress parasitic oscillations in the supply circuit.
5) Power supplies should have a low source impedance and be capable of supplying up to 250 mA at approximately three volts during the initial voltage rise following switch on.

TABLE 1
Attenuation of 10 GHz microwaves by various materials. Note: true only for thicknesses greater than 1 wavelength (3 cm).

material	attenuation (one way)	notes
heavy rain	0.2 dB/km	not significant in short range radar
dense fog	0.1 dB/km	not significant in short range radar
dry wood	10 to 50 dB/m	very variable, greater when wet
Plexiglas Perspex	15 dB/m	methyl methacrylate type plastic
polyethylene/ polystyrene	<1 dB/m	dry surfaces
expanded polystyrene	<1 dB/m	dry and fresh
glass	up to 50 dB/m	extremely variable
pure water	approx. 5000 dB/m	

INTRUDER ALARM

A simple burglar alarm with superior performance.

eti

PROJECT 528

AT THE beginning of this century there were only three crimes a year for every one thousand people. By 1971 there were three for every one hundred — ten times as many. In the UK, statistics have shown that from 1964 to 1970 the number of indictable offences rose by 50% — and the rate is steadily increasing.

This increase in crime rate is common to the entire western world, and seems to be related to affluence rather than to poverty as was previously thought by many.

Hence, these days, the chances of your home being burgled are high indeed, and getting higher. Each householder should therefore give serious consideration to protecting his home by an effective alarm system.

A burglar alarm for the home should preferably be battery operated (as it is quite easy to switch off the power from outside most houses), should be reliable over long periods and should not be subject to false alarms.

In the ETI 528 Alarm the CMOS IC has sufficiently low power drain (less than 1 mA) to make battery operation feasible. And by virtue of the high noise immunity of CMOS (half supply voltage) the unit is not susceptable to false alarms due to lightning flashes etc. Add to this the inherent reliability of integrated circuits and you have the basis of a very simple, but very effective system.

Three modes of operation are built in to the unit which functions as follows.

ALARM MODE

Microswitches or reed relays fitted to each window and door are arranged to have closed contacts when the door, etc, is shut. All contacts are wired in a series loop such that if any door or window is opened, the loop will be broken activating the alarm. The series loop should be wired between the 'external loop' and 'common' terminals shown in Fig. 4.

SILENT ENTRY

This mode of operation allows the owner, when leaving the premises, 30 seconds to open and close the front door before the alarm mode is activated. Additionally it allows the owner 30 seconds to disable the alarm after entering through the front door. Thus the front door microswitch is not included in the normal alarm loop but to its own 'silent entry' loop. The silent entry switch should be wired between 'silent entry' and 'common' — see Fig. 4.

EMERGENCY

In this mode, any contact closure from a switch or sensor (eg fire, smoke or gas detector) will immediately sound the alarm. Wire switch/s across 'emergency' terminals (Fig. 4).

CONSTRUCTION

Assemble all components to the printed circuit diagram in accordance with the component overlay diagram, Fig. 3. *Do not* fit the CMOS IC until all other components are in place. Make sure that the diodes, the transistor and the tantalum capacitors are all orientated correctly before

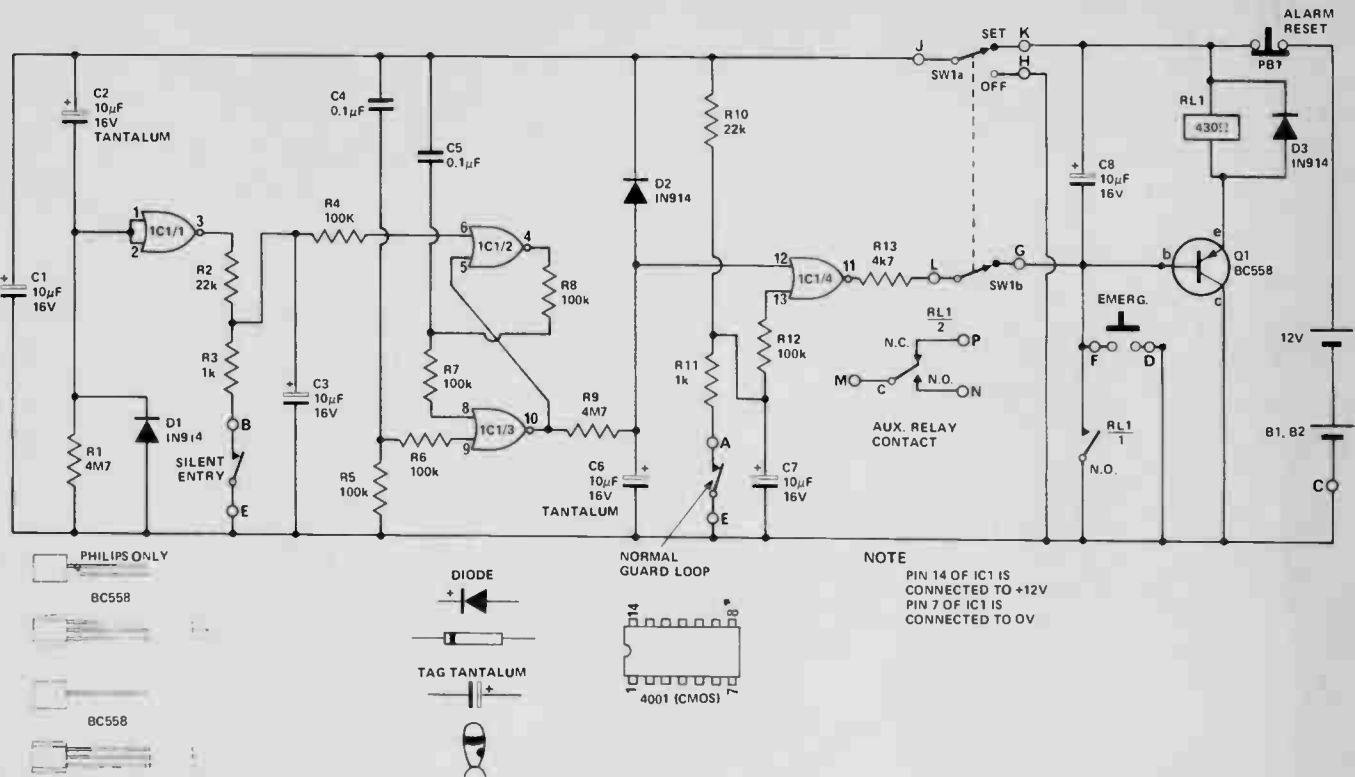World Radio History
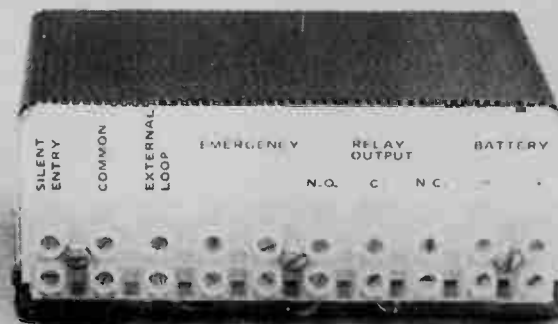
INTRUDER ALARM

