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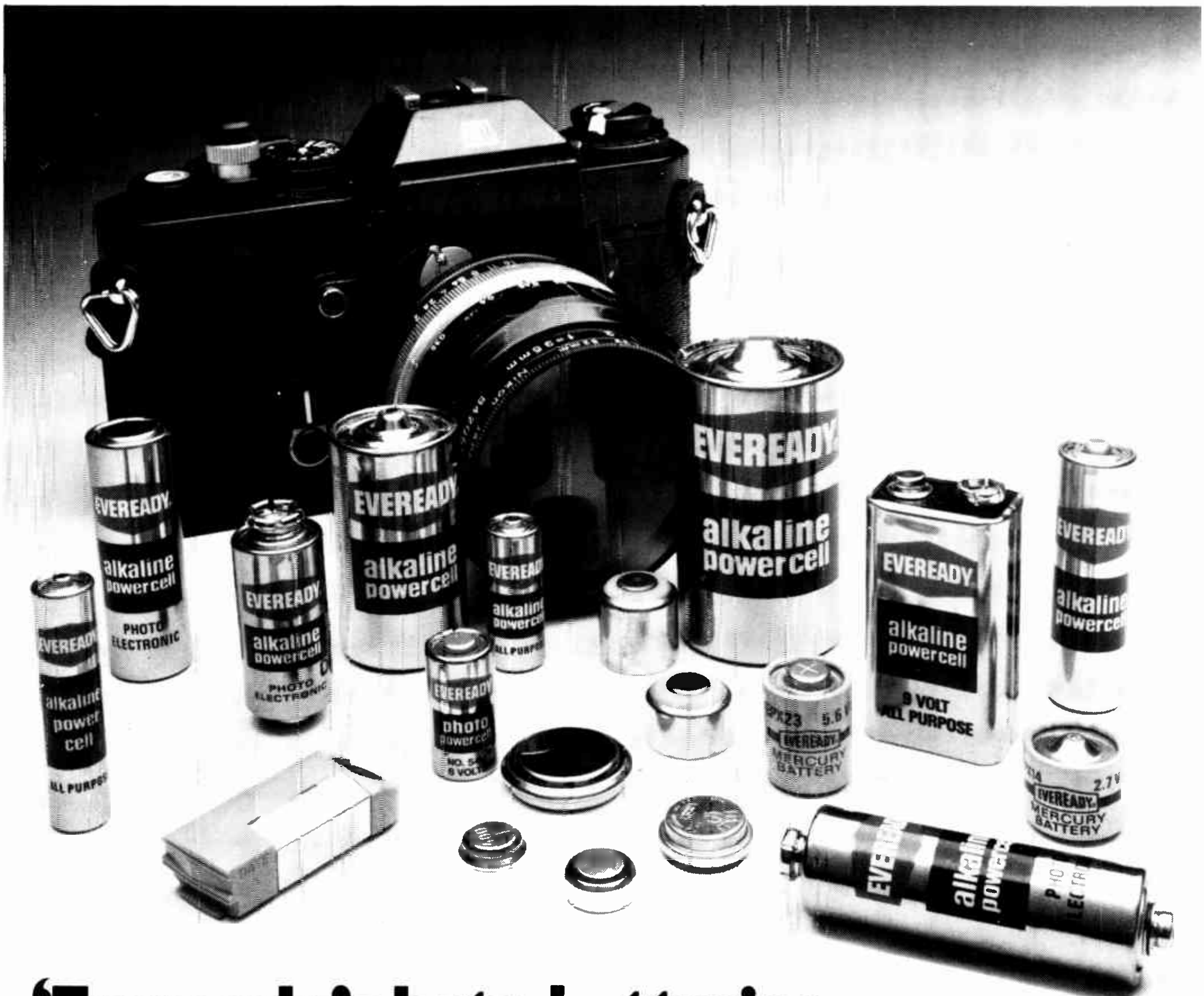
TOP PROJECTS

Vol. 6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TOP PROJECTS Vol. 6

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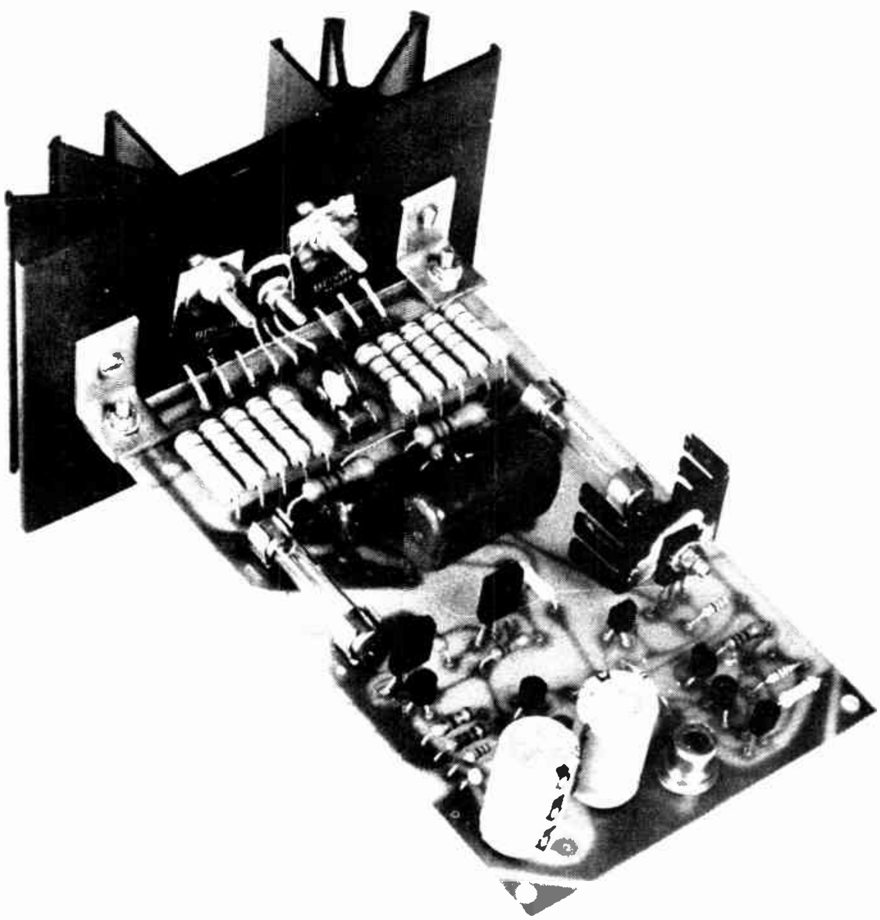
SIMPLE 60W LOW DISTORTION AMPLIFIER MODULE

The popularity of our first 50 W 'universal' amplifier modules has been very high since they were published several years ago. Since that time the state of the art has moved on. This project, designed by Phil Wait from an original circuit by Trevor Marshall, is intended to replace the ETI 480 and features simpler mechanical construction, low distortion (particularly TID) and generally better performance.



MANY DIFFERENT amplifier circuits have appeared in popular electronics magazines over the years. The most popular audio projects we have ever published were the 100 watt guitar amp. (ETI 413, published in December 72 and still going strong!), the 422 amp. and the 480 series of power amp. modules.

While these seemed to have satisfied a large demand, our attention has been drawn to the need for something a 'step up' from there — something that approaches the current 'state of the art' for hi-fi equipment. Lower distortion than previously obtained, better bass performance and flexibility was the message we received from reader's letters and kit and component suppliers ("Why don't you . . .", "What I'd like to see . . .", "I need a . . .", etc.).

Late last year we set in motion the 'wheels' necessary to bring this project into fruition. Our major design hurdles were cleared with room to spare with the assistance of talented West Australian designer, Trevor Marshall.

A great many factors place sometimes quite severe constraints on project design — particularly component availability and ease of construction; not forgetting that this design had to perform significantly better than those that came before it.

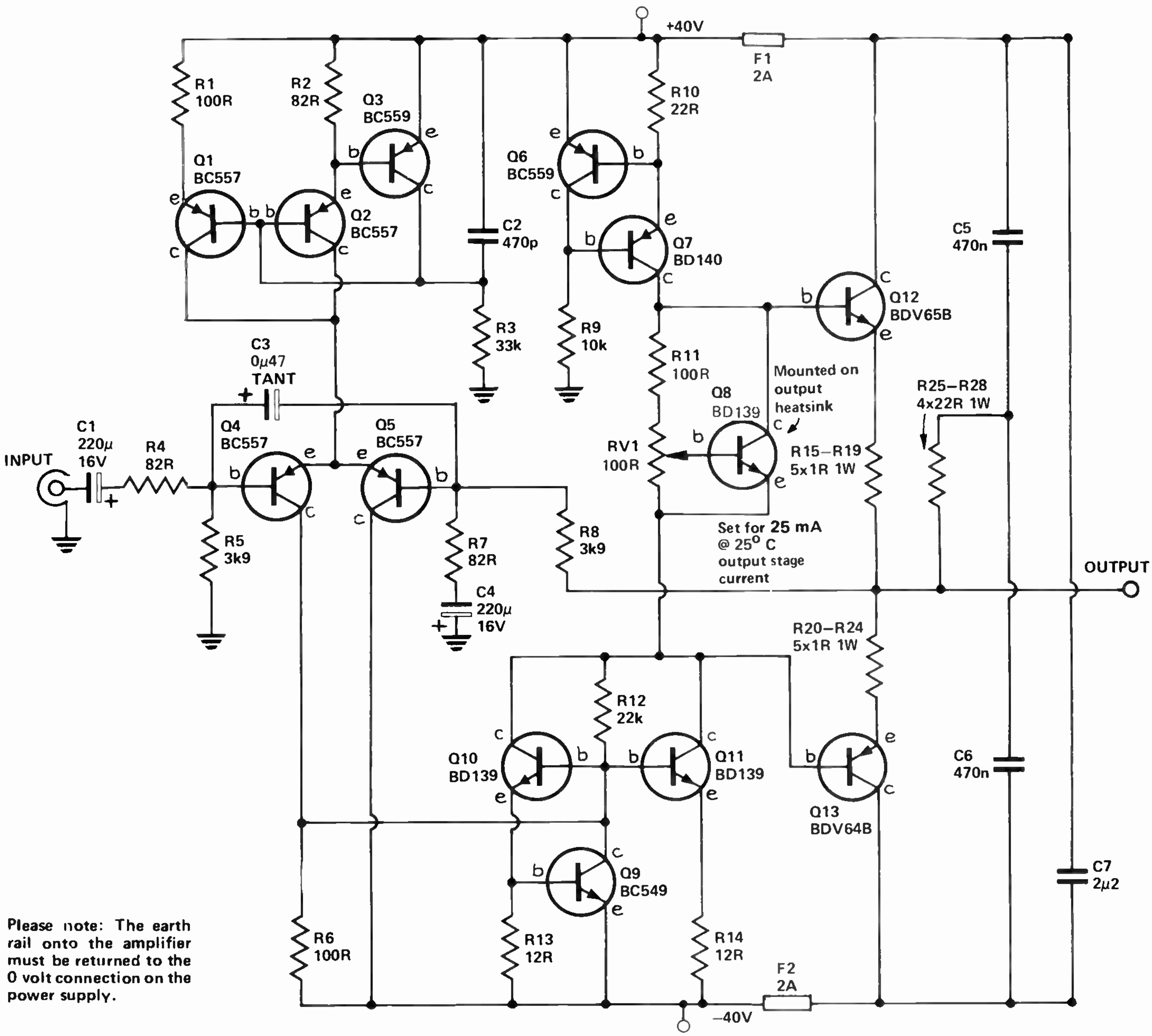
There is clearly little point in describing a project that includes components that are impossible to get or one that is difficult to construct.

A strong point that came across to us from reader feedback and from the popularity of our 480 series of amplifiers was that constructors favoured a modular concept. It seems that the days of the single-board stereo amplifier project have come and gone.

This power amplifier offers a significant improvement in specifications and ease of construction over most kit amplifiers offered to date. It has been designed particularly with low transient intermodulation distortion in mind.

Although a difficult parameter to measure, transient intermodulation distortion is an inherent characteristic of many amplifier designs — especially those which incorporate large amounts of feedback to even out frequency response and reduce harmonic distortion. The heavy feedback 'school' of design produces an impressive list of specifications — but the difference *to the ear* between such an amplifier and one designed for low TID has to be heard to be believed.

60W AMPLIFIER MODULE



Please note: The earth rail onto the amplifier must be returned to the 0 volt connection on the power supply.

HOW IT WORKS – ETI 470

The input stage of the amplifier consists of an emitter coupled differential pair (Q4, Q5) with a constant current source (Q1, Q2 and Q3). The use of a constant current source reduces distortion, as well as the possibility of high frequency oscillation and prevents any ripple on the positive supply from unduly affecting the input stage. Unequal emitter resistors (R1, R2) allow the currents in Q4 and Q5 to be optimised. Input lag compensation is provided by C3, limiting the slew rate of the amplifier to reduce high frequency intermodulation. The gain of the differential pair, driving Q10 and Q11, is very low.

Almost all the gain of the amplifier is obtained from the parallel pair Q10 and Q11. They are operated with series (R13, R14) and shunt (R12) feedback, and a constant current source (Q6, Q7). This results in a highly linear stage.

Q9 protects Q10 and Q11 from high peak currents or damage should a fault occur. When the current through R13 exceeds the safe limit, Q9 conducts and shorts out the drive to Q10 and Q11.

Bias from the output stage is set by RV1 and a shunt regulator (Q8). Q8 is mounted on the same heatsink as the output stages and stabilises the output bias current against heatsink temperature rise. Resistors R15-R24 in the emitters of the output Darlingtons, Q12 and Q13, maintain operation in their safe region as well as reducing the chance of thermal run away.

Protection against ultrasonic oscillation is provided by C7 and the network consisting of R25-R28 and C5, C6.

Both DC and AC feedback is taken from the output, via R8, to the negative input of the differential pair, the amount of feedback being set by the ratio of R8 to R7. C4 increases the feedback, and therefore decreases the overall gain, at very low frequencies. The feedback also automatically holds the DC output voltage at close to zero volts.

Choice of Power Supply

The design of the power supply can mean the success or failure of an otherwise well-designed amplifier. The supply voltage should be well-regulated, varying less than 10% from no load to full load, and be able to supply high peak currents.

However, if a voltage regulator is employed it too must be capable of delivering the very high peak currents occasionally demanded. This necessitates an expensive regulator device and large, expensive filter capacitors.

The alternative is to use a fairly large transformer and large value filter capacitors on a capacitor-input bridge rectifier. This is what we chose.

The circuit given here shows a power supply suitable for supplying a stereo amplifier using two of these modules. The filter capacitors C8 and C9 consist of two 2500 uF, 50 volt electrolytic capacitors connected in parallel. This is the minimum we would recommend.

In general, the largest value filter capacitor one can afford is a good rule of thumb! *It has been suggested to us that values as high as 20 000 to 50 000 uF makes an audible difference in performance.* (Watch the rectifier specifications though!).

Improved performance can be obtained for a modest increase in cost by having a separate supply for each channel module. This improves the regulation, reduces crosstalk and increases the amount of power available before output clipping commences.

The choice of transformer will determine power output. A 28-0-28 volt, 2 A transformer (Ferguson PF3577 or similar) will power a module to 60 watts (RMS) power output, while a 26-0-26 volt, 2 A type (e.g. Dick Smith M-0148 C-core) will permit 40 watts.

The power supply output should be limited to a peak DC voltage of about 40 volts (for 60 W output). A C-core transformer will generally improve the hum and noise output figures apart from having a reduced field, thereby reducing possible hum pickup problems.

If the amplifier module is to be used with a 4-ohm speaker system the supply voltage must be limited to about 30 volts maximum, otherwise the output devices will attempt to deliver over 100 watts followed by rapid self destruction!