Fig. 1. Circuit diagram of the ETI Burglar alarm.
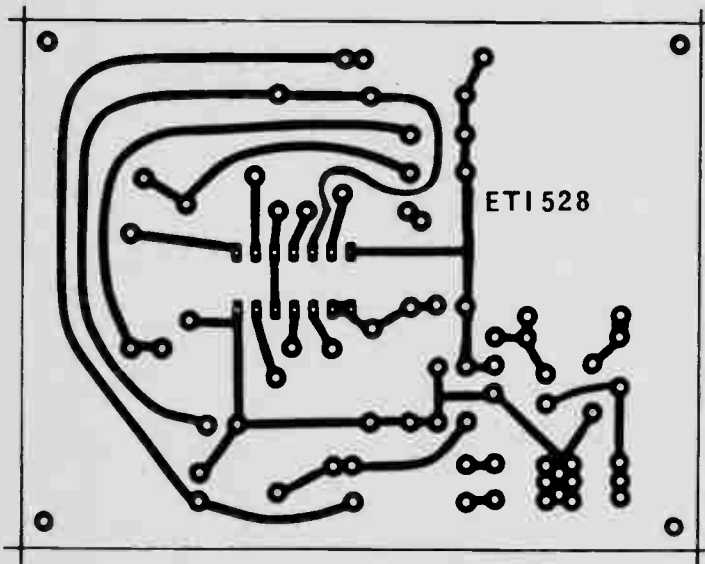

Fig. 2. Printed circuit board lay-
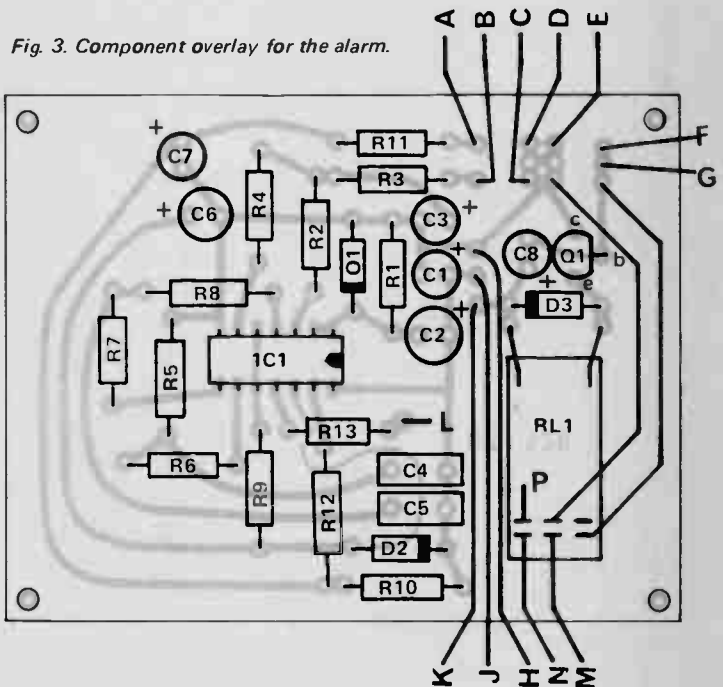out for the alarm. Full size
90 x 70 mm.

Fig. 3. Component overlay for the alarm.

soldering. The relay should be cemented in position on the board with a little contact cement or 5-minute epoxy.

CMOS integrated circuits are supplied with their pins inserted into black conductive foam. The ICS should be left in this foam, which protects them from damage due to static electricity, until you are ready to insert them into the printed circuit board. On no account should the devices be stored in ordinary polythene foam (the static electricity generated by withdrawing the device may well destroy it).

To insert the device into the printed circuit board, first check the orientation of the device, avoid touching the IC pins and insert as quickly, and with as little fiddling, as possible. Then using a lightweight soldering iron (with a clean tip) solder pins 7 and 14 first. These pins are the

supply rails and their connection allows the internal-protection diodes to safeguard the gates against electrostatic damage. The remaining pins may then be soldered.

The completed printed circuit board should then be assembled into the box, together with the switches and terminal block, and the complete unit wired with reference to the component overlay and the wiring diagram Fig. 4.

The completed alarm unit should be located in a reasonably well concealed position close to the 'silent entry' door.

The alarm bell is best located in a high, well concealed and not readily accessible position. As very high voltages are generated across the bell 'make and break' contacts it is preferable to use a separate bell battery of suitable voltage rather than to connect it across the main system battery.
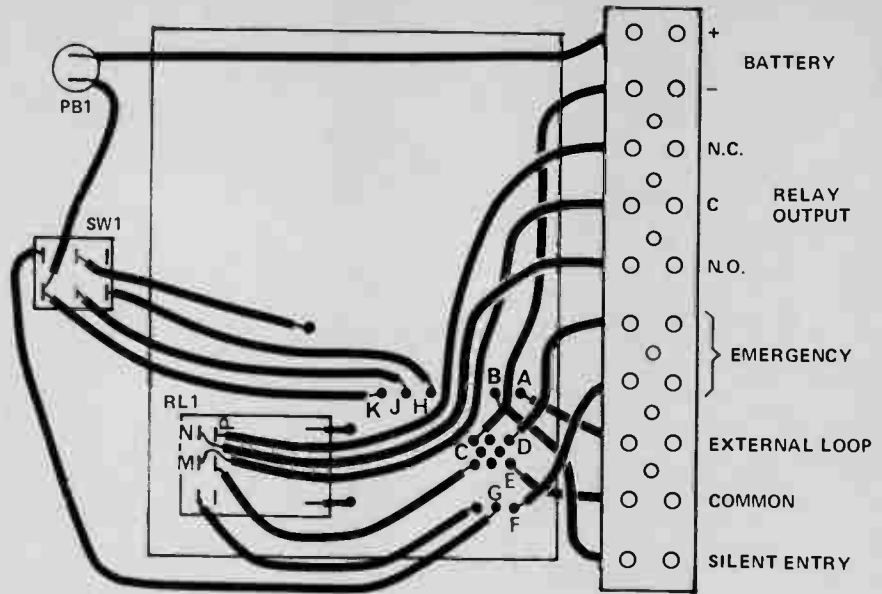

Fig. 4. Wiring diagram showing connections from printed circuit board to switches and connector strip.

HOW IT WORKS ETI 528

The alarm has three different modes of operation as described in the text.

When power is first applied, i.e. normal alarm mode enabled, capacitor C2 initially has no charge. This momentarily lifts the inputs of IC1/1 to +12 volts. The capacitor then charges slowly via R1 and the voltage presented to IC1/1 falls exponentially to zero. The output of IC1/1 will be zero if the input is over 7 volts, and at +12 volts if the input is less than 5 volts. There is a small linear region, around 6 volts, in which the output changes from zero to +12 volts. With the values given to C2 and R1 a delay of 30 seconds is provided which may be altered, if required, by changing C2. During this delay opening or closing the silent entry door will not affect the level presented to pin 6 of IC1/2.

An RS flip-flop is formed by IC1/2 and IC1/3 in which the control inputs (pins 6 and 9) are normally low (zero volts). On first switch-on pin 9 is pulled up momentarily to +12 volts by C4 before returning to zero. This presents a "1" to the input of IC1/3 and therefore its output will be low (see Table 1). Since pin 7 is at zero, and pin 5 is also at zero, (connected to pin 10) the output of IC1/2 will be high. Since this is coupled to the input of IC1/3 the flip-flop will be locked into the state

where IC1/3 output is low.

The only way the flip-flop can be reversed is for the input to pin 6 to go high. However during the first 30 seconds, as explained above, the output of IC1/1 is low. Hence, opening or closing the silent entry door during this time will not set the flip-flop and activate the alarm.

After this 30 second period, opening the silent entry door will present a "1" to pin 6 which will cause the flip-flop to change state. Closing the silent entry door will now have no effect and the flip-flop will remain set.

The high output of IC1/3 will allow C6 to charge slowly to +12 volts via R9. When this voltage reaches 6 volts (about 30 seconds) it will cause the output of IC1/4 to go low (assuming the normal alarm loop is closed). The low output of IC1/4, via emitter follower Q1, pulls in relay RL1

activating the alarm. When the relay closes contacts RL1/1 cause it to latch on, and only removing power by pressing PB1 will reset it.

If at any time the normal guard loop is broken, when the alarm is activated, a "1" is presented to pin 13 of the IC1/4 causing the output to go low and the relay to close.