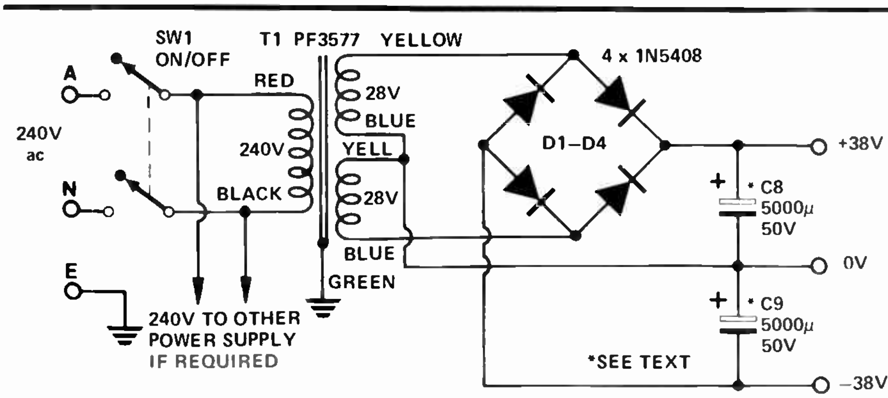
Adventurous constructors may wish to try adding a second set of Darlington output devices, with their own emitter resistors as per the circuit, connected in parallel with the original pair. This combination may supply 100 watts or more into a four ohm speaker load. This technique is also recommended if you are contemplating driving highly

ETI 470 SPECIFICATIONS

Power Output	60 watts into 8 ohms (∓40V supply)
Frequency Response	10 Hz to 100 kHz ∓0.5 dB
Input Sensitivity	500 mV rms for 60 W output
Hum and Noise	better than −110 dB on full output (dependent on power supply)
Feedback Ratio	35 dB
Distortion	at 1 kHz, 30 V p-p output into 8 ohms, Closed Loop 0.04 % (open loop 1 %)

Stability: The amplifier was found to be completely stable when operated into reactive loads consisting of R + C, L + C and pure L

Intermodulation (calculated values)	at 1kHz, 30 V p-p output into 8 ohms,
3rd order	less than 0.015 %
5th order	less than 0.0023 %
	(Intermodulation reduces with reduced power)



WHY LOW TID?

Looking at the circuit and a quick glance at the specifications, there's little in the circuit that looks outstandingly different from others. So what makes this amplifier special?

The difference in concept that makes this amplifier unique is the use of a very linear, high gain driver stage (Q10, Q11), with a constant current source (Q6, Q7), so that the gain of *this* stage is dependent upon the input impedance of the output transistors. However, *their* input impedance is dependent upon their gain, and therefore *the gain of the amplifier stage is dependent solely upon the characteristics of the output devices.*

Series and shunt feedback is used with Q10 and Q11 which results in a highly linear stage with a very low input impedance (about 28 ohms). The gain of the differential pair when fed into this low impedance is close to unity, so almost all the gain of the amplifier is concentrated in Q10 and Q11.

Provided the phase shifts in the differential pair and the gain stage are negligible the feedback loop is unconditionally stable.

There are two other design features which result in low TID.

The total open loop (feedback disconnected) distortion is only 1% at 30 V p-p output. So, very little feedback is necessary to reduce this to an acceptable level.

Protection of the output transistors is done by fuses, rather than electronically, and very high transient currents can be fed to the speaker without being affected by the (inevitably) non-linear impedance of an electronic protection circuit.

reactive loads such as electrostatic loudspeakers.

Construction

All components are mounted on a pc board – including the output devices. This method of construction is recommended. The module has been designed so that it is mechanically simple to assemble, much simpler than our ETI 480 module. Wiring errors are also avoided when a pc board is used.

Firstly, assemble and solder all the components on to the printed circuit board with the exception of Q12, Q13 (the output Darlingtons) and Q8. Carefully observe the polarity of all the electrolytic capacitors and orientation of the transistors.

The board is then mounted hard against the heatsink using small right-angle brackets. Be careful to avoid shorting the ends of the one ohm emitter resistors, R15-19 and R20-24, to the brackets.

If the module is to be mounted in a chassis the bottom (copper) side of the pc board should be 25 mm above the bottom of the heatsink. This will allow the use of 25 mm spacers to support the 'input' end of the board (furthest from the heatsink). It is expected that kits will include pre-drilled heatsinks and suitable brackets.

Once the board is attached to the heatsink the output Darlingtons, Q12 and 13, and Q8 may be mounted. Insert them in the pc board and then press them back against the heatsink to form their leads to the right shape. Do not solder their leads yet.

Smear heat conducting compound on either side of the mica insulators (don't use too much though) and insert these between the devices and the heatsink.

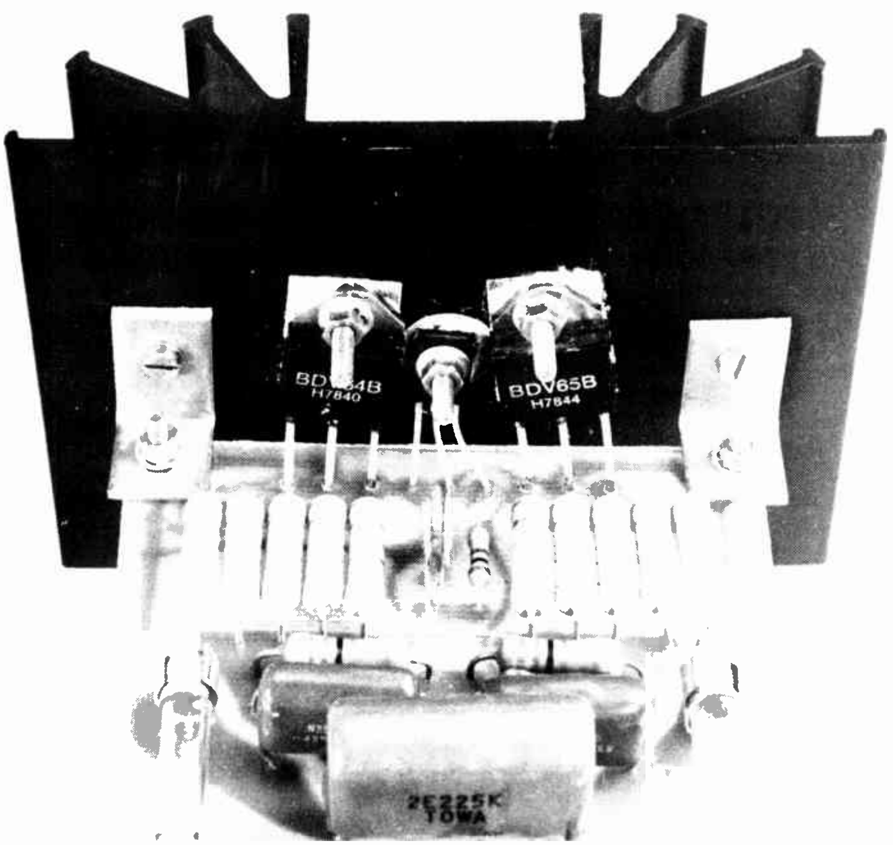
Assemble the washers and mounting bolts for these, finally checking with an ohm meter that there is not a short circuit between the metal tags(collectors) of the devices and the heatsink.

The input connection to the module is via a single-hole mounting RCA socket. This is mounted directly on the pc board. The centre pin connects to C1 via a short length of tinned copper wire.

If this facility is not required the RCA socket may be omitted and a length of shielded cable soldered directly between C1 and the pc board common.

The power supply and speaker connections are soldered directly to the appropriate copper lands on the underside of the pc board.

The 'earthy' side of the speaker must be returned directly to the zero volt connection of the power supply, as close to the filter capacitors as possible (preferably direct to the negative terminal). Do not connect this side of the speaker to the amplifier board.



PARTS LIST - ETI 470

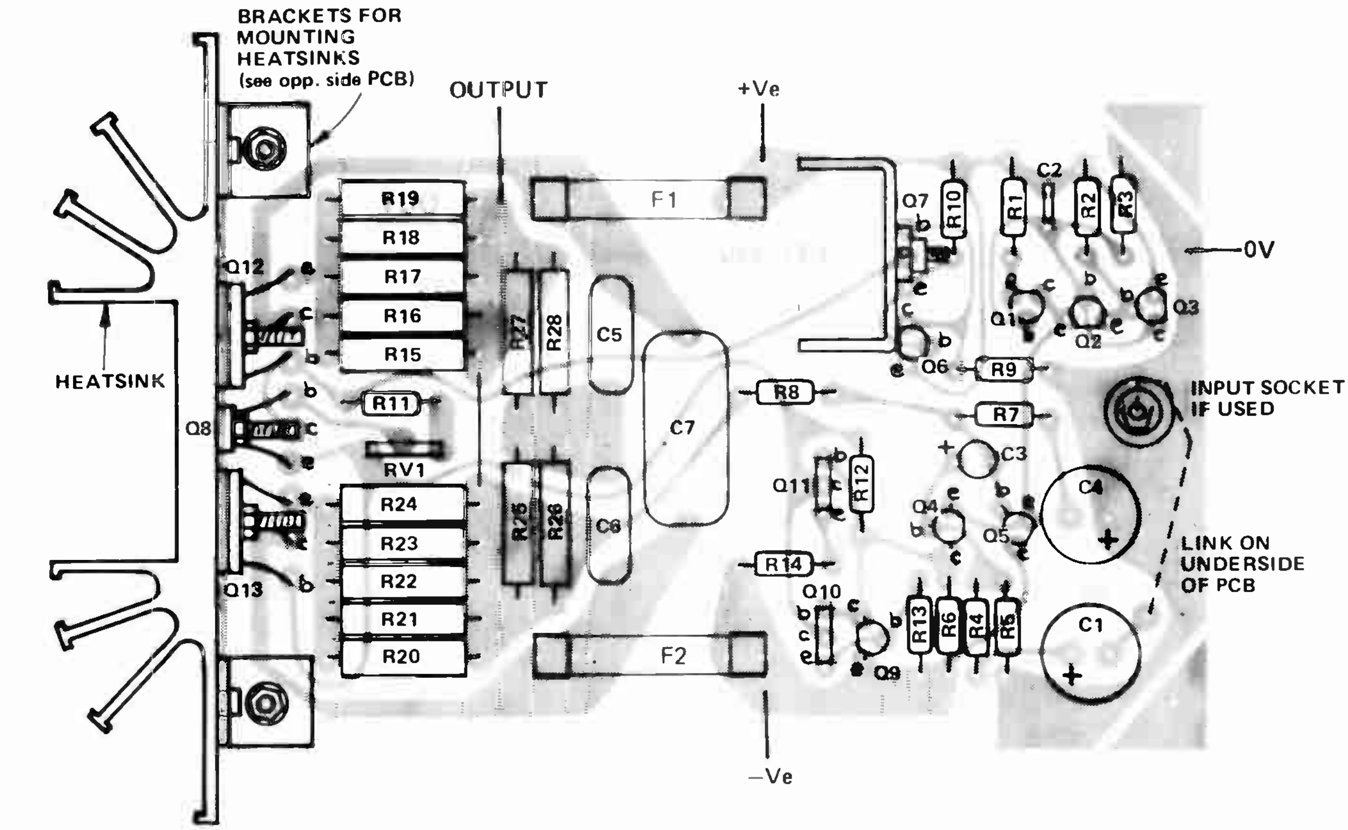
Resistors	all ¼W, 5%, except R15-R28
R1	100R
R2	82R
R3	33k
R4	82R
R5	3k9
R6	100R
R7	82R
R8	3k9
R9	10k
R10	22R
R11	100R
R12	22k
R13, 14	12R
R15–R24	1R 1 watt
R25–R28	22R 1 watt
Potentiometer	
RV1	100R mini trimpot (vertical)
Capacitors	
C1	220μ 16V electro
C2	470p ceramic
C3	0μ47 35V tant
C4	220μ 16V electro
C5, 6	470n greencap
C7	2μ2 greencap
Semiconductors	
Q1, 2	BC557, DS557
Q3	BC559, DS559
Q4, 5	BC557, DS557
Q6	BC559, DS559
Q7	BD140
Q8	BD139
Q9	BC549, DS549
Q10, 11	BD139
Q12	BDV65B
Q13	BDV64B
Miscellaneous	
SK1	single hole, panel mounting RCA socket.
F1, F2	2 Amp 3AG Fuses.

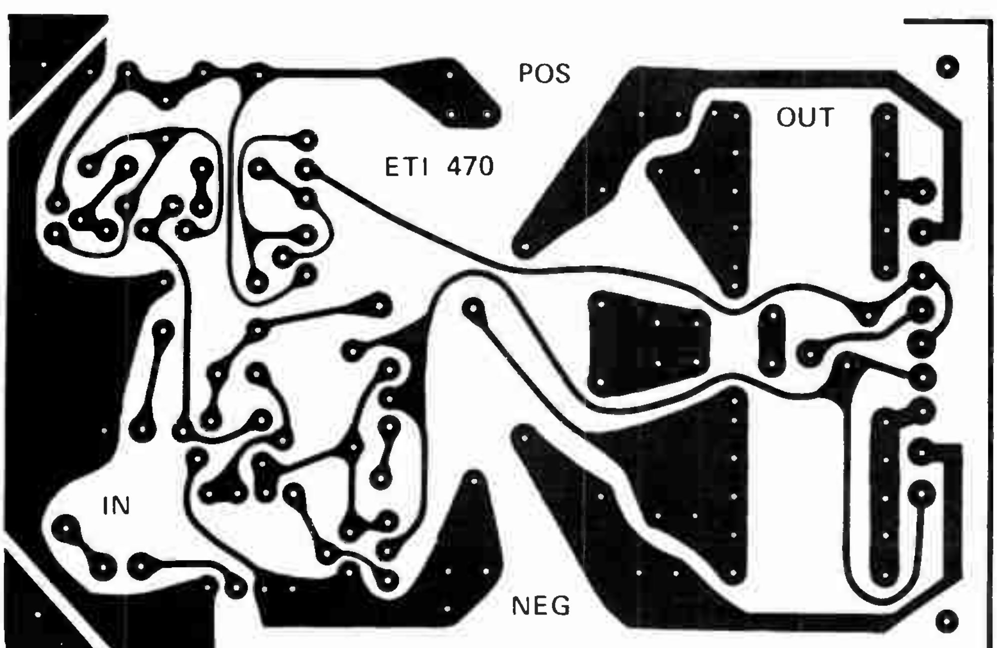
Fuse holders, heatsink for Q7, mica insulating kits (for Q8, Q12 and Q13), flat sided heatsink (75mm x 110mm), angle brackets, ETI 470 pcb.

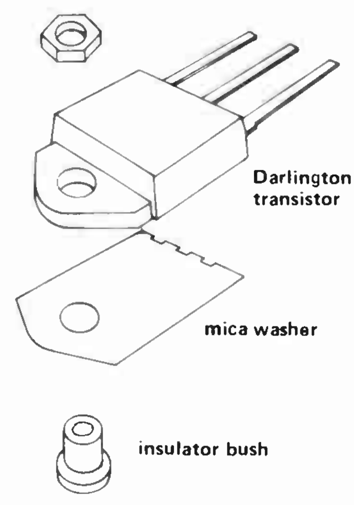
Parts List for Power Supply

D1–D4	IN5404 or sim
C8, 9	5000μ 50V electro (see text)
SW1	240V DPDT switch
T1	28V-0V-28V, 2 amp transformer Ferguson type PF3577 or similar (see text)

Left: closeup view of the output stage showing how the Darlington transistors are mounted and how the pc board attaches to the heatsink







TO220 PACKAGE
Insulator and bolt assembly diagram

▶

60W AMPLIFIER MODULE

Components

The Darlington output transistors are the only 'special' components, all others are generally available from kit and component suppliers.

The Darlington transistors are available through Silicon Valley stores at:

23 Chandos St., St. Leonards, NSW; (02) 439 2965.

380 Bridge Rd., Richmond, VIC; (03) 429 4780.

170 Sturt St., Adelaide, SA (08) 51 4080.

22 Ross St., Newstead, QLD; (07) 52 1339.

7 – 9 Kirk St., Grey Linn, Aukland, NZ; 76 11 69.

Mail Order PO Box 898, Crows Nest, NSW 2065.

Or from:

Applied Technology, 1a Pattison Ave., Waitara NSW. (02) 487 2711.

Radio Despatch Service, 869 George St., Sydney, NSW; (02) 211 0816.

It is expected that kits will also be available through these outlets.

Heatsinks

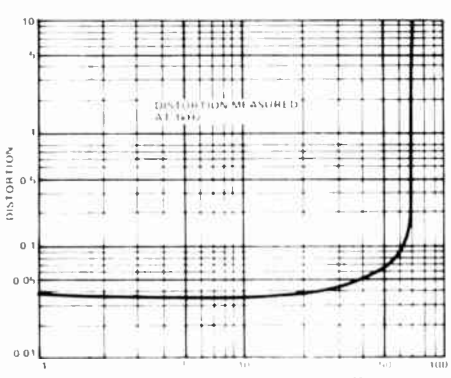
Heatsinks on any amplifier are a compromise between cost and temperature rise.

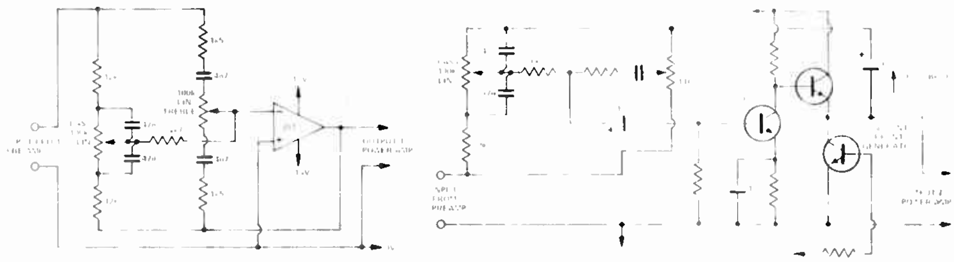
Unless you are going to play long passages of organ music, or run a disco, you will probably find that relatively small heatsinks run quite cool.

However, Darlington transistors are hard to temperature stabilise and should be run as cool as possible. This is why we have opted for a fairly large heatsink compared to otner designs. The transistors should be bolted directly to the heatsink, not through a steel chassis. A slit could be cut in a chassis large enough to slide the assembled amplifier through the rear. Heatsink fins should always be vertical to provide the most efficient convection cooling.

The heatsink recommended for the output devices in this project is a flat-sided type with radial fins, 75 mm in length. Other flat-sided types are available with straight fins, and these too would be suitable. A similar length should be used. In general the heatsink should have a thermal resistance, mounting surface to ambient, of around 1° C per watt.

A small 'flag' heatsink is attached to Q7, a BD140 flatpack transistor. A commercial heatsink may be employed (they're only about 60 cents) or a small strip of aluminium may be bent up, drilled, and bolted to the transistor. See that the metal area of the BD140 and a face of this heatsink are in contact. Heatsink compound should be used.





Two suggested tone control circuits for a preamp to suit this module. Low output impedance is an important consideration. Choice of discrete or IC circuitry is given.

Setting Up

Once the amplifier has been assembled and carefully checked, the bias current for the output devices must be set. Remove the fuses, F1 and F2 and connect a 100 ohm resistor across each fuse holder. Remove any input signal. Connect the power supplies and measure the voltage drop across each of these resistors. Adjust the trim pot RV1 for a reading of 2.5 volts across each resistor. This corresponds to a bias current of 25 mA. The reading should be nearly the same across each resistor. Next check that there is no DC voltage across the output terminals.

If the reading across each of the resistors cannot be adjusted, or if there is a DC voltage across the output greater than one volt then there is a fault and the fuses should not be inserted.

If all is well, remove the two resistors and insert the fuses. Connect the speaker and away you go.

Preamp Considerations

The input impedance of this amplifier is relatively low, falling at very high frequencies. Consequently, it must be fed from a low impedance source.

When driving the amplifier with a preamp-tone control unit, the output is best taken from an emitter follower circuit (to provide the required low source impedance) or directly from the output of an operational amplifier. In either case, it *must* be taken from the point where the output is fed back to the tone control circuitry.

Two suggested tone control circuits suitable for the application are illustrated in Figure 5. Both use a 'Baxandall' type tone control network with feedback derived from the output point.

The circuit at right uses discrete components which may suit some constructors better. The left circuit, using a commonly available op-amp, has higher distortion than the discrete circuit.

A preamp-control unit project to suit the amplifier module is described in the next article.

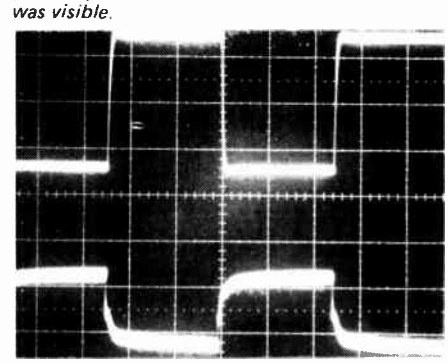
PULSE TESTING

Operation into severely reactive loads was examined by looking at the ac component of the Vbe of Q10 as a measure of the 'overshoot' of the loop and to see if transient overload occured.

f = 1 kHz. CRO is 0.2 mS/div. Output is 30 V into 8 ohms.

Upper trace 10 V/div. Output into 8 ohms.

Lower trace 10 mV/div. Vbe of BD139 gain stage. *No evidence of transient overload was visible.*



JAYCAR Pty. Ltd. — AUDIO KITS and COMPONENTS

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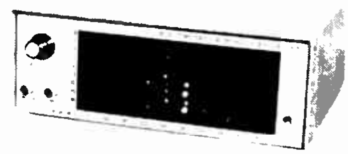
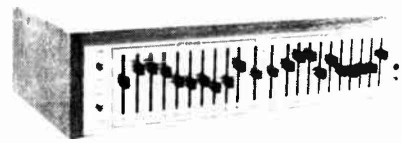


489 Spectrum Analyser

This 10 band LED display analyser can be used in conjunction with most equalisers for accurate acoustic compensation.



485 Graphic Equaliser

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- Available rack mounted

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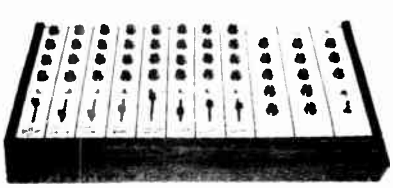
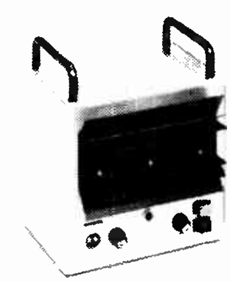


414 Master Mixer

- 8-input channels with volume, bass, treble, pan, echo send and sensitivity select
- 2-output channels with 5 stage equalisation, VU meters, overload indication, master volume, pan and echo level



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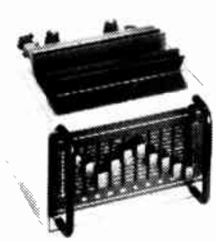

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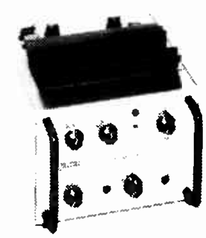

3.

480 Series Amplifiers

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2. 100W Power Slave with inbuilt Graphic Equaliser.
3. 2-input 100W Guitar Amplifier with tone controls.

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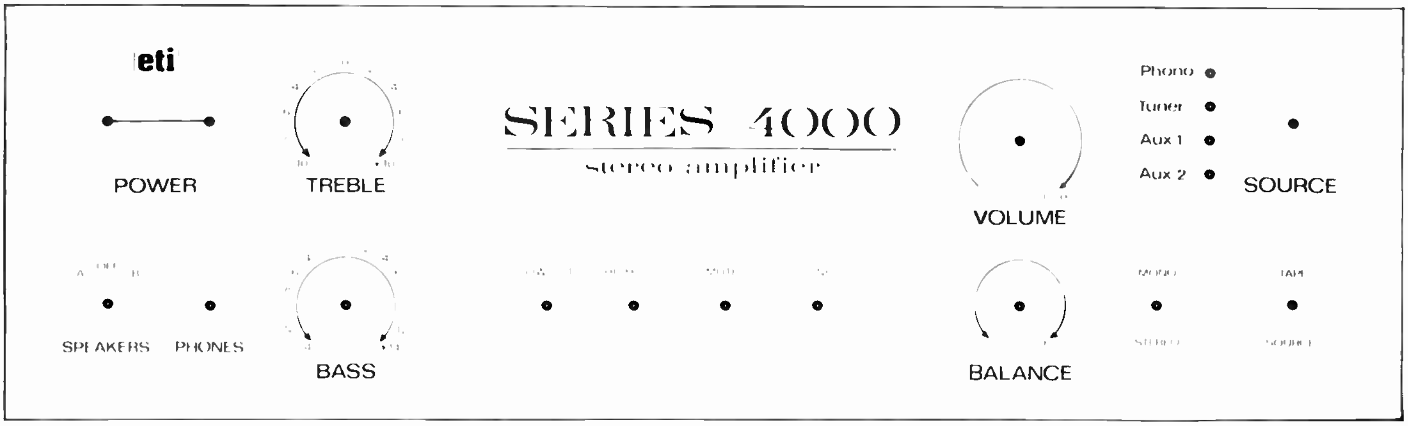
Project 471

High performance stereo preamp control unit

Phil Wait

This project is designed to complement our 60 watt low distortion amplifier module and forms part of a complete stereo system, our "Series 4000" project.



THIS stereo preamplifier is designed to drive two 60 watt, low distortion amplifier modules (ETI 470), described in the previous article.

The requirements for this preamplifier/control unit were set down after many hours of office discussion. In fact it would be fair to say that the final design was evolved, rather than conceived.

Amongst the first requirements were low hum and noise and low distortion – much lower distortion than the amplifier modules it would be required to drive. Low distortion in a preamplifier is relatively easy to achieve and makes the subsequent addition of a high quality class A headphone amplifier worthwhile.

In the final design, we feel we have achieved performance figures well up front amongst commercial equipment.

Features considered essential included loudness, high cut and low cut filters. These are common in commercial preamp/control units but lacking on most kit designs. The low cut filter incorporated in our design will effectively reduce bass rumble while the high cut filter is useful for reducing tape hiss or 'monkey chatter' and heterodynes from an AM tuner.

The disc amplifier stage of a preamp must be capable of handling very high input signals before clipping to preserve dynamic range, especially as moving coil cartridges with voltage boosting transformers and/or amplifiers are finding increasing popularity. The disc input of this design can handle 400 mV peak-to-peak before clipping, giving it a dynamic range in excess of 100 dB!

Finally, and by far the most difficult of our requirements to implement, was the idea that all switches and potentiometers be mounted directly onto the pc board, with as few links and external leads as possible. All this, while preserving an attractive and stylish front panel layout! The advantage of this is that assembly is easy, and straightforward and there is less room for wiring errors to creep in and, should it be necessary, the board can be removed for servicing in its complete, functional form. All interconnections to and from the board are via RCA sockets using standard audio 'jumper' leads.

The 60 watt power amplifier module and this preamp/control unit project form the basis of our "Series 4000" high performance stereo amplifier project (page 18).

Construction

All the components, including the pots, switches and LEDs, are mounted onto the pc board. The board is then fixed, component side forward, behind the mounting panel of the case using standard 25 mm spacers and countersunk screws. A dummy facia – with the control markings etc on it, is subsequently held in place by the switch nuts.

If all directions are followed, then construction is quite straightforward – it's easier to do than describe!

Firstly, the mounting panel and facia must be cut and drilled to the dimensions shown on the drawing (unless you have bought a kit, in which case this may already be done). The drilled pc board may be used as a template. Dimensions shown in brackets refer to the facia panel which must be cut slightly smaller if you wish to use the same case for your stereo as we have.

The holes for the pot shafts are only 7 mm in diameter on the facia panel to ensure correct knob alignment. Countersunk holes are drilled in the mounting panel, but not in the facia, for the bolts securing the pc board through the spacers.

Once the mounting panel and facia are drilled, carefully check the alignment of all holes with the corresponding holes in the pc board. The drilling must be reasonably accurate.

ETI 471 – STEREO PREAMPLIFIER SPECIFICATIONS (Measured on prototype)

Distortion	0.015% at 1 kHz 0.015% at 10 kHz (For all inputs, with 500 mV RMS output – distortion is mainly 2nd harmonic).	**Output**	7 V p-p before clipping
		Tape output	150 mV RMS
		Sensitivity	For 500 mV RMS output phono: 3 mV RMS other: 150 mV RMS (Phono overload level is 400 mV p-p).
Hum and Noise	83 dB unweighted (With respect to 10 mV phono input).		
		Tone controls	Bass: ± 13 dB at 50 Hz Treble: ± 11 dB at 10 kHz
Frequency Response	Phono: Within 0.5 dB of RIAA from 20 Hz to 20 kHz (Follows new IEC curve). Other inputs: 20 Hz to 20 kHz ± 0.5 dB Subsonic rolloff: 6 dB/octave below 20 Hz	**Filters**	High: 6 dB/octave, –3 dB at 5 kHz Low: 6 dB/octave, –3 dB at 100 Hz
		Loudness	8 dB boost at 150 Hz and 10 kHz.
		Mute switch	20 dB attenuation

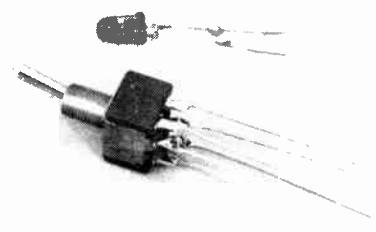
Once this mechanical work is completed the components may be mounted on the pc board. Start with the RCA sockets. Take care not to use too much force on the nuts and check that electrical contact has been made to the earth plane of the pcb using an ohm-meter. Join the centre pin of the RCA sockets to the pc board pads using lengths of tinned copper wire – refer to the overlay.

Mount the potentiometers next so that their terminals are directly above the pads on the pc board. The lower pot terminals can be cut, bent down and soldered directly onto the pads. Connect the upper pot terminals to the pc board, as shown in the overlay, using tinned copper wire.

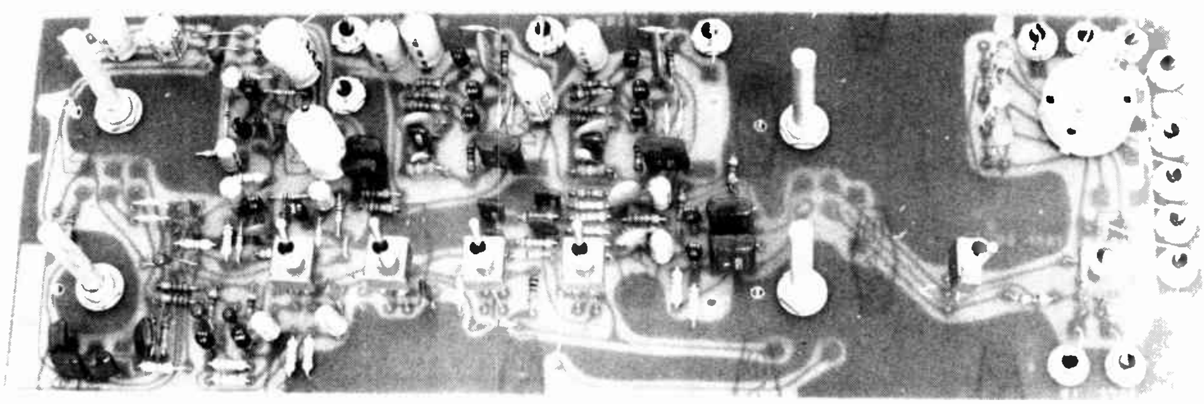
Either of two types of rotary switch may be used for the source selector. We have specified a C & K pc-mounting type but a standard rotary wafer switch may be used instead. The C & K switch mounts directly onto the pc board. If a standard rotary switch is used it will bolt to the front panel of the case and is wired in as detailed shortly.

Once the major parts are assembled onto the pc board, all the minor components may be loaded and soldered in place. Make sure that any large components (electrolytics particularly) are less than 25 mm high, otherwise they will foul the front panel. Check that all transistors, tantalums and electrolytics are correctly oriented. Refer to the overlay as you proceed.

The switches and LEDs must be mounted and spaced correctly off the pc board. Solder 50 mm lengths of tinned copper wire onto each of the switch terminals and LED leads (see illustration). Pass the wires through the ▶



Above: The switches and LEDs have lengths of wire soldered on to them so that they can be inserted into the pcb before being attached to the front panel. They can then be soldered in place. This procedure ensures that there is no strain on the joints. Below: the completed unit. Full details of metalwork will be given in a later article, in which we will describe how to use this preamp with two of the ETI 470 60W units to build a high-performance, low cost stereo amplifier.