When the emergency switch is closed the base of Q1 is taken to zero and the relay closes and latches. This action will take place regardless of whether the alarm is enabled or not.

Diodes D1 and D2 discharge capacitors C2 and C6 respectively via SW1 when it is in the "off" position, thus ensuring that the 30 second delay is always obtained. Resistors R6, 7 and 12 protect the CMOS IC against voltages in excess of the supply rails. Capacitors C3, 5, 7 and 8 add further protection against false triggering due to lightning etc.

INPUT		OUTPUT
A	B	
0	0	1
1	0	0
0	1	0
1	1	0

TRUTH TABLE FOR
2 INPUT NOR GATE
4001 (CMOS)
NOTES
INPUT
1 means >55% supply voltage
0 means <45% supply voltage

World Radio History
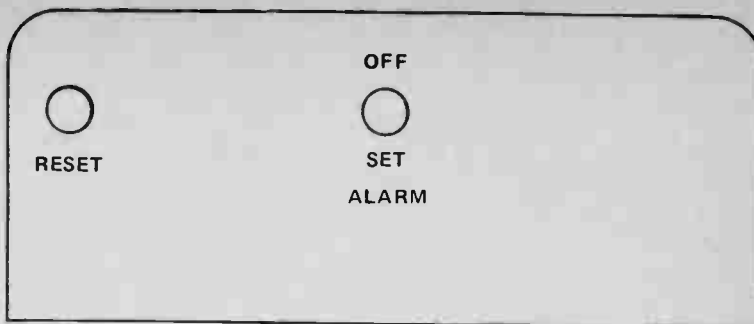
INTRUDER ALARM

OFF

RESET

SET

ALARM

Fig. 5. Front panel artwork.

Fig. 6. Rear panel artwork.

SILENT ENTRY | COMMON | EXTERNAL LOOP | EMERGENCY | RELAY OUTPUT | BATTERY

N.O. C. N.C. — +
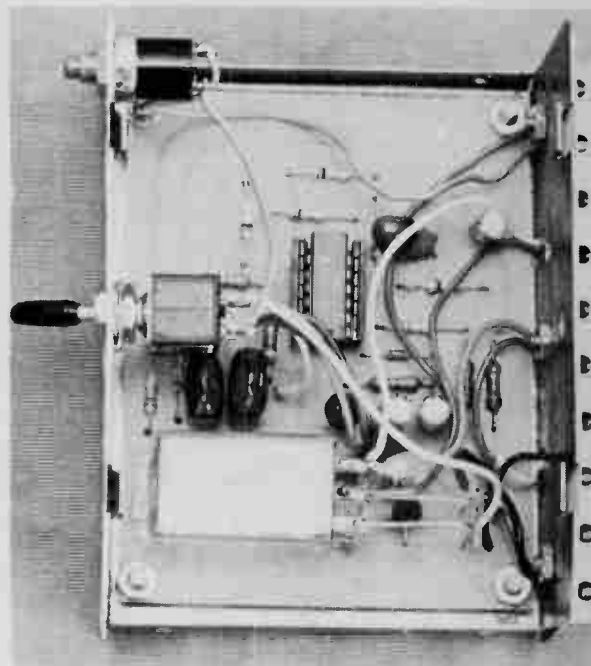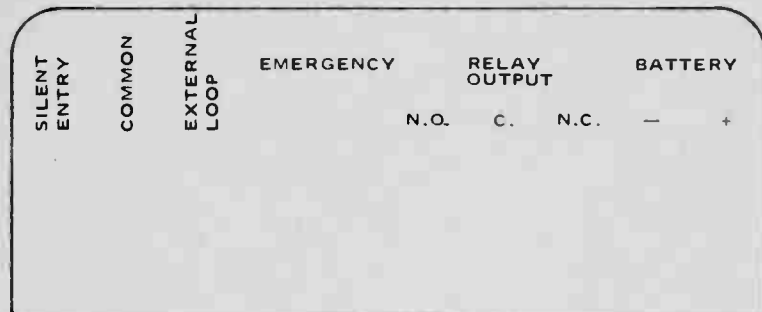
ETI 258 INTRUDER ALARM PARTS LIST

R1, R9	Resistor	4M7 ohm ¼W 5%
R2, R10	"	22k ohm ¼W 5%
R3, R11	"	1k ohm ¼W 5%
R4, R5, R6, R7, R8, R12	"	100k ohm ¼W 5%
R13	"	4k7 ohm ¼W 5%
C1,C3,C7,C8	Capacitor	10µF 16v electrolytic
C2,C6	"	10µF 16v tag tantalum
C4,C5	"	0.1µF polyester.
D1,D2,D3	Diode	IN914
Q1	Transistor	BC 558, BC 178 or equivalent
IC1	Integrated Circuit	SCL4001A, MC14001, etc.
SW1	Switch	DPDT subminiature
PB1	Switch	Push button switch NC.
RL1	Relay	Miniature cradle relay, 430 ohm coil, two c/o contacts.

PC Board ETI 528, box 200B Venticase (CELOTEK) or similar, 10 way nylon terminal block, two 6 volt lantern cells, hookup wire.

World Radio History

COLOUR ORGAN

WARNING. All components on the board and the heat sink, upon which the triacs are mounted are at mains potential. Use extreme care as you would any exposed wiring carrying 240 volts. Avoid working on the unit whilst it is connected to 240 volt mains, make sure any test equipment you are using is isolated from earth, and that you yourself are well insulated from the floor by a rubber mat etc.

Produce all the colours of the rainbow in synchronism with your music!

THE SUBJECTIVE appreciation of music may be considerably enhanced by adding a coloured light display. If the three primary colours, red, green and blue, are projected onto a translucent screen, or some other diffuse material, and selectively modulated by the instantaneous amplitude and frequency content of the music you are listening to, the three colours mix to produce all the colours of the rainbow (as well as white) in synchronism with the content of the music.

A difficulty arises when you try to determine what frequency a 'blue' note should be, or for that matter red, green or any other colour. Bass instruments predominate the frequency range below 220 hertz. Vocals cover the midrange to about 1200 hertz. The higher fundamental notes of wind and string instruments complete the treble register to about 4000 hertz. Harmonics of course extend well beyond this.

It is generally agreed that red should represent low notes, green mid range, and blue the high notes. After much critical listening to tone oscillators and recorded music, in conjunction with light displays our panel of discriminating 'muso's' agreed that 'red' notes should extend to A — an octave below middle C. Green over the

next three octaves and then followed by 'blue'. This is accomplished by dividing the frequency spectrum into three bands by means of filter networks. The amplitude content of each band is averaged and used to modulate the brilliance of the associated lamps.

For best effect, the direct light from the lamps should not be seen. It is not very stimulating, and in fact can be disturbing, to watch globes flashing on and off. However, the lights can quite readily be arranged to shine behind a translucent panel or be reflected off a wall. Alternately large diameter spheres made from crushed glass or plastic are available as standard lighting fixtures. We tried one that had been converted to accommodate three 100 watt coloured globes. Another simple effective arrangement we tried consisted of a cone which we made from a large sheet of translucent drafting film. This was positioned over our 250 watt floodlights mounted inside a five-gallon drum. Incandescent blue lamps are generally inefficient so we added an extra blue lamp in order to achieve colour balance. A lot of creative fun can be had trying different arrangements!

To keep this project as economical as possible we used only one control to vary the input sensitivity. Individual

controls however can easily be added if desired. This involves substituting a log potentiometer with an appropriate series resistor in place of each of the resistors R23, R24 & R25.

CONSTRUCTION

We wound the line filter chokes, L1, L2 & L3, on three pieces of ferrite rod 30 mm long. These were cut from a 9 mm dia. aerial rod. To cut the rod, first file a V groove around the circumference of the rod at the point where it is to be cut. The groove need only be about 0.5 mm deep and can be cut with the sharp edge of a small triangular file.

Grip the rod in a vice, at the notch, being careful not to screw up the vice too tightly, as the material is also very brittle and shatters easily. Now give the rod a gentle tap and the rod will part cleanly. Wind the chokes as detailed in Table 1.

The trigger transformers are wound on pot cores having split bobbins, again as detailed in Table 1.

The heat sink should be constructed from a piece of aluminium as shown in Fig. 4. Carefully follow the component overlay, when assembling the board checking that all diodes, transistors and electrolytic capacitors are inserted the right way around.

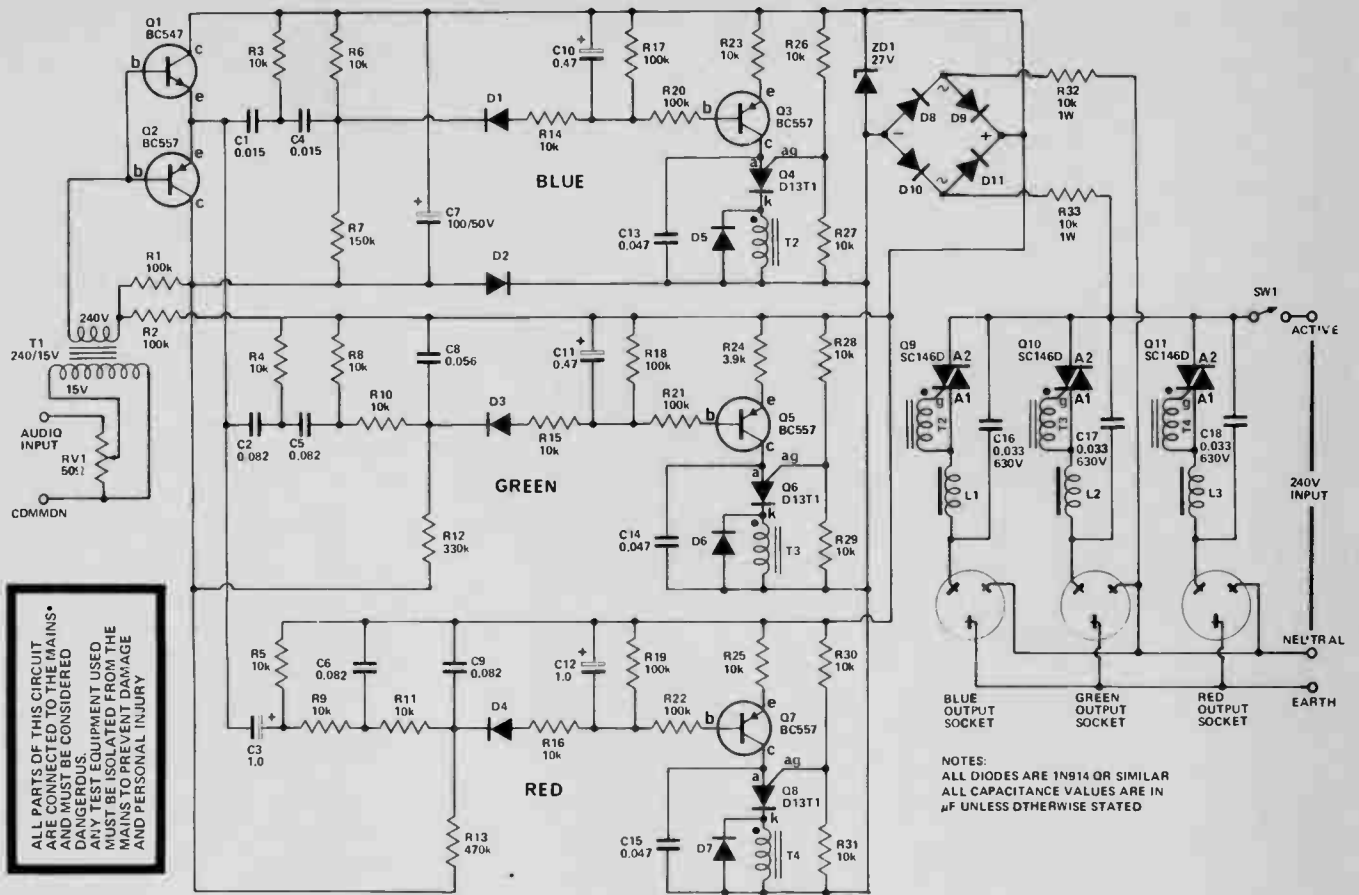The line chokes are secured to the PC board by tinned copper wire looped

COLOUR ORGAN

Fig. 1. Circuit diagram of the colour organ.

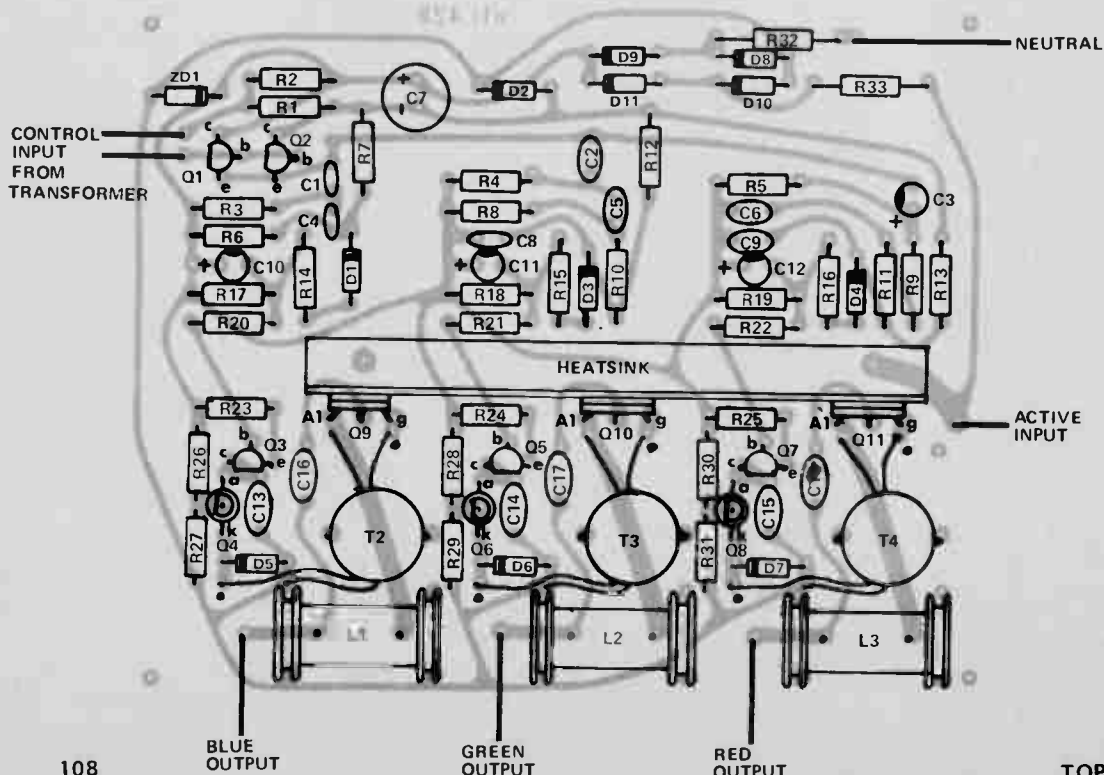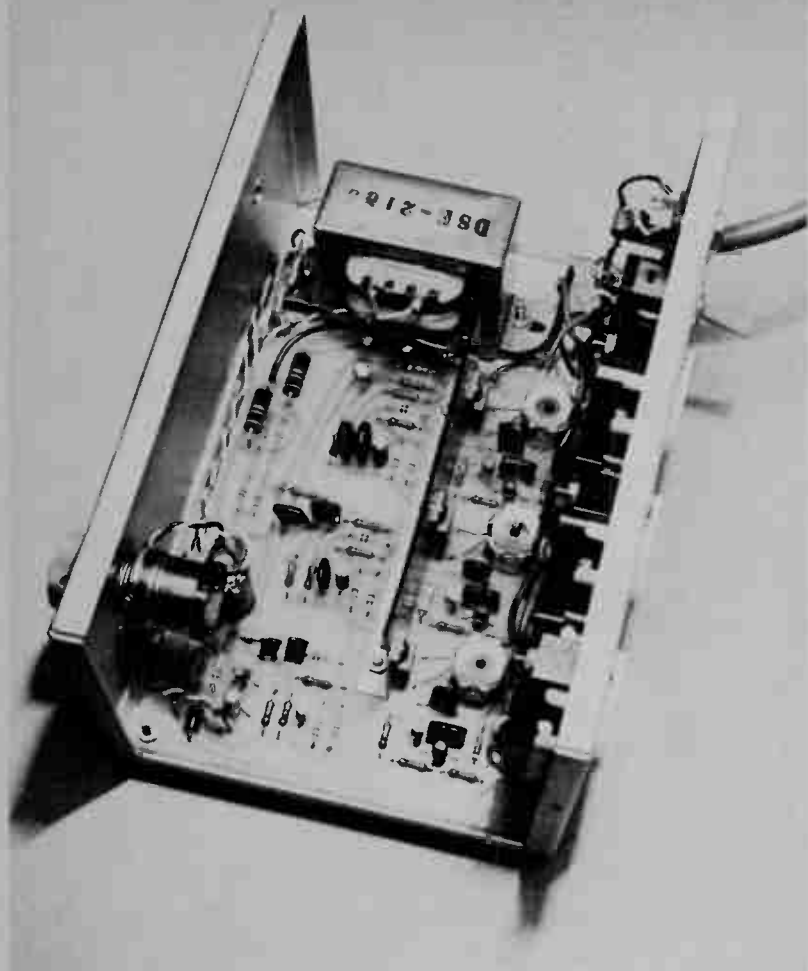ALL PARTS OF THIS CIRCUIT ARE CONNECTED TO THE MAINS• AND MUST BE CONSIDERED DANGEROUS. ANY TEST EQUIPMENT USED MUST BE ISOLATED FROM THE MAINS TO PREVENT DAMAGE AND PERSONAL INJURY.