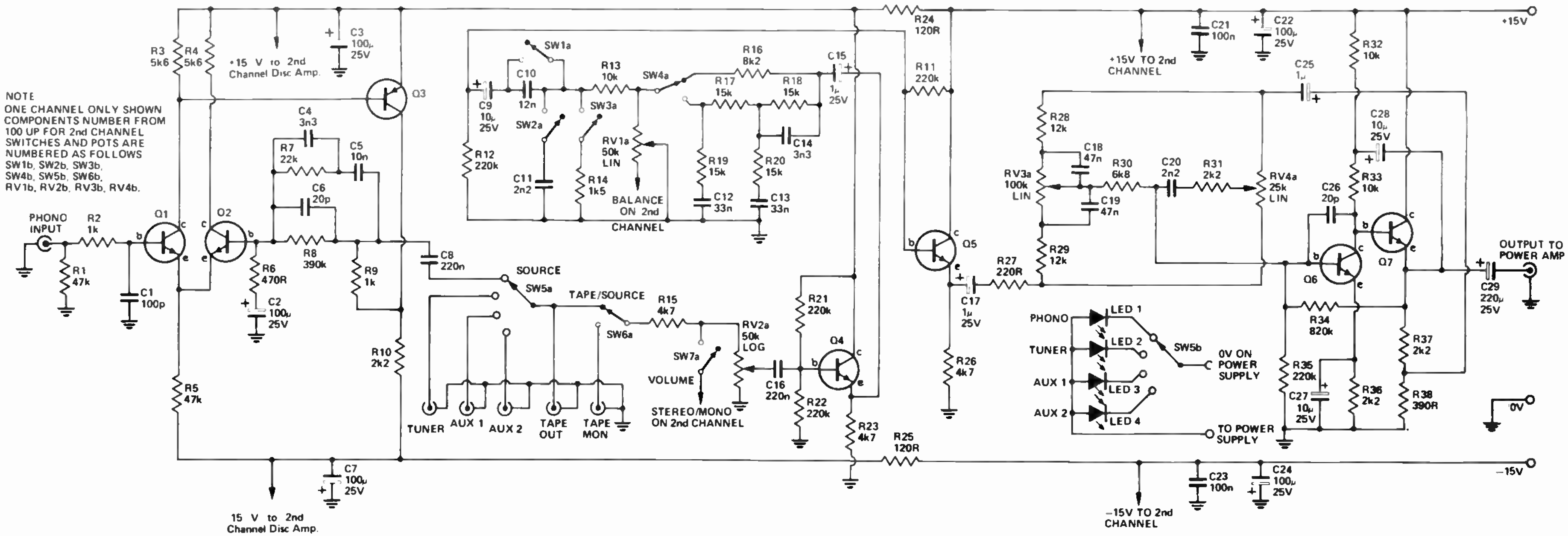


Fig. 1. Preamplifier circuit diagram. Only one channel has been shown for clarity. The component numbering of the other channel begins at 101.

HOW IT WORKS - ETI 471

The signal from a magnetic cartridge is fed to the base of Q1 via a low pass filter, (R2 and C1) for attenuation of radio frequencies. Q1 and Q2 form a differential pair, each half operating at low collector current to minimise noise. The output of the differential pair is taken from the collector of Q1 and further amplified by Q3. Feedback is taken to the base of Q2, the negative input of the differential pair, through the RIAA equalisation network. Overall gain of the phono stage is set by the ratio of the feedback network impedance to the value of R6.

Subsonic bass roll-off of 6 dB/octave, to conform to the new IEC 65 specification, is achieved by a high pass filter consisting of C8 and RV2.

Output from the disc preamplifier is then fed via the Source Switch (SW5), Tape-Source switch (SW6), R15 and the volume control (RV2), to an emitter follower, Q4. This emitter follower presents a high impedance for the aux inputs and a constant impedance for driving the filters.

When switched in, the loudness network boosts the high and low frequencies with respect to the midrange. In actual fact, all frequencies are attenuated but the midrange is attenuated more. When the loudness is switched out, R16 approximates the impedance of the network.

Muting is achieved by switching R14 to earth. The ratio of R14 to R13 sets the attenuation to 20 dB. C11 shunts high frequencies to earth for high cut, while C10 reduces low frequency content when switched in, providing low cut.

A second emitter follower, Q5, presents a constant impedance to the filters and acts as a low impedance source to the tone control stage.

A Baxandall tone stage is used here, a common circuit in many designs. Q6 is a gain stage with a bootstrapped collector load, via C28, to the output. Bootstrapping increases the gain by increasing the effective collection load impedance. Q7 is an emitter follower connected directly to the collector of Q6. This provides a very low output impedance. DC bias for Q6 is taken from tne output.

Some of the output signal is fed back to the tone controls and split into high and low frequencies by RV3 and RV4. By adjusting the controls the percentage of the input to the negative feedback signal appearing at the base of Q6 can be varied, thereby varying the overall gain of the amplifier at either high or low frequencies. The gain of the tone stage is set by the ratio of R37 to R38. As R38 is reduced in value the negative feedback is reduced and therefore the overall gain is increased.

To preserve the very low output impedance of the pre-amplifier the balance control is placed ahead of, rather than after, the tone stage.

Power supply filtering and decoupling is provided by 100 µF capacitors and resistors in each rail.

Source indication is by LEDs from the spare section of the source switch. No current limiting resistor is on the pc board for the LEDs as one will be included in the power supply. (To be described).

corresponding pc board holes for these components but do not solder them in place yet. Check that the LED leads are the right way round.

Assemble the pc board onto the case mounting panel (using the 25 mm spacers and countersunk screws). Place the facia over the front panel, securing it in place with the switch nuts (three hands and a prehensile nose might help! . . . a little sticky tape and deft juggling is all that's really necessary). Once you've got it all together the protruding wires may be soldered to the pc board. Ensure that no short circuits have occurred.

That completes the assembly. For servicing purposes the pc board and all switches, LEDs and pots — all the operating controls — may be removed simply by undoing several nuts, removing the facia and the countersunk screws beneath.

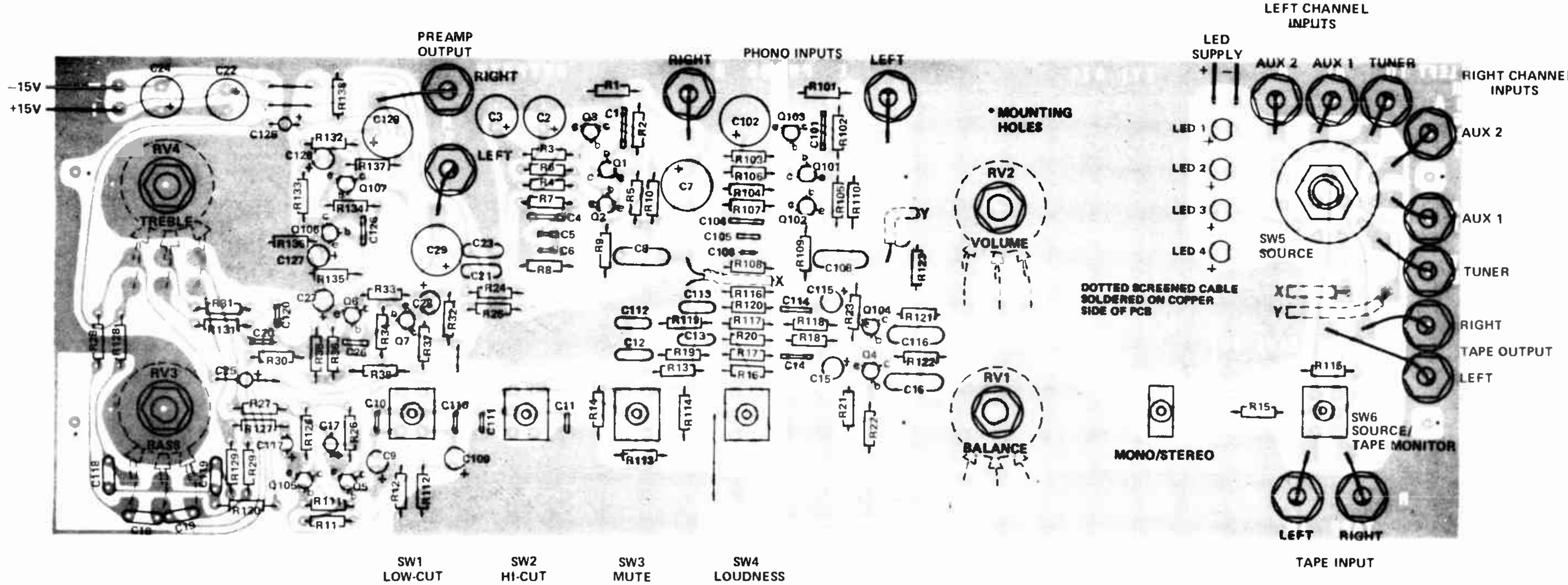


Fig. 2. Component overlay. Note that lengths of shielded cable are used to connect the outputs of the disc preamplifiers to the selector switch.

PARTS LIST - ETI 471

Resistors all ¼W 5%

R1, R101 . . . 47k
R2, R102 . . . 1k
R3, R4, R103,
R104 . . . . . . 5k6
R5, R105 . . . 47k
R6, R106 . . . 470R
R7, R107 . . . 22k
R8, R108 . . . 390k
R9, R109 . . . 1k
R10, R110. . . 2k2
R11, R12,
R111, R112 . . 220k
R13, R113. . . 10k
R14, R114. . . 1k5
R15, R115. . . 4k7
R16, R116. . . 8k2
R17 – R20,
R117, R120 . . 15k
R21, R22,
R121, R122 . . 220k
R23, R123. . . 4k7
R24, R25 . . . 120R
R26, R126. . . 4k7
R27, R127. . . 220R
R28, R29,
R128, R129 . . 12k
R30, R130. . . 6k8
R31, R131. . . 2k2
R32, R33,
R132, R133 . . 10k
R34, R134. . . 820k
R35, R135. . . 220k
R36, R37,
R136, R137 . . 2k2
R38, R138. . . 390R
R118,R119 . . 15k

Potentiometers

RV1 . . . . . . 50k single linear
RV2 . . . . . . 50k dual log
RV3 . . . . . . 100k dual linear
RV4 . . . . . . 25k dual linear

Capacitors

C1, C101. . . . 100p ceramic
C2, C3, C102 . 100μ 25V electro
C4, C104. . . . 3n3 greencap
C5, C105. . . . 10n greencap
C6, C106. . . . 20p ceramic
C7. . . . . 100μ 25V electro
C8, C108. . . . 220n greencap
C9, C109. . . . 10μ 25V electro
C10, C110 . . . 12n greencap
C11, C111 . . . 2n2 greencap
C12, C13,
C112, C113 . . 33n greencap
C14, C114 . . . 3n3 greencap
C15, C115 . . . 1μ 25V tantalum
C16, C116 . . . 220n greencap
C17, C117 . . . 1μ 25V tantalum
C18, C19,
C118, C119 . . 47n greencap
C20, C120 . . . 2n2 greencap
C21. . . . . . . 100n greencap
C22. . . . . . . 100μ 25V electro
C23. . . . . . . 100n greencap
C24. . . . . . . 100μ 25V electro
C25, C125 . . . 1μ 25V tantalum
C26, C126 . . . 20p ceramic
C27, C28,
C127, C128 . . 10μ 25V electro
C29, C129 . . . 220μ 25V electro

Semiconductors

Q1, Q2,
Q101, Q102 . . BC549, DS549, BC109
Q3, Q103 . . . BC559, DS559, BC179
Q4–Q7, Q104
–Q107 . . . . . BC549, DS549, BC109

LED1–LED4 . TIL220R or sim LED's

Switches . . . . (see text)

SW1–SW4 . . . DpDT min toggle switch
SW5. . . . . . . 3 pole 4 pos rotary switch
SW6. . . . . . . DpDT min toggle switch
SW7. . . . . . . spdt min toggle switch

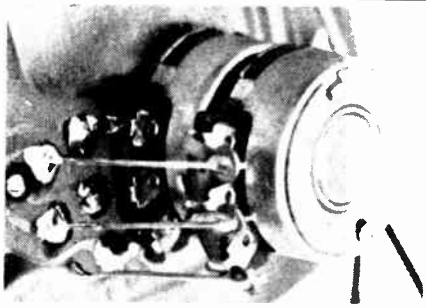
Miscellaneous

14 RCA panel mounting single hole sockets, ETI 471 pcb, tinned copper wire, length shielded cable, 25 mm spacers, 30 mm screws, nuts, mounting panel and facia plate.

Power Supply

The preamplifier/control unit is capable of giving extremely good performance – but only with a good power supply. The supply should be well regulated and filtered for noise, especially if zener regulation is used.

Our article on page 31 describes a suitable dual 12 V power supply design which will provide dc for both the 4000 preamplifier and two of the 60 W modules described in the last article.



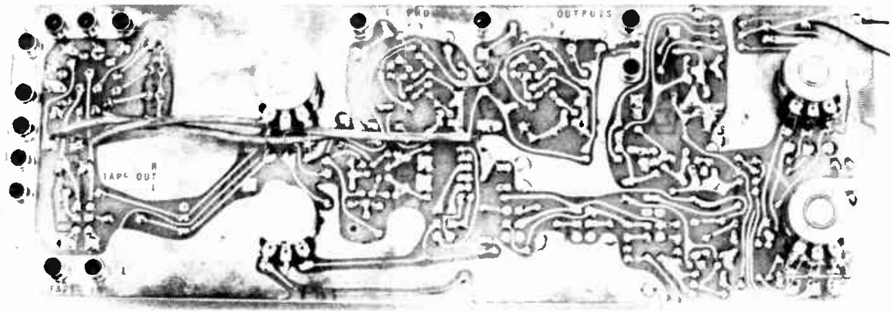
Potentiometer connections to the pcb are made via lengths of tinned copper wire.

Further Suggestions

We have designed this preamplifier to use commonly available components. However, some constructors or kit suppliers may wish to improve the appearance and the ease of construction of the project. One way of doing this is to use different switches.

The SOURCE switch which we suggest is a C & K Lorlin three-pole, four position pc mounting rotary switch. If only wire terminal models

Rear view of the assembled preamp, showing how the potentiometers and shielded cables are mounted. Note the use of pc mounting phono sockets for ease of assembly.



are available, the eyelets can be cut off and the switch mounted as if it were a pc mounting model.

C & K toggle switches may be used for the other switch functions. These are available on order with 'paddle' levers and 25 mm wire wrap terminals. The switches make the preamp look very professional and can also be directly mounted onto the pcb.

The appearance of the LEDs can be improved by using C & K Cliplite covers. These are available in a variety of colours.