NOTES:
ALL DIODES ARE 1N914 OR SIMILAR
ALL CAPACITANCE VALUES ARE IN µF UNLESS OTHERWISE STATED

Fig. 2. Component overlay for the colour organ.

BLUE OUTPUT

GREEN OUTPUT

RED OUTPUT

World Radio History

HOW IT WORKS

Audio is fed to the input from the loudspeaker terminals of the amplifier. RV1 controls the input sensitivity and transformer T1 steps up the input voltage as well as providing safety isolation from the 240 volt mains on the remainder of the circuit. Transistors Q1 and Q2 provide a low impedance drive for the three filters and present a constant load to the transformer thereby keeping the level independant of varying frequency.

The 'red' channel is driven via a two stage 12 dB/octave low pass filter. The principal frequency determining components are R9, R11 & C6, C9. Diode D4 rectifies the signal which is converted to an average dc level by R16, R19, R22, C12. This varies the bias on transistor Q7 which operates as a constant current source.

The instantaneous current is set by the applied bias, and by the value of Q7 emitter resistor R25. The resulting constant current charges C15 and when the voltage across C15 equals the reference voltage set at the anode gate terminal (ag) of the programmable unijunction transistor (P.U.T.) Q8, the P.U.T. fires discharging C15 through the primary winding of trigger transformer T4.

The resultant pulse, from the secondary of T4, fires triac Q11 thus switching power to the red lamp. The firing cycle of the P.U.T. is synchronised to the 50 Hz mains by the unfiltered supply derived from Zener diode ZD1. Diode D7 bypasses the reverse flyback pulse from the triac and ensures the pedestal voltage of C15 remains constant.

The operation of the green and blue channels is similar with the exception of the filters. Components C2, C5, C8, R4, R8 & R10 form a bandpass filter for the green channel, whilst C1, C4, R3 & R6 make a high pass filter for the blue channel. Chokes L1, L2 & L3 in combination with capacitors C16, C17 & C18 are incorporated in order to reduce radio frequency interference.

round the grommets and then soldered to the board. As the triacs used are rated at 10 amps, the main limitation on the maximum load is the associated domestic wiring which would limit the total load to 2400 watts. We have designed the heat sinks with this in mind. If it is required to drive heavier loads the area of the heat sink should be increased and possibly triacs rated to carry higher current substituted. Of course then ordinary domestic power outlets should not be used.

A 300 millivolt input is sufficient to drive the lamps to full brilliance. At one hundred hertz the input impedance is approximately 12.5 ohms, accordingly any amplifier capable of delivering a watt or more would suitably drive the unit.

Set the amplifier volume control to the normal listening level, then adjust the input sensitivity control such that the lamps only light up to maximum brilliance on musical peaks. If this control is not set correctly the input level will be too high with the result that the lamps will all light up together regardless of the frequency content of the programme. If everything is working at this stage, you can now watch the changing moods and drift into happy ecstasy! ►
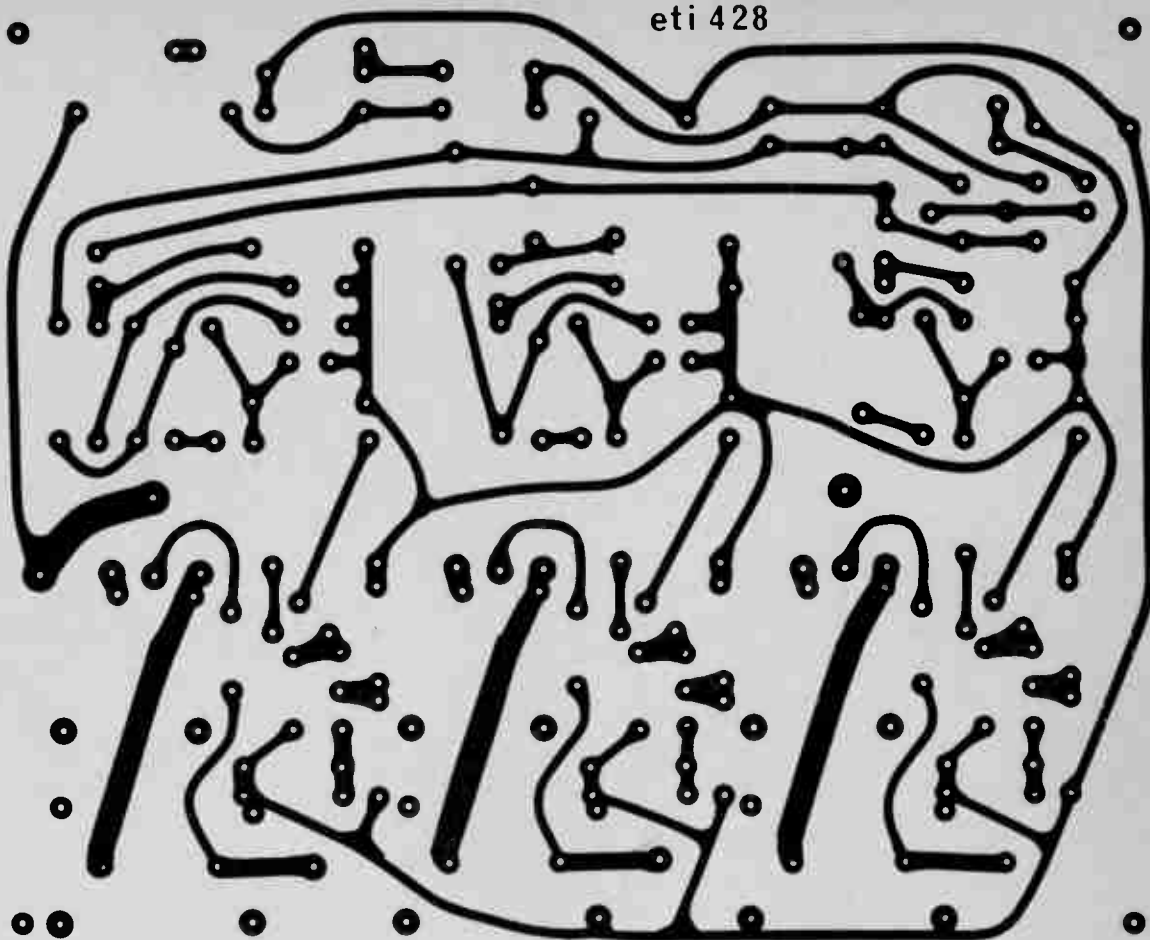
COLOUR ORGAN

Fig. 3. Printed circuit board layout for the colour organ.
Full size 127 mm x 158 mm.
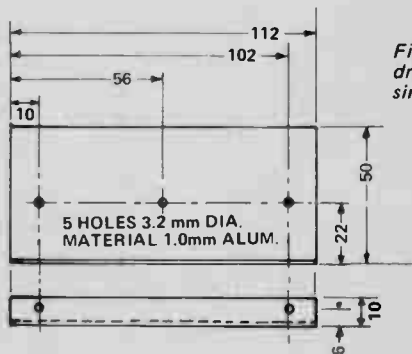
Fig. 4. Dimensions and drilling details for heat sink bracket.

112
102
56
10
50
22
10
6
5 HOLES 3.2 mm DIA.
MATERIAL 1.0mm ALUM.

TABLE 1   **CHOKE WINDING DATA**

L1, L2 & L3

Core	30 mm length of 9.6 mm dia ferrite rod.*
Winding	40 turns 0.63 mm (22 B&S) wound in two layers, each 20 turns, close wound using the centre 15 mm only of the core.
Insulation	two layers of plastic insulation tape over complete winding.
Mounting	use rubber grommet (9.6 mm ID) over each end and join to DC board by looping turned copper wire round grommets and secured into holes provided.

* Made from an aerial rod — file a groove around it at the desired cutting point then snap off.

TABLE 2   **PULSE TRANSFORMER — WINDING DATA**

T2, T3, T4

Core	Philips P18/11 (any variation of P18 will do)
Former	Philips 4322-021-30280 (preferred) or 4322, 021, 30270
Clip	Philips 4302, 021, 20000.

Winding (double section bobbin)
Primary — 30 turns 0.40 mm (26 B&S) one section
Secondary — 30 turns 0.40 mm (26 B&S) second section
Bring leads out at opposite ends of coil.

Winding (single section bobbin)
Primary — two complete layers 0.40 mm (26 B&S) close wound
Insulation — two layers of plastic insulation tape
Secondary — two complete layers 0.40 mm (26 B&S) wire close wound
Bring leads out at opposite ends of coils.
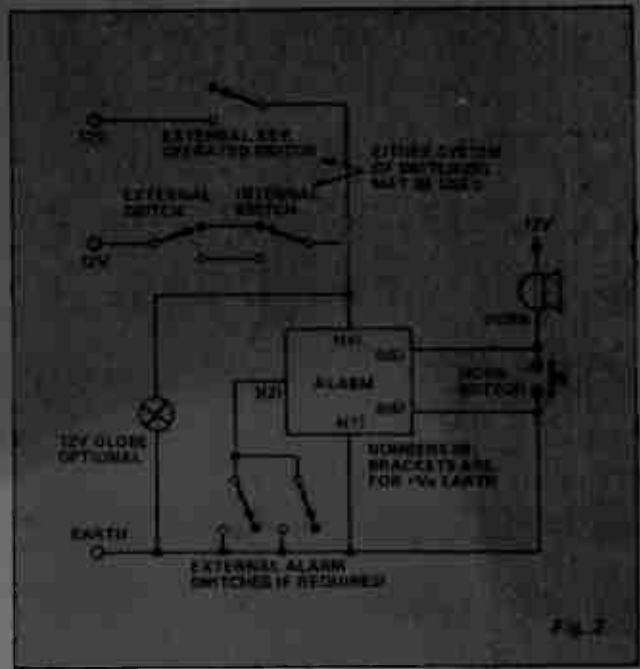
Protect your car with this simple effective circuit.

ONE OF LIFE'S more devastating experiences is to walk out of your house in the morning and find that your car has disappeared!

But this need not happen to you, for an effective alarm system, as described here, may be quite easily constructed and installed at low cost.

The ETI 313 car alarm uses one single IC and a minimum of other components. It will, when actuated, blow the horn at one second intervals, and will continue to do so until deactivated by means of a key switch etc.

The alarm is triggered by any drop in the battery supply voltage caused by an increase in loading on the vehicle's electrical system. Thus, if a door is opened, the interior light will be activated and the increase in electrical load will trigger the alarm.

This operating principle simplifies installation, for practically all vehicles have courtesy lights activated by switches on at least two of the doors — and it is a fairly easy task to install further switches on the other doors if required.

Both the boot and under bonnet areas may be protected in a similar manner — indeed many vehicles have lights already fitted in these areas, if not, it is a simple matter to fit them into the circuit such that they come on when the boot lid etc is opened.

These lights are of course very useful apart from their alarm function, but remember — they must operate at all times, not just when the ignition is on.

The alarm is sensitive enough to be activated by anyone pressing the brake pedal — or even by opening the glove box (where a lamp is fitted of course).

The unit is designed for use with cars having 12 volt electrical systems. It may be used with either positive or negative earth systems without modification.

In addition to the power sensing alarm mode other precautions may be
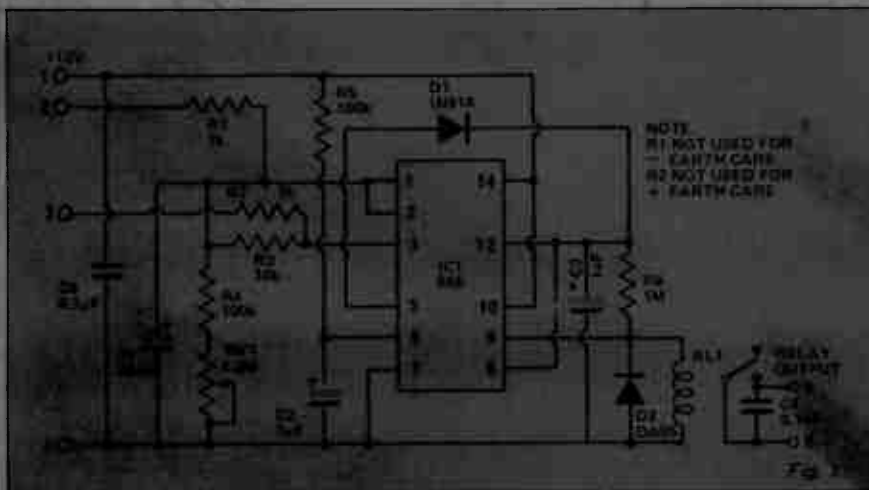
taken by adding further alarm microswitches. For example microswitches may be fitted to the suspension such that if anyone tries to lift the car, in order to tow it away, the alarm will go off. If such switches are used they should be connected between terminal 2 or 3 or the alarm (see Fig 1 and 2), depending on whether the vehicle has a positive or negative earth system, and earth.