C & K switches are available from:

Radio Despatch Service,
869 George Street,
Sydney 2000

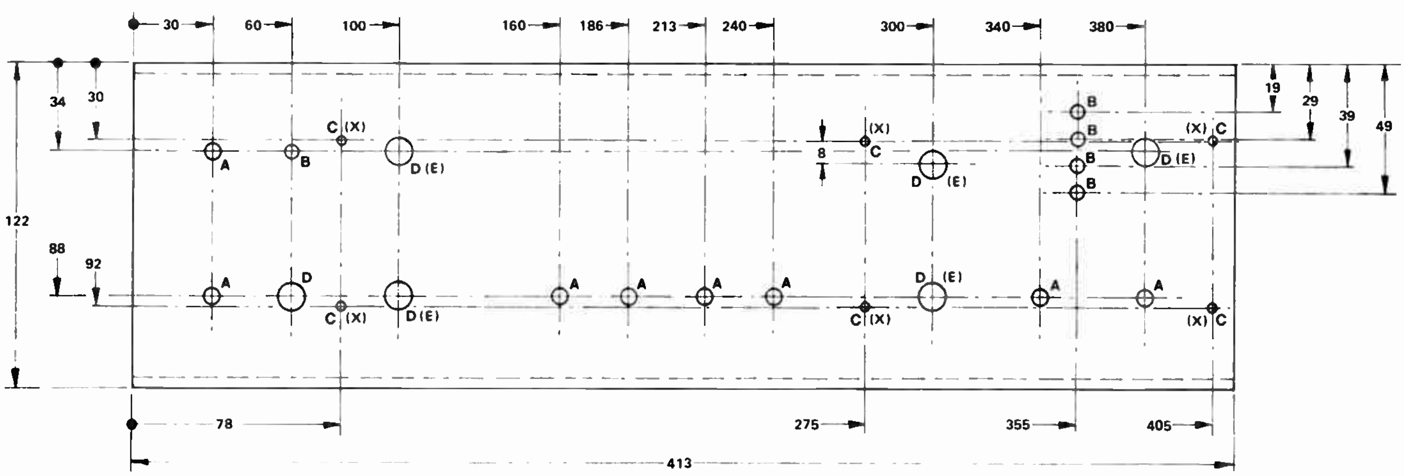
George Brown,
174 Parramatta Road,
Camperdown, NSW

JES Electronic Components,
13 Melrose Street,
Sandringham, VIC

C & K Electronics,
2/6 McFarlane Street,
Merrylands, NSW

Printed circuit board patterns for this project can be obtained from Electronics Today, 4th Floor, 15 Boundary St, Rushcutters Bay 2011. Send large stamped, self-addressed envelope.

This photo shows how the input sockets are wired into the pcb.



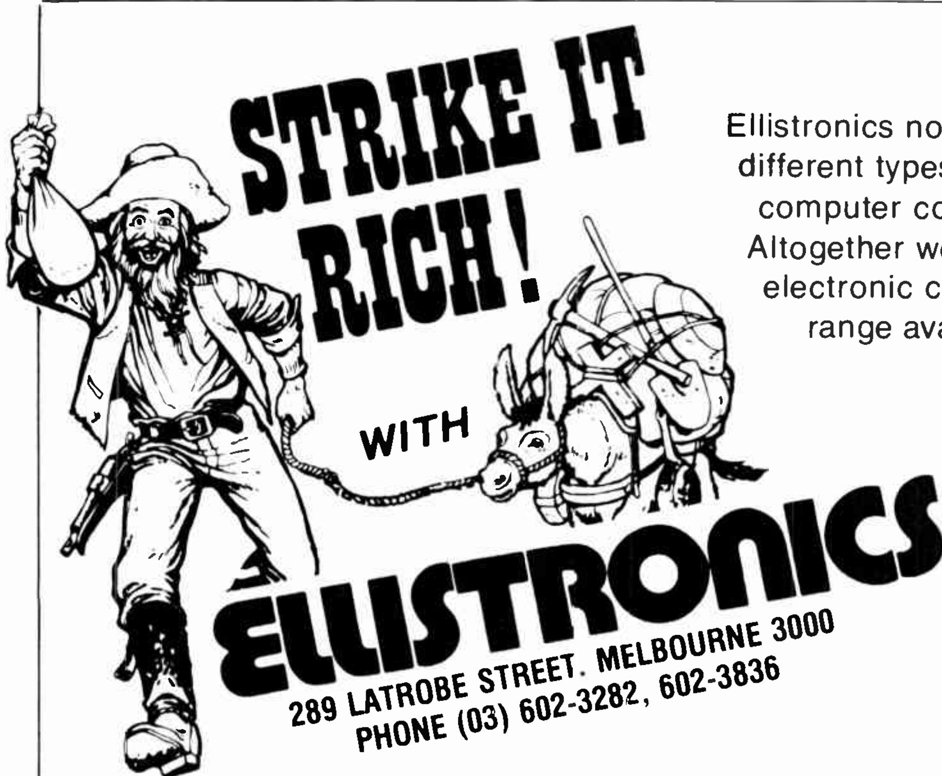
HOLES MARKED
A – 6mm
B – 4.5mm
C – 3mm COUNTERSUNK
D – 10mm
E – 7mm

HOLE SIZES IN BRACKETS ARE FOR FACIA PANEL ONLY

FOR HEIGHT OF FACIA PANEL TRIM 4mm FROM TOP AND BOTTOM OF FRONT PANEL DIMENSION. (AS INDICATED BY DOTTED LINE.)

ALL DIMENSIONS ARE IN MILLIMETRES

DO NOT SCALE DRAWING



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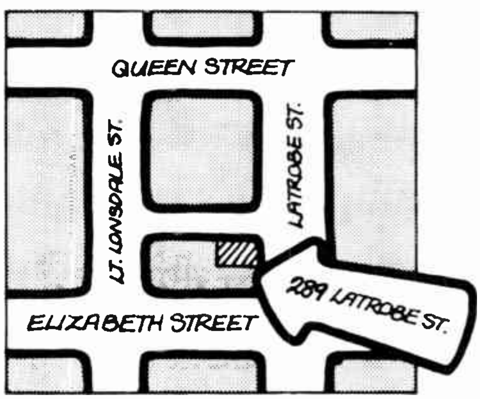

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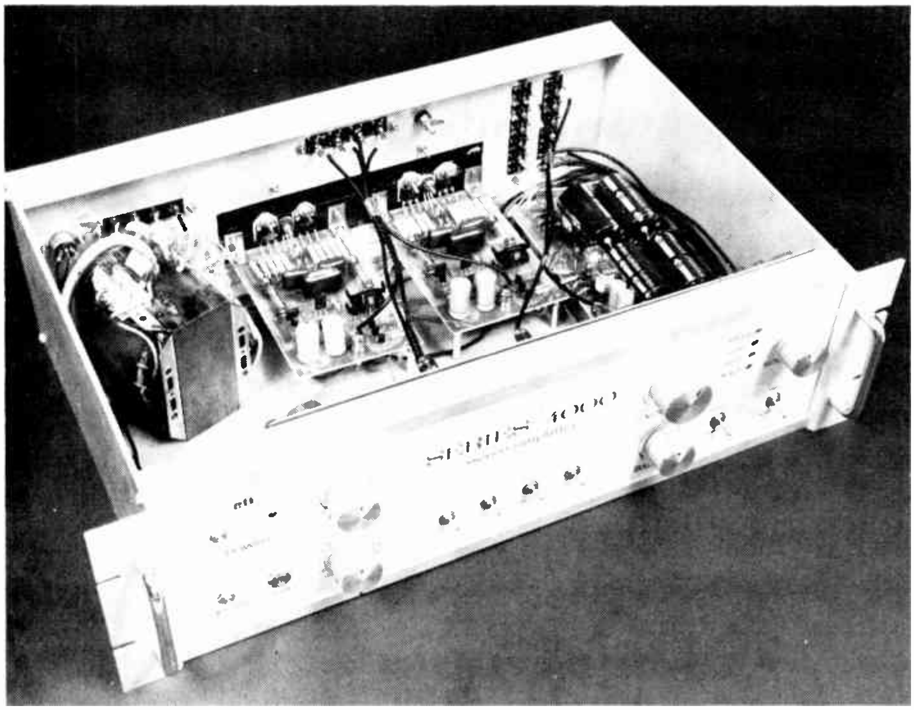
The "Series 4000" stereo amplifier

Here's how to assemble a high-performance 60 watts per channel stereo amplifier using our ETI-470 modules and the ETI-471 preamp control unit.

Circuit design
Trevor Marshall / Phil Wait

Mechanical design/layouts
Phil Wait

Front panel art
Bill Crump



The completed stereo amplifier is shown here mounted in a handsome rack-mounting case. This particular style of case is also available with wooden end cheeks if that is what you prefer.

THIS ARTICLE presents the complete Series 4000 amplifier made from the ETI 470 60 watt module and the ETI 471 preamplifier.

We chose to build the amplifier into a single box, being the most economical method as only one box and power supply is used for the preamp and both power amplifiers. However, this method has several drawbacks. Firstly, since the preamp and power amp share the same power supply, the regulation for the preamp must be very good, otherwise low frequency instability can occur, caused by the drop in supply line voltage when the outputs draw high current getting back into the preamplifier.

Hence we have chosen IC regulators for the preamplifier supply lines.

Secondly, the magnetic field from the large transformer and associated AC wiring required to supply the power amplifier modules is quite large and almost impossible to keep out of the sensitive preamp stages. Therefore you will notice that the specification for hum in the completed amplifier is lower than that of the individual units. We took this measurement using a standard EI lamination transformer (Ferguson PF 3577) after rotating it for minimum hum to the position shown in the wiring diagram.

The hum induced by the transformer can be further reduced by using a C-core

ETI 4000 SERIES STEREO AMPLIFIER — Specifications of prototype

Power output	60 watts @ 0.1% THD one channel driven 55 watts @ 0.1% THD both channels driven
Distortion	0.05% THD @ 30 V p-p output across 8 ohm load, both channels driven.
Hum	–70 dB on full output using standard transformer
Noise	–80 dB on full output
Damping factor	57 (measured at 100 Hz, 1 kHz and 10 kHz).
Frequency Response	Phono: Within 0.5 dB of RIAA from 20 Hz to 20 kHz (Follows new IEC curve). Other inputs: 20 Hz to 20 kHz ± 0.5 dB Subsonic rolloff: 6 dB/octave below 20 Hz
Tape output	150 mV RMS
Sensitivity	For 500 mV RMS output phono: 3 mV RMS other: 150 mV RMS (Phono overload level is 400 mV p-p).
Tone controls	Bass: ± 13 dB at 50 Hz Treble: ± 11 dB at 10 kHz
Filters	High: 6 dB/octave, –3 dB at 5 kHz Low: 6 dB/octave, –3 dB at 100 Hz
Loudness	8 dB boost at 150 Hz and 10 kHz.
Mute switch	20 dB attenuation

type, or better still a toroidal transformer, which have a contained field, but these are often hard to get and expensive to the hobbyist.

We feel that the specifications of the amplifier are very good, however the purist (with plenty of money) may like to do it this way:

The two power amplifier modules, together with individual power supplies using say, 30 000 uF capacitors, could be mounted in a separate box to the preamplifier, which could then be powered from the ETI 581 (June 77) regulated supply.

This would no doubt improve the power output and transient performance of the amplifier but the cost would be much greater.

Construction

Construction details for the preamplifier and power amplifiers have been described previously, all that remains is to house them together, with the power supply, in a suitable box. As we said before, many variations are possible – here is how we did it.

Assemble the power supply board first, taking care to correctly orientate the semiconductors, IC regulators and capacitors. To simplify construction we used pc pins for all terminations to the boards.

The photo of the rear panel shows the position of the input and output connections. Slots are cut in the panel for the connector blocks and a large cut running across the back panel is used to inset the power amplifier modules from the rear. Holes then must be drilled for the earth terminal, external power socket, power cord, mounting screws for the terminal blocks and holding screws for each power amplifier – which pass through the top of each heatsink fastening it to the panel.

The case measures 420 mm x 135 mm x 285 mm and is made from aluminium extrusion with easily removable panels. Available with either metal rack mounting or wooden sides, it can be purchased from suppliers listed at the end of this article.

One thing to watch though is that anodised aluminium does not conduct electricity and, after assembling the box, the various metal parts will probably not be connected to each other, causing a multitude of problems. To overcome this, strap the rear and side panels to the common earth point at the headphone jack on the front panel. (Yes, we found this out the hard way).

After the preamplifier/front panel, power amplifiers and power supply have been mounted in the box and the input/output sockets mounted onto the rear panel the unit can be wired as shown in the wiring diagram.

Common to all amplifier designs, the earth wiring is very critical. Most instability and hum problems can be traced to earth "loops" or incorrect wiring.

The common lead from each channel speaker is returned directly to the OV point on the power supply. A wire is then taken from this point and fed to one power module, to the other, and then to the preamplifier. To avoid an earth loop the braid of the shielded cables from the preamplifier to the power amplifier is not carried through the connector block on the rear panel. OV leads for the LEDs and external power are also returned to the power supply common. The common is then earthed to the chassis at the headphone socket together with the transformer shield and mains earth. This is the **ONLY** earth point onto the chassis.

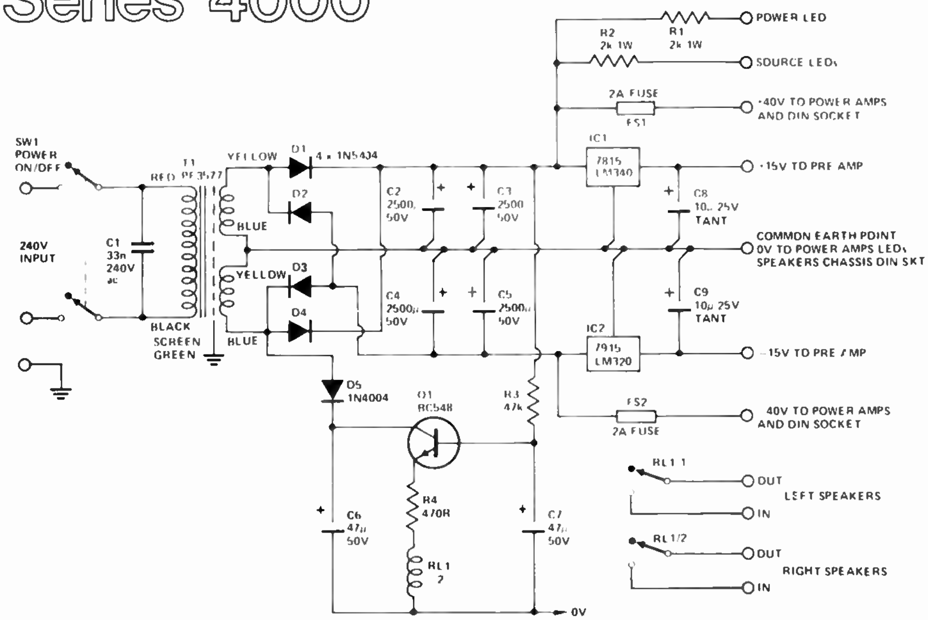
All the ac and speaker wiring is fed along the back and down the left side of the case as shown, well away from the sensitive parts of the amplifier. The dc wiring from the power supply to the preamplifier is carried along the front.

Lengths of shielded cable with RCA plugs on one end are used to connect the input sockets to the preamplifier. These can be made by cutting RCA patch cords to the appropriate length, one cord making two leads. The shields of these cables should not be connected together or to the case at the input sockets.

All that remains is to solder the 330 ohm resistors from the speaker switch to the plugs on the headphone socket.

Check that all wiring is correct and there are no frayed ends. The procedure for setting the bias current for the output transistors is given on page 10. As soon as this is done, insert the 2 A fuses and the amplifier can be switched on.

If you have the older 50 watt ETI 480 modules these could probably be used in place of the ETI 470 module, though we haven't tried it.



Power supply

The power supply for this amplifier uses a 28V-0-28V transformer rated at 2 A to provide +/- 40 Vdc rails for the power amplifiers. Two regulators, IC1 and IC2, supply very stable +/- 15 V rails for the preamplifier.

Current limit resistors are mounted on the pc board to power the front panel LEDs. This permits some flexibility to allow us to think up other things to do with the LEDs later.

Fuses are also provided on the board to protect the power supply from a short circuit in the dc output lines. If the dc output facility on the rear panel is not used the fuses can be short circuited, as each power module is protected by its own fuses.

When an amplifier is first switched on, the two supply lines rarely come up to full voltage simultaneously. This causes a loud 'thump' in the speakers which may damage them.