CONSTRUCTION

Construction of the alarm is extremely simple and anyone capable of using a soldering iron should not have any difficulty. All components, including the relay, are mounted on a small PC board as shown in the component overlay diagram.

Note the polarity of electrolytic capacitors, the IC and diodes. In particular make sure that the germanium diode D2 is mounted in the correct position and with the correct orientation. When soldering use a small, light-weight iron and preferably small gauge solder. Solder quickly and cleanly. Only apply the iron for sufficient time to cause the solder to flow around the joint. These precautions will ensure that components are not damaged by excessive heat. The unit should then be mounted in a small plastic, or metal, box.

Two different switching systems may be used to enable the alarm. Use either an external key switch mounted in a convenient, but not obviously seen location, or a two way system of concealed switches — one inside and one outside. The switch inside is used to enable the alarm (after opening the door) and the external one to disable the alarm before entering the car. This latter system has the advantage that anyone watching will not see where the external disable switch is located.
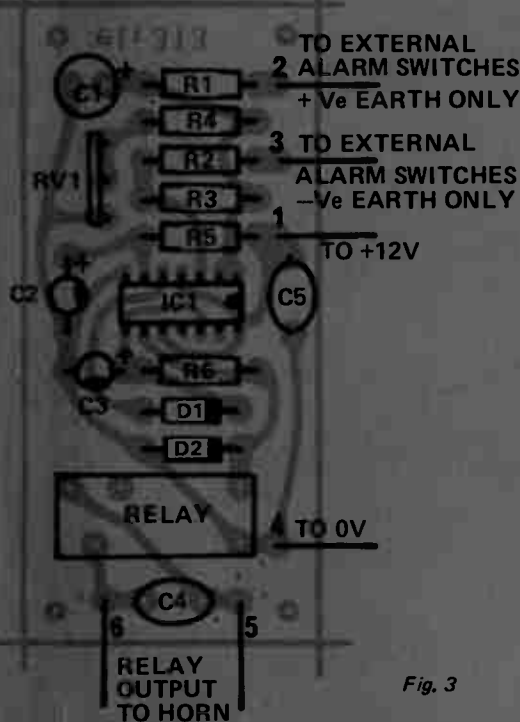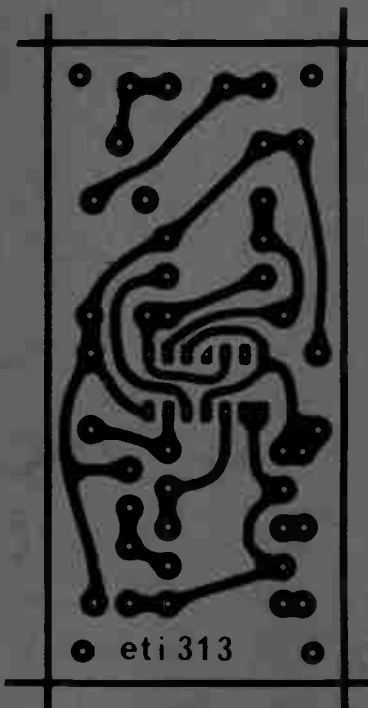
When a load, especially an incandescent lamp, is switched onto a battery the battery voltage will drop instantaneously and then return to normal. The amplitude and duration of this negative going spike in the supply is dependant on the size of the lamp used but is of sufficient amplitude, even with small globes, to trigger an alarm circuit.

The NE556 IC contains two NE555 timer IC's in a single case. One of the timer sections is used to detect the supply spike and to put on the second timer which produces a one Hz output to the relay and horn.

Each timer section contains two comparators, a LOW comparator set at 1/3 supply and a HIGH comparator set at 2/3 supply. These comparators set a flip-flop which provides an output.

When the power is first applied, the voltage at pin 6 (input to the low comparator) is initially low for about half a second while C2 charges via R5. This sets the output of the flip-flop to a high state where it will remain regardless of further excursion in the voltage at pin 6.

The only way that the output may be set low again is for the input to the high comparator (pin 2) to be taken past its threshold. This threshold voltage is available at pin 3 and by using a voltage divider (R3, R4 and RV1) a slightly lower voltage is derived from it. This is used as a reference level to the HIGH comparator input (pin 2) Capacitor C1 is used to bypass any fast transients which may appear at the input (pin 2).

If the supply falls, the voltage on pin 3 will also fall. If it falls below the voltage at pin 2, the output will fall again to a low state and will stay there. The capacitor C1 will also be discharged via pin 1.

The second half of the IC is connected as a free-running multivibrator having a frequency determined by R6 and C3, of about 1 Hz. If the output of the first stage is high, the diode D1 will force the multivibrator to lock into the low state. When the output of the first stage goes low the multivibrator is freed to oscillate.

This one hertz output switches a relay which in turn controls the horn, or any other suitable device. The diodes across the relay prevent reverse voltages being generated which could damage the IC. This must be a germanium type for correct operation.

PARTS LIST — ETI 313

R1,2	Resistor	1k ½watt 10%	D1	Diode IN914 or similar	
R3	"	10k ½watt 10%	D2	Diode OA95 (must be germanium)	
R4,5	"	100k ½watt 10%	RL2	Relay 12 volt 280 ohm coil, 6A	
R6	"	1M ½watt 10%		contacts. Associated Controls type	
RV1	Potentiometer	2.2 meg		E3201 or similar.	
C1	Capacitor	25μF 25 volt electrolytic	PC board ETI 313		
C2,3	"	1μF 25 volt electrolytic	SW1	Switch	SPST key operated
C4,5	"	0.1μF polyester	SW2,3	"	SPDT toggle (see text)
IC1	Integrated Circuit	NE556	metal or plastic box to suit.		

TO EXTERNAL
2 ALARM SWITCHES
+ Ve EARTH ONLY

3 TO EXTERNAL
ALARM SWITCHES
—Ve EARTH ONLY

1 TO +12V

4 TO 0V

RELAY
OUTPUT
TO HORN

Fig. 3

eti 313

PLEASE NOTE

When this project was originally published, some constructors experienced incorrect ON/OFF timing relay latching.

This may be caused by diode D2 in that, in some cases, it does not adequately limit the reverse voltage generated across the relay This reverse voltage may trigger the IC. This can be cured in one of two ways.

1. Replace diode D2 with an EM401 or similar. Break the track between resistor R6 and diode D2 and place a second EM401 diode across this break such that its cathode and the cathode of diode D2 are together.