PARTS LIST - ETI 472

Resistors
- R1, R2 . . . . . 2k 1W 5%
- R3 . . . . 47k ¼W 5%
- R4 . . . . 470R 1W 5%

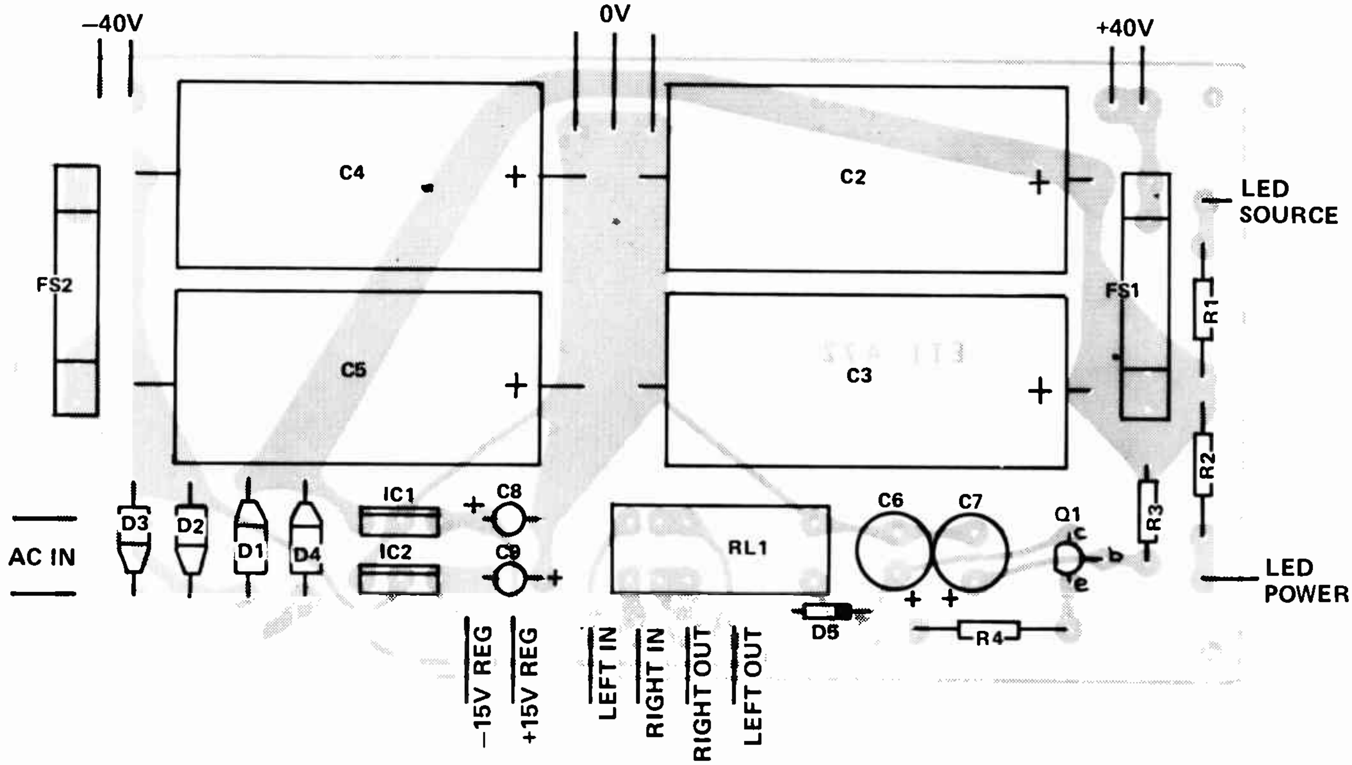
Capacitors
- C1. . . . . 33n 240V ac metalized paper
- C2–C5 . . . . . 2500µ 50V electro
- C6, C7 . . . . . 47µ 50V electro
- C8, C9 . . . . . 10µ 25V tantalum

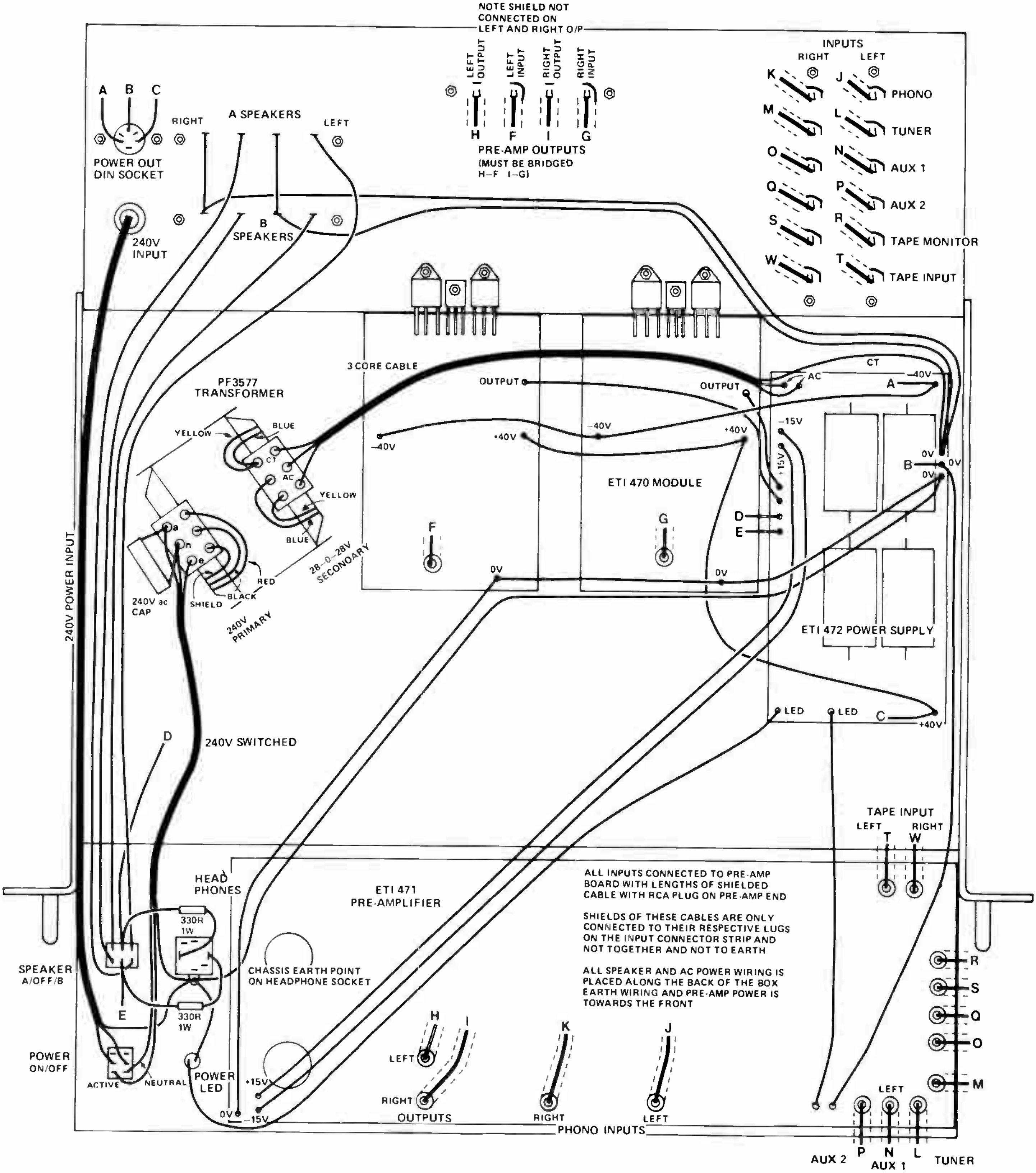
Semiconductors
- D1–D4. . . . . IN5404 or sim
- D5 . . . . IN4004, A14A or sim
- Q1 . . . . BC548, BC108, DS548
- IC1 . . . . 7815, LM340-15, 15V regulator
- IC2 . . . . 7915, LM320-15, -15V regulator

Miscellaneous
- T1. . . . . PF3577 or similar (Ferguson)
- FS1, FS2. . . . 2 amp fuses (if used)
- RL1. . . . . . . pcb mounting, 2 pole changeover relay, 12V coil, Pye 265/12/G2V, DS cat S7130 or sim
- SW1. . . . . . . 2 pole 240 VAC miniature toggle switch.

CHASSIS PARTS LIST

- Headphone socket . . . 6.5 mm jack skt.
- Speaker switch . . two pole, two position, centre off min. toggle switch
- 16 RCA plugs or eight patch leads cut in half, two short RCA patch leads, power lead and clamp.
- Two, 330R, 1W resistors
- Two, 3-way plastic mains terminal strips
- Two, 4-way speaker terminals
- Two, 6-way RCA panel sockets
- One, 4-way RCA panel socket
- One, 5-pin DIN socket





To avoid this an "anti-thump" circuit connects the speakers several seconds after the amplifier is turned on.

It works this way; as the power rails come up to voltage a capacitor, C7, charges via R3. Transistor Q1 conducts pulling in the relay, RL1, and connecting the speakers after the power rails have had enough time to stabilise.

The printed circuit board pattern for this project is on page 158.

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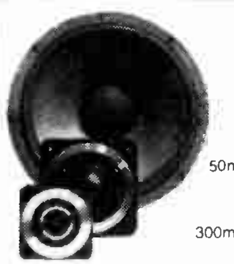

AD70601/WB
178mm (7")
Lower Midrange

AD02160/SQ8
Squawker
(AD02161/SQ8)
50mm (2") Midrange

AD12250/WB
300mm (12"0 Woofer)
100 watts RMS

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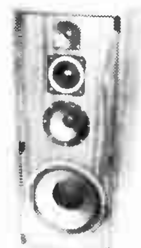

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FANTASTIC ETI "SERIES 4000" AMPLIFIER

Series 4000 Amp: with rack mount metal case as used by ETI — with wooden sided case (same as metal but no flange or handles — if special "C" core transformer required add extra $10. This kit contains absolutely everything build this high performance amplifier (equal to some commercial mps around $600). All that's required is your labour and time and you could be saving up to $400 or more!

This kit includes the two ETI 470 modules, ETI 471 high performance stereo preamp control unit. ETI 472 power supply case, front panel and all necessary wiring and hardware to make this kit the most professional you have ever built. We can say this with complete honesty as we have made up a kit to demonstrate. With each set of instructions for the ETI 4000 we have included a two page insert on "How we constructed our ETI 4000" with hints and advice you wouldn't normally find in kit instructions.

"THE BRUTE" — develops 300 watts into 4 ohms, 200 watts into 8 ohms

COMPLETE KIT FOR ETI 466 300 WATT AMPLIFIER MODULE (less heatsink and power transformer), exactly as described by ETI including heatsink bracket, all nuts, bolts, silicon grease etc.

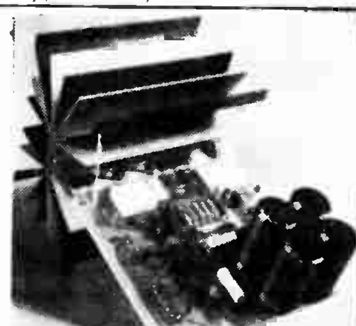
HEATSINK FOR ETI 466 AMP. This can be done in two ways as mentioned by ETI i.e. you can make your own out of aluminium (which is not as easy as it looks and is very critical), or you can buy the PHILIPS 65D6C HEATSINK for $29.50. (NB this is the only commercial heatsink available in Australia that is recommended.

FAN is also available if required for $29.00.

TRANSFORMER to suit ETI 466 amplifier. All parts for ETI 466 are available separately. ETI 466 Printed Board MJ15003, MJ15004.

CASE FOR AMP. We have three cases suitable for the ETI 466 (all un-punched). ETI 4000 Amp Case (wooden sided) Dick Smith Rack Mount.

ETI 466. See ETI Feb 80. The most powerful amplifier ETI has had to date, at minimal cost compared to assembled units.



ETI 471 HIGH PERFORMANCE STEREO PRE-AMP CONTROL UNIT KIT

Designed to complement 60 watt ETI 470 modules, but is such an exceptional design it can be used to update existing systems or incorporate in new designs, as it has features unheard of in other pre-amp designs, eg all connections through RCA sockets and controls going direct to PCB. Everything designed for very very low distortion.

KIT incl hardware etc. (Front panel included — only in complete kit)

"THE MINICOLOR"

Music to light converter kit.

VERY ECONOMICALLY PRICED

FEATURES

- One control operation
- Quality P.C. fibreglass board
- P.C. board ready assembled & pre-tested
- No soldering needed
- Assemble in ½ hour with simple tools
- Very simple to follow instructions

(Dimensions 160x 100x 125mm)

SPECIFICATIONS.

Input sensitivity 500mV Lamp load up to 1800 WATTS. Present frequency division Bass 15 to 250Hz, middle 250 to 1200Hz, treble 1200 to 5000Hz.

It will suit almost any audio amplifier — you don't have to be technically inclined to get the machine working as all the hard part has been done for you and is completely guaranteed. Coloured 100w spot floods B.C. — red, green, yellow, blue. Standard base for lamps. Swivel base for lamps.

INDUCTION BALANCE METAL DETECTOR

A really sensitive design operation on a different principle rom that of other published circuits. The "induction Balance" metal locator will really sniff out hose buried coins and other items of interest at great depths (depending on the size of the object). Here's real value — why pay a fortune to find a fortune — absolutely everything supplied except for a broom handle for shaft and former for coil. (Full instructions included).

STOP PRESS:
SPECIAL TOROIDAL TRANSFORMER NOW AVAILABLE OR 4000 AMP.

60 WATT LOW DISTORTION AMPLIFIER MODULE ETI 470

Complete 60 watt amplifier kit (as used in ETI 4000 kit). Absolutely everything including heatsinks and all hardware. Features very low distortion and very simple mechanical construction (replaces ETI 480). Can be used to replace existing amplifier modules and bring your present system up to scratch.

ETI 472 POWER SUPPLY KIT

Complete set of parts, including all hardware, as for this exceptional power supply. With standard power transformer. With special "C" core transformer.

All components are available separately for ETI 4000 Amplifier
• ETI 470 PCB • ETI 471 PCB • ETI 472 PCB • BDV64B • BDV65B •Washers and brushes for BDV64?65B (set of 4) • Wooden sided case • Metal case •Silk screened front panel

150 WATT VALVE AMPLIFIER

AFTER MANY ENQUIRIES FROM CUSTOMERS AND MUSICIANS, ELECTRONIC AGENCIES HAVE PRODUCED A KIT FOR THIS VERY VERSATILE & RUGGED AMP (DESIGNED BY ETI — MAY '80). COMPLETE KIT IS NOW AVAILABLE FOR A SURPRISINGLY LOW PRICE. (COMPLETE KIT INCLUDES ABSOLUTELY EVERYTHING TO CONSTRUCT AMP — ALL ELECTRONIC COMPONENTS, CASE, HARDWARE ETC. (N.B. EXPANDED ALUMINIUM COVER NOT SUPPLIED)

MAIL ORDER: $1.00 plus 5 percent of order value up to $80, thence a flat $4. Heavy items sent "freight-on" through carrier

At first we tried mounting the power supply board in front of the transformer near the preamplifier, but found the proximity of the speaker wiring to the tone control stage caused high frequency instability if the treble control was advanced. The power supply board is now mounted at the opposite side of the case to the transformer and the ac secondary wiring run across the back.

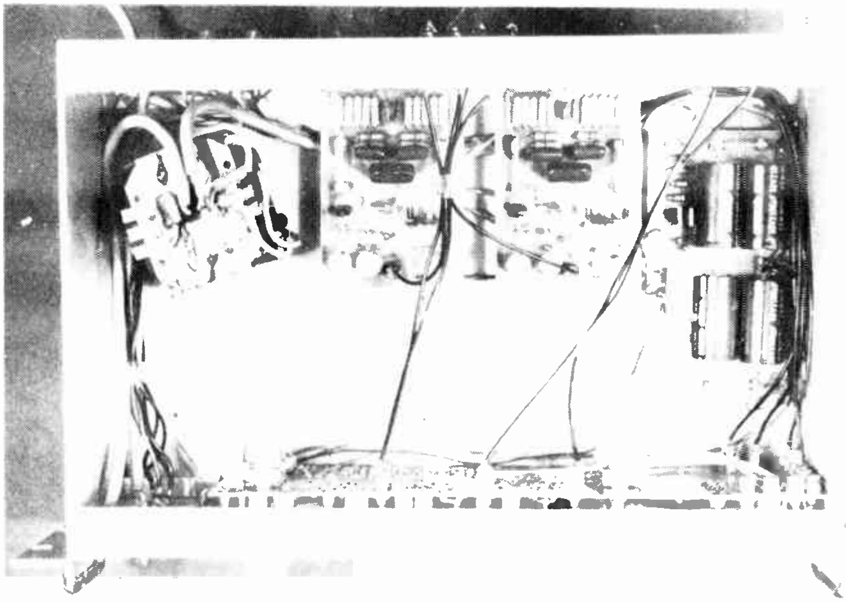
Two three-terminal connector strips are mounted on top of the transformer, using the holes in the mounting plates, to take primary and secondary connections. The shield (green wire) makes up the third wire on the primary side and is run together with the 240 V wiring to the front panel. We used three-core mains flex for connections from the transformer to the power switch and the power supply pc board. A suppression capacitor (C1) is mounted across the transformer primary on the connector block.

Make sure that the power switch you have is rated for 240 Vac, as some being sold are only 125 Vac rated and sometimes fail catastrophically.

Short patch leads will have to be made up to connect each of the preamplifier outputs to their respective power amplifier inputs.

Suppliers

The following suppliers have informed us they have all special components used in this project.



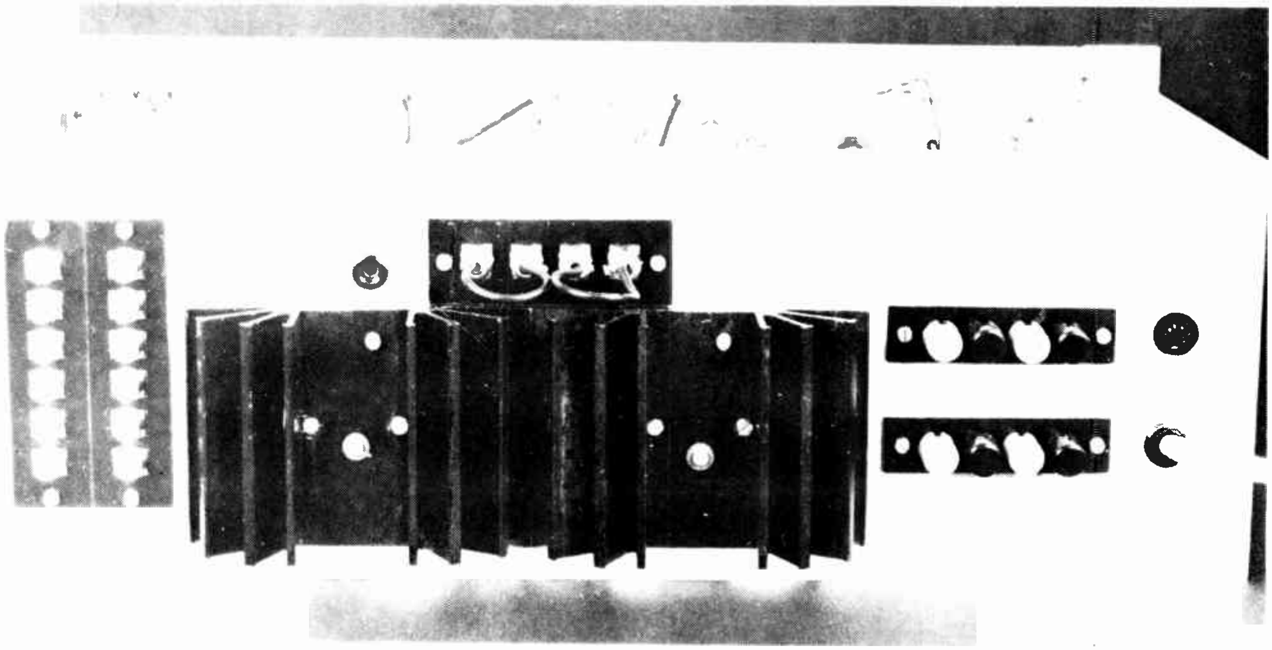
This internal view shows the placement of the main modules and the orientation of the power transformer. The latter will have to be oriented individually to reduce hum levels to the minimum obtainable.

NSW:
- Applied Technology, Hornsby
- DR Hi-Fi and Electronics, Dee Why
- Electronic Agencies, Concord
- Jaycar, Sydney
- Radio Despatch, Sydney
- Silicon Valley, St. Leonards
- Mode Electronics, Botany

Victoria:
- All Electronic Components, Melbourne
- Ellistronics, Melbourne
- Rod Irving Electronics, Northcote

Power Darlington Transistor Equivalents

Owing to the large demand for the Philips Darlington transistors used in the 60 watt power modules they may be temporarily hard to get as new orders take a few weeks to arrive. Texas Darlingtons TIP 142 and TIP 147 appear to be the same and we have tested them in the circuit without any change in performance.

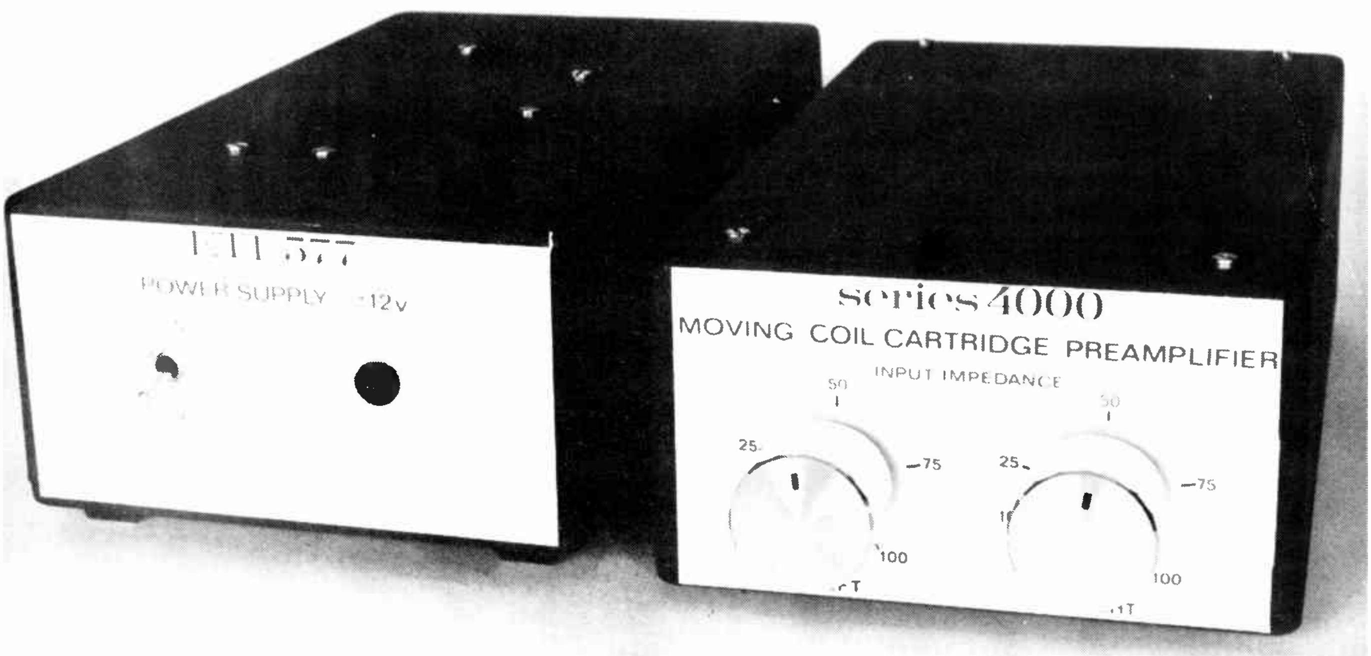


Project 473

Series 4000 moving-coil cartridge preamplifier

David Tilbrook

Designed to complement our popular Series 4000 stereo amplifier, this project features performance equal to, or better than, top quality commercial preamps currently available.



OVER THE LAST several years there has been a dramatic increase in the number of moving coil cartridges released. The design of this type of cartridge results in a number of advantages over the more usual phono cartridge which works on a moving magnet principle.

Modulations on the wall of the record are tracked with a diamond stylus attached to a long arm called a cantilever. In the moving-magnet cartridge a small magnet is attached to the cantilever so that stylus movement causes movement of the magnet. Two pick-up coils are mounted close to the magnet so that the windings of the coils intersect the lines of magnetic flux from the magnet. As the stylus moves the magnetic flux seen by the pick-up coils varies in direct proportion to the stylus movement, and small electrical signals are generated in the coils.

The moving-coil cartridge works in a similar way but inverts the roles of the pick-up coils and magnet. The magnet assembly is held stationary while the pick-up coils are mounted on the cantilever assembly and move with the stylus modulations (hence the name 'moving coil').

The pick-up coils are reduced drastically in size and weight compared to the coils used in moving magnet cartridges. This results in a total cantilever weight that is much smaller than in the typical moving magnet cartridge. Since the weight is greatly reduced the ability of the stylus to react to transients is increased and an overall improvement in signal accuracy results. Moving coil cartridges generally have superior frequency response characteristics and improved phase response at high frequencies. But they also have disadvantages.

The small pick-up coils have a very low impedance resulting in much lower signal levels than available from normal phono cartridges. In fact, the voltages present on the typical moving-coil cartridge at a recording velocity of 10 cm/sec can be in the order of 150 μV! This is generally insufficient to drive an amplifier to anything like full power. Furthermore, since the output level is some 30 dB below that expected by the amplifier then a great reduction in the signal-to-noise ratio will result. An amplifier with a short circuit signal to noise ratio of 80 dB for example, which is quite a good figure, will end up with a signal noise ratio of about 50 dB – which is distinctly *bad*.

The internal impedance of moving-coil cartridges is around 5 ohms and to achieve the low recommended load impedance required it is clearly not satisfactory to simply load down the input of the average phono input with a resistor since this does nothing to overcome the signal-to-noise ratio problems.

The solution to these problems is to insert some voltage gain between the output of the cartridge and the phono input. This can be done in two ways. Firstly, it is possible to use a transformer to boost the voltages up to the desired level and they are capable of very good results. But, transformers are still limited in transient performance and noise. To obtain the necessary voltage gain the turns ratio must be relatively high. Since the impedance ratio is related to the square of the turns ratio, the output impedance must, of necessity, be high also – usually around 30 k for a 50 Ω input impedance. This is substantially higher than the output impedance of normal phono cartridges and degrades the noise figure of the phono input stage. A solution to this is to use a pre-preamplifier instead of a transformer to achieve the necessary voltage gain.

SPECIFICATIONS – ETI 473 moving coil cartridge preamp.

Gain	28 dB (x 25 approx).
Frequency response	29 Hz to 48 kHz ±1 dB.
Input impedance	Adjustable 3.3 to 100 ohms.
Noise	Total equivalent input noise 0.3 nV$\sqrt{}$Hz. Over a 20 kHz noise bandwidth—42nV. Signal-to-noise ratio, with respect to an input level of 150 μV: -71dB.
Total Harmonic distortion	With respect to an input level of 0.2mV, unmeasurable (below noise). Calculated to be 0.0015% (see text). Rising to 0.015% for a 30 mV input signal at 1 kHz.
Channel separation	Better than 61 dB.
Input overload margin	better than 80 dB.

Preamp requirements

Preamplifiers have their disadvantages also. The biggest problem by far is the design of an extremely low noise input stage with the correct input impedance to load the cartridge according to the manufacturers' recommendations. The distortion must be kept to a minimum and the frequency response should be as flat as possible. These design goals are not unique to a moving coil cartridge preamplifier but they are difficult to achieve owing to the very low output voltage of the moving coil cartridge.

The required low input impedance can be achieved in several ways. Firstly, we can make the input stage a common base configuration. In this type of circuit the input is connected to the emitter of the transistor so that the input impedance is determined by the emitter resistor in parallel with the base-emitter junction of the input transistor, which can be quite low. However, this does not solve the problem of input stage noise.

The other possibility, and the one I elected to use in this design, is common emitter configuration. The impedance of the base-emitter junction of a bipolar transistor is a function of the amount of current flowing in the emitter of the transistor. This will be largely determined by the collector current and not by the base current, which will contribute only a small amount of the total emitter current. A study of base-emitter turn-on characteristics shows that the impedance of the base-emitter junction is approximately equal to:

$$\frac{26\beta}{I_e\ (\text{mA})}$$

where 'β' is the small signal current gain of the transistor.
and 'I_e' is the current in the emitter of the transistor in mA.

So, to reduce the input impedance of the first stage it is simply necessary to increase the emitter current. But this increases the current density in the input transistors, increasing the noise generated by the input stage.

To understand why this happens it is necessary to look more closely at the causes of noise.

Noise

There are two main sources of noise in transistors: shot noise and I/f noise. Shot noise is the main cause of noise at middle and high frequencies and is generated when an electron attempts to cross a potential barrier. It is therefore directly related to the amount of charge flowing in the device. More specifically, it is given by the equation:

$$\overline{I_s^2} = 2qi_{dc}B\ (\text{amps})^2$$

(mean shot noise current)

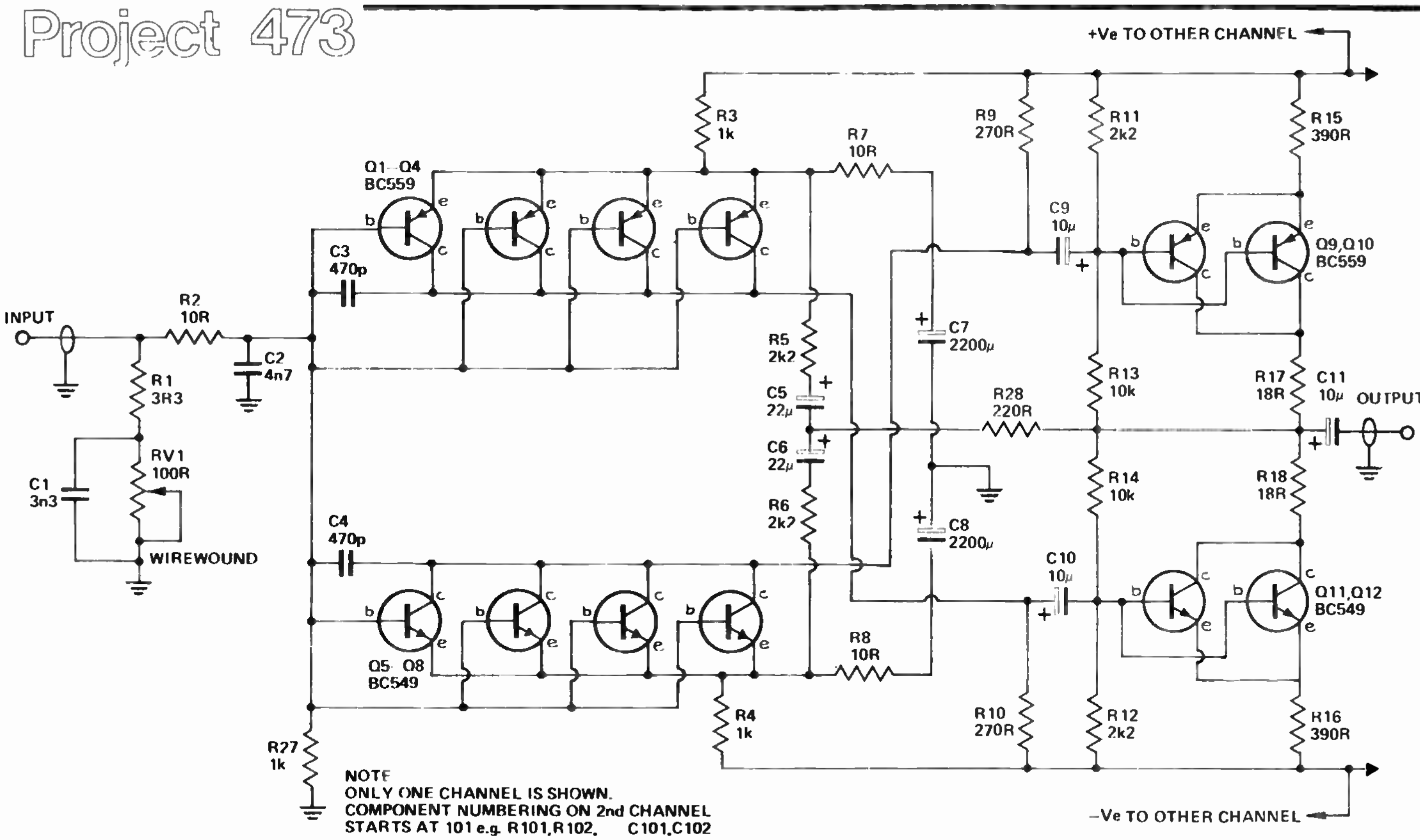
where 'q' is the charge of an electron, in coulombs
'i_{dc}' is the dc current in amps
and 'B' is the noise bandwidth in Hz.