2. Add a 200 ohm 1 watt resistor between the +12 volt line and the output (pin 9) of the IC.

TRANSISTOR CONNECTIONS

TRANSISTORS	CONNECTIONS
BC107	1
BC108	1
BC109	1
BC147	3
BC148	3
BC149	3
BC157	3
BC158	3
BC159	3
BC177	1
BC178	1
BC179	1
BC182K	4c
BC182L	4a
BC237	4c
BC238	4c
BC239	4c
BC307	4c
BC308	4c
BC309	4c
BC547	2
BC548	2
BC549	2
BC557	2
BC558	2
BC559	2
BD139	6
BD140	6
C30	14
C106	15
MJ802	10
MJ2955	10
MJ4502	10
MJE340	8
MJE340K	9
MJE2371	9
MJE2521	9
MJE2955	8 (K Suffix-9)
MJE3055	8 (K Suffix-9)
PN3638	4b
PN3643	4b
PN3644	4b
SC141	16
SC146	16
SC151	
TIP29	12
TIP30	12
TIP31	12
TIP32	12
TIP33	11
TIP34	11
TIP35	11
TIP36	11
TIP41	12
TIP42	12
TIP2955	11
TIP3055	11
TT800	5
TT801	5
2N2160	
2N2646	13
2N2647	13
2N3055	10
2N3638	7
2N3638A	7
2N3643	7
2N3644	7
2N5457 (MPF103)	4e
2N5458 (MPF104)	4e
2N5459 (MPF105)	4e
2N5484	4e
2N5485 (MPF106)	4e
2N5486	4e
2N5631	10
2N6027 (D13T1)	4d
2N6031	10
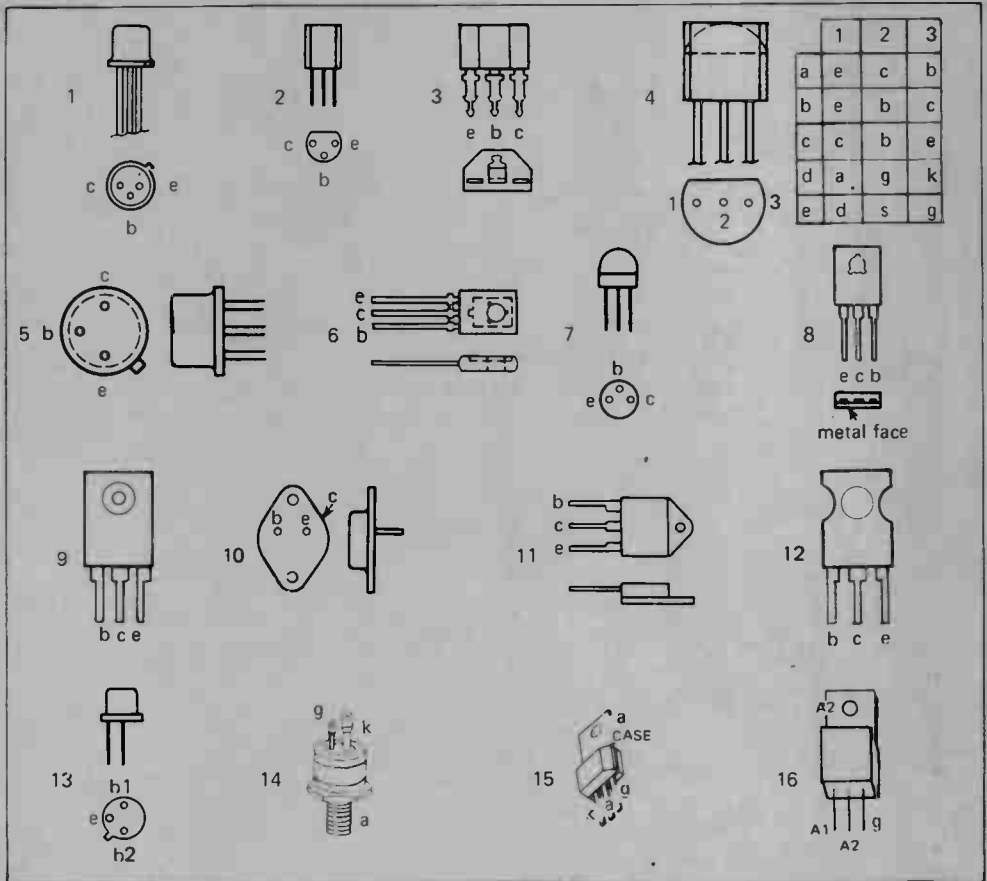
Note — Case 4 is used for various transistor configurations and the different connections are indicated in the table on the right of the case. For example, if connections 4c are indicated in the transistor list consult row c (far left on chart). The connections corresponding to pins 1, 2 and 3 are as follows, pin 1 is collector (c), pin 2 is base (b) and pin 3 is emitter (e).

Advertisers' Index

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● Handy pinjack tester for versatile rugged services.
● New mechanism has been devised to level up the
quality. ● Unique design has
been adopted for easier range
selection. ● Silicon-diode
rectifier enlarged frequency
coverage. ● Economy multitester
with high sensitivity.

DC Voltage: 10,50,250,1000 volts
AC Voltage: 10,50,250,1000 volts
DC Current: 250μA, 1mA, 10mA,
250mA
Resistance: 10 kΩ, 1 MΩ
Decibels: -10 to +62 dB

$13.69

MODEL M303 30,000Ω/V DC

● 23μA meter movement with dotted graduation scale
and a long arc mirror. ● Accurate stable AC, V
measurement can be offered by
silicon-diode rectifier which
enlarges frequency coverage.

DC Voltage: 0.3, 3, 12, 60, 300,
1,200 volts.
AC Voltage: 6, 30, 120, 300, 1,200
volts.
DC Current: 60μA, 6mA, 60mA,
600mA.
Resistance: 8 kΩ, 80 kΩ, 800 kΩ,
8 MΩ
Decibels: -20 to +17, 31, 43, 51,
63 dB.

$21.25

MODEL SK-33 10,000Ω/V DC.

● Fifteen year's production assures its quality and
usability. ● One of the finest pocket portable VOMs
with 17 ranges for repair and
service work on both electrical
appliances and industrial
maintenances. ● Easy-to-read
meter with mirror scale.

DC Voltage: 0.5, 2.5,
10,50,250,1000 volts.
AC Voltage: 10, 50, 250, 500,
1,000 volts.
DC Current: 100μA, 25mA, 250mA
Resistance: 3 kΩ, 300 kΩ, 3 MΩ
Decibels: −10 to +22, 36, 50, 56,
62 dB.

$17.54

MODEL SK-200 50,000Ω/V DC

● Wide range setting assures professional performance in
lab as well as field work. ● High internal resistance
minimises the loading effect
under test and enables it to take
more precise measurements.
● Furnished with 10A, AC & DC
ranges.

DC Voltage: 0.5, 2.5, 10, 50, 250,
500, 2,500 volts.
AC Voltage: 5,10, 50, 250, 500,
1,000 volts.
DC Current: 25μA, 250μA, 5mA,
50mA, 500mA, 10A
AC Current: 10A
Resistance: 5 kΩ, 500 kΩ, 5 MΩ,
50 MΩ
Decibels: -20 to +16, 22, 36, 50,
56 dB.

$32.26

MODEL SK-120 20,000Ω/V DC

● One of the most popular and recommendable VOMs in
our Rapar series, which features easy operation and
reliable quality. ● Silicon-diode
rectifier enlarged frequency
coverage. ● Precision instrument
for checking semiconductor
circuits. ● Applicable to
educational purposes and
industrial uses.

DC Voltage: 0.3, 3, 12, 60, 300,
1,200 volts.
AC Voltage: 6, 30, 120, 300, 1,200
volts
DC Current: 60μA, 6mA, 60mA,
600mA
Resistance: 8 kΩ, 80 kΩ, 800 kΩ,
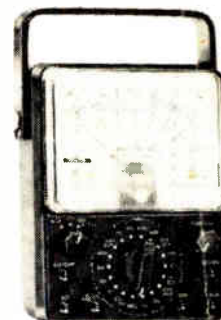8 MΩ
Decibels: -20 to +17, 31, 43, 51,
63 dB.

$20.03

MODEL SK-100 100,000Ω/V DC

● 100,000 ohms per volt DC minimises extremely the
loading effect to the circuits under test. ● The finest
bench-sized multitester provided
with laboratory accuracy and
versatile utility for electric
works and electronics field.
● Polarity reversal switch, 12A
AC & DC range and advanced
mechanism.

DC Voltage: 0.3, 3, 12, 60, 300, 600,
1,200 volts.
AC Voltage: 6, 30, 120, 300, 1,200
volts.
DC Current: 12μA, 300μA, 6mA,
60mA, 600mA, 12A.
AC Current: 12A
Resistance: 2 kΩ, 20 kΩ, 200 kΩ,
20 MΩ
Decibels: -20 to +17, 31, 43, 51,
63 dB.

$44.63.

World Radio History