1/f noise has a random amplitude like shot noise but its spectral density has a 1/f characteristic. This means that the noise amplitude increases as frequency decreases and becomes the dominant source of noise at low frequencies. As with shot noise, its equation reveals that it is directly related to the current flowing in the transistor.

$$\overline{I_f^2} = K\frac{(I_{dc})^a}{f}B$$

where 'I_{dc}' is the dc current in amps
'K' and a are constants that are a function of the particular device
f' is the frequency in Hz
and 'B' is the noise bandwidth.
Notice that as I_{dc} is increased, so too is the 1/f noise (I_f^2)

It is clear from this that, in order to keep noise generated by shot and I/f noise to a minimum, it is necessary to keep the current density in the input stage low. But, as we saw earlier, to obtain the necessary low input impedance we have to increase the emitter current. The solution to this is to use several transistors in parallel to form the input device. This decreases the current density in each of the transistors since the necessary emitter current can be shared by all of the input devices. It also places the impedances of the base-emitter junctions in parallel, further decreasing the input impedance of the first stage. Furthermore, since each transistor is a completely independent noise generator their noise voltage will tend to reduce each other (a process too complex to examine in detail here).



HOW IT WORKS – ETI473

The input stage consists of Q1 to Q8 plus associated circuitry. Q1 to Q4 and Q5 to Q8 are in parallel to reduce the current density providing a low input impedance stage having very low noise. A detailed account of how this works is given in the text.

Capacitor C1 and C2 fix the upper frequency roll-off characteristics as well as shunting the input with the desired load capacitance for the moving-coil cartridge. The configuration of R1 and R2, C1 and C2 was found to give the best loading for a variety of moving-coil cartridges.

The potentiometer RV1 allows the input impedance to be varied over the range most commonly recommended by cartridge manufacturers.

Negative feedback is applied via the network consisting of R28, capacitors C5 and C6 and resistors R5 and R6. Some degenerative feedback for the input stage is applied to the first stage by the emitter resistors R7 and R8. Capacitors C9 and C10 are coupling capacitors to the second stage while bias for this stage is determined by R11, R12, R13 and R14.

The power supply consists of a series regulator Q13 and Q14. The potential dividers R21/R23 and R22/R24 divide the voltage present at the output of the regulator and drive the transistors Q15 and Q16, and the LEDs. The transistor base-emitter junction in series with the LED will drop 0.6 + 1.65 volts. Therefore, whenever the voltage present at the centre of the potential divider tries to increase above 2.3 volts the transistor increasingly, conducts decreasing drive to the pass transistors Q13 and Q14.

This is a relatively low noise regulator since the voltage reference is LED and not a zener diode which is a noisy device. Resistors R19 and R20, together with capacitors C12 and C13 form 6 dB per octave low-pass filters on the supply rails to further reduce noise that may be generated by the regulated supply. . .

This configuration works very well and the noise levels of this preamplifier rival any of the commercially available units.

To see just how difficult it is to obtain a satisfactory signal to noise ratio at these signal levels it is necessary to look at another form of noise called 'thermal noise'. This is caused by the agitation of charged particles in any conductor due to their temperature. Every passive component will generate thermal noise and short of dunking the whole thing in liquid helium to cool it off, there is simply no way of getting rid of it. Thermal noise is given by the equation:

$$\overline{e_R^2} = 4kTRB \text{ volts}^2$$

where 'T' is the temperature in degrees Kelvin (K).
'R' is the value of the resistance.
'B' is the noise bandwidth
'k' is Boltzmans constant, equal to 1.38×10^{-23} W-sec/K.

From this equation we can calculate the theoretical noise that will be generated by the moving coil cartridge itself. This clearly is the absolute lowest noise figure that is possible with the input stage generating no noise of its own (which is very unlikely!).

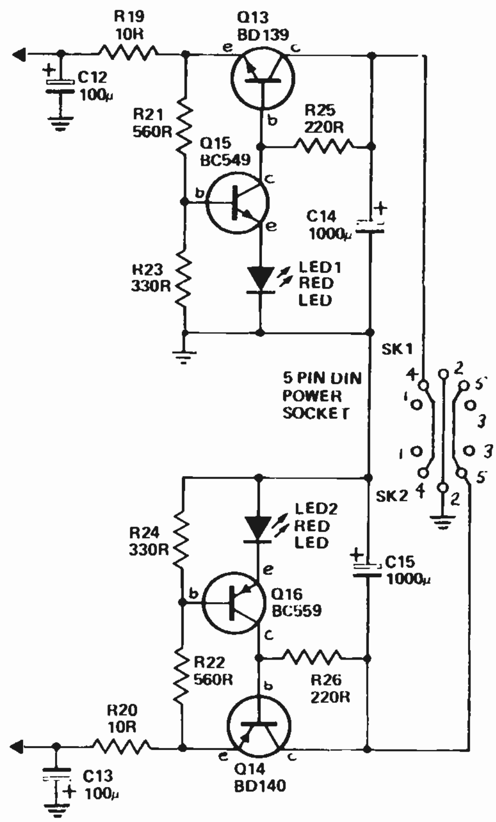
If we let the temperature of the transistor be 300 Kelvin (i.e.: mean atmospheric temperature) and the noise bandwidth be 20 kHz (the hi-fi audio band), then since the dc resistance of the cartridge is about 5 ohms the equation becomes:

$$\overline{e_R^2} = 4 \times (1.38 \times 10^{-23}) \times 300 \times 5 \times (20 \times 10^3)$$

Therefore $\overline{e_R} = 4.07 \times 10^{-8}$ volts or 41 nV.

So, the thermal noise of the cartridge itself is 41 nV.

Actually, this calculation is not quite right since the noise bandwidth is defined as having a 'brick wall' response. An amplifier with 3 dB point of 20 kHz that is falling at a rate of 6 dB per octave will actually have a noise bandwidth much greater than 20 kHz. Furthermore, if we want to be able to quote noise figures to enable comparison between different input stages, it is valuable to quote noise voltages independently of noise bandwidth. This can be done quite easily by dividing the noise voltage by the square root of the bandwidth. The dimensions of this new figure will be "volts per root Hz",



and our result for the thermal noise of a moving coil cartridge becomes:

$$\frac{41}{\sqrt{20\,000}} \ \text{nV}/\sqrt{\text{Hz}}$$

or 0.29 nV/√Hz

Now, if we are aiming at a signal to noise ratio of 70 dB with respect to a signal voltage of 150 nV (0.15 mV), which is the expected signal level at a recording velocity of 10 cm/sec., then the equivalent input noise of the amplifier will be given by the equation:

$$-70 = 20\log\left(\frac{N}{0.15\times10^{-3}}\right)$$

and is equal to 0.33 nV/√Hz.

The necessary equivalent input noise is in the same order of magnitude as the noise being generated by the cartridge itself!

Designing an input stage with this sort of noise isn't easy, especially when it is considered that the noise generated by even the quietest transistor is in the order of several nV/√Hz for usable emitter current. This is substantially worse than the requirement.

Performance features

The total equivalent input noise of this unit was measured at 0.3 nV/√Hz. With respect to a noise bandwidth of 20 kHz, this corresponds to an input noise of 42 nV, giving a signal to noise ratio with respect to an input signal of 150 nV (0.15 mV) of 71 dB. At this level, the noise generated by the cartridge itself will be one of the dominant noise sources.

The circuit uses a symmetrical configuration with NPN and PNP transistors set up in such a way that asymmetrical distortions tend to cancel. Normally distortion products are generated differently for positive and negative signal excursions and this tends to produce second harmonic distortion products. The configuration used in this circuit results in very low second and third harmonic distortion. This has enabled a total harmonic distortion figure of around 0.0015% to be obtained.

The problem with quoting distortion figures of this order is that they are too low to be measured directly, being well hidden under the noise level. The only way a figure can be obtained is to remove the overall negative feedback, measure the distortion and then divide by the gain difference when the feedback is reapplied. Unfortunately, feedback does not affect all the distortion products equally, but the figure is still meaningful.

Another advantage of the symmetrical design of the input stage is that it does away with the need for an input capacitor. This is a definite advantage when dealing with low input impedances since the value of the capacitor would have had to be very large to obtain a flat frequency response at low frequencies.

The signal voltages present in the preamplifier are naturally extremely low and for this reason the power supply has been kept as a separate unit to reduce the possibility of 50 Hz induction from the power transformer.

A voltage regulator supplies the necessary ±6 volts. As it is critical to achieve low noise it is important that the regulator does not put noise onto the supply rails which would degrade the noise performance of the unit. Normally the voltage reference used for regulators of this type is a zener diode but, as the zener is reverse biased, it generates a comparatively large amount of noise. In this design an LED was used as the voltage reference. A red LED operated in the forward-biased mode drops a constant 1.65 volts and generates very little noise.

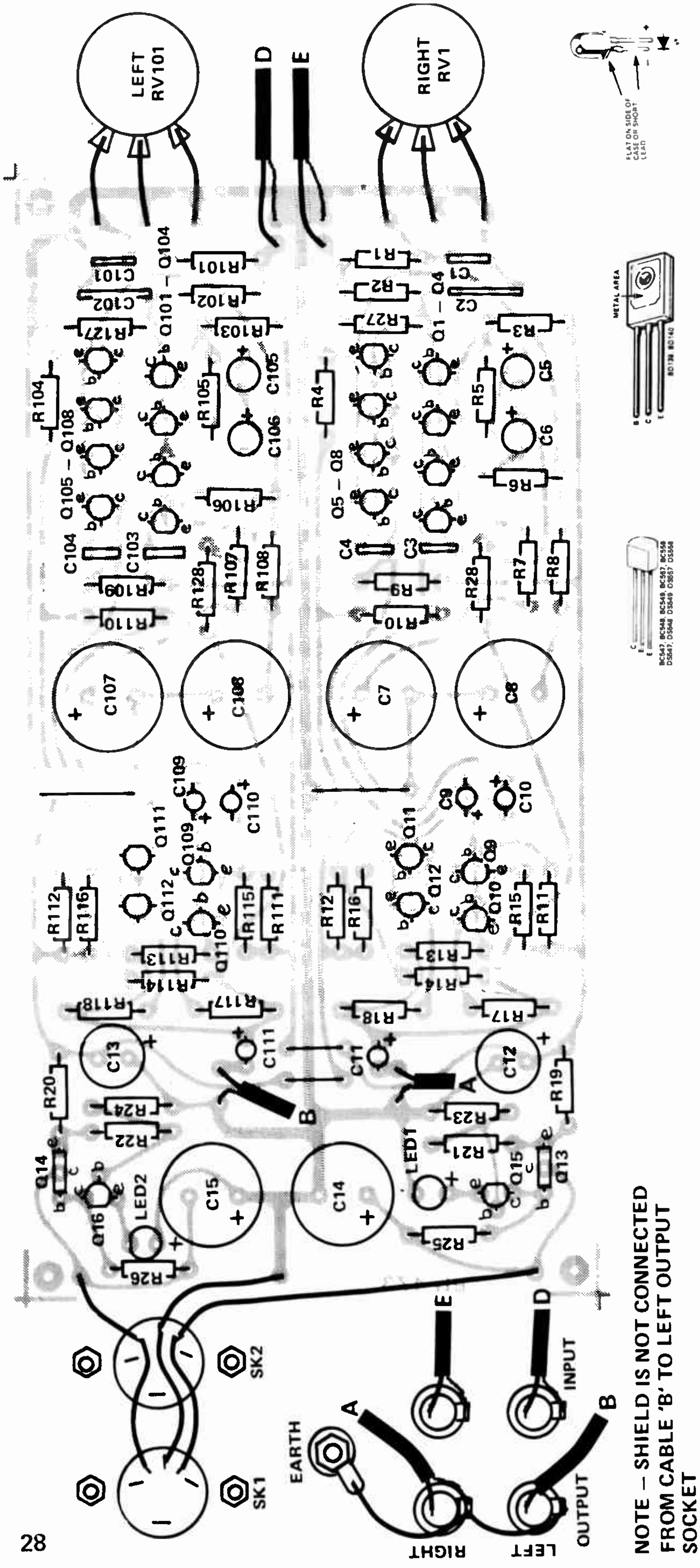
Construction

Construction is relatively straightforward since most components are on the mounted pc board. Other construction methods are possible but performance may not match that of our prototype.

Mount the resistors and capacitors first, followed by the transistors. Since there are quite a few transistors on the board placed close to each other, don't make the mistake I did and get them mixed up! Cut the necessary lengths of shielded cables and solder them onto the board keeping the ends as short as possible. Solder the necessary lengths of hookup cable to the board and after checking all components mount the board in the chassis.

I used a diecast aluminium box and quite frankly wish I hadn't. The shielding to external magnetic fields really isn't good enough. I found I had to be careful where the preamp was placed or it would pick up hum from the magnetic field produced by the power amp's transformer. Use a steel box if you can, if not, just be careful where it is placed.

Once the board is mounted in the chassis, the pots and rear panel hardware can be mounted and the wiring completed according to the wiring layout diagram shown. Here again I came unstuck. The first system I used to ground the shielded cables caused a monumental hum loop (and I still don't really understand why!). The final method tried is shown in the wiring diagram and this works very well. The shielded cables coming from the outputs on the board have only one of their shields connected to the output RCA sockets which are wired together and connected to the chassis at the ground terminal. This type of terminal is supplied with the necessary hardware to insulate them from the chassis. In this case however, we want the terminal to connect firmly to the case to provide the necessary ground connection. It is important that the RCA sockets be insulated from the case and that the ground connection made to them is according to the wiring diagram. If the unit is going to be used with the recommended power supply there should be no hum problems. This power supply, ETI 557, is described later in this book. It is wired so that the O volt line is not connected to the chassis of the power supply. This is important, otherwise a hum loop around the units' mains grounds will result. If you wish to use a power supply other than the 577 then it will be necessary to ensure that the O volt line from the supply does not connect to the power supply chassis. Do not 'cure' the problem by disconnecting the ground wire at the 240 volt plug as this will remove any ground connection from the power



supply chassis. This is not only dangerous, it's illegal.

Powering up

Before turning the unit on make a final check of the board. Check the orientation of the transistors, electrolytic and tantalum capacitors and the LEDs. If all is right, turn down the volume control completely and switch the power supply on. The LEDs in the

PARTS LIST - ETI 473

Resistors all ½W, 5%

- R1, R101 . . . 3R3
- R2, R102 . . . 10R
- R3, R4, R103, R104 . . . . . . 1k
- R5, R6, R105, R106 . . . . . . 2k2
- R7, R8, R107, R108 . . . . . . 10R
- R9, R10, R109, R110 . . . . . . 270R
- R11, R12, R111, R112 . . 2k2
- R13, R14, R113, R114 . . 10k
- R15, R16, R115, R116 . . 390R
- R17, R18, R117, R118 . . 18R
- R19, R20 . . . 10R
- R21, R22 . . . 560R
- R23, R24 . . . 330R
- R25, R26 . . . 220R
- R27, R127. . . 1k
- R28, R128. . . 220R

Capacitors

- C1, C101. . . . 3n3 ceramic
- C2, C102. . . . 4n7 ceramic
- C3, C4, C103, C104 . . . . . . 470p ceramic
- C5, C6, C105, C106 . . . . . . 22µF 16V tantalum
- C7, C8, C107, C108 . . . . . . 2200µF 25V electro
- C9–C11, C109–C111 . . 10µF 16V tantalum
- C12, C13. . . . 100µF 25V electro
- C14, C15. . . . 1000µF 25V electro

Transistors

Use only types specified - substitutes may result in inferior performance.

- Q1–Q4, Q101–Q104. . BC559
- Q5–Q8, Q105–Q108. . BC549
- Q9, Q10, Q109, Q110 . . BC559
- Q11, Q12, Q111, Q112 . . BC549
- Q13. . . . . . . BD139
- Q14. . . . . . . BD140
- Q15. . . . . . . BC549
- Q16. . . . . . . BC559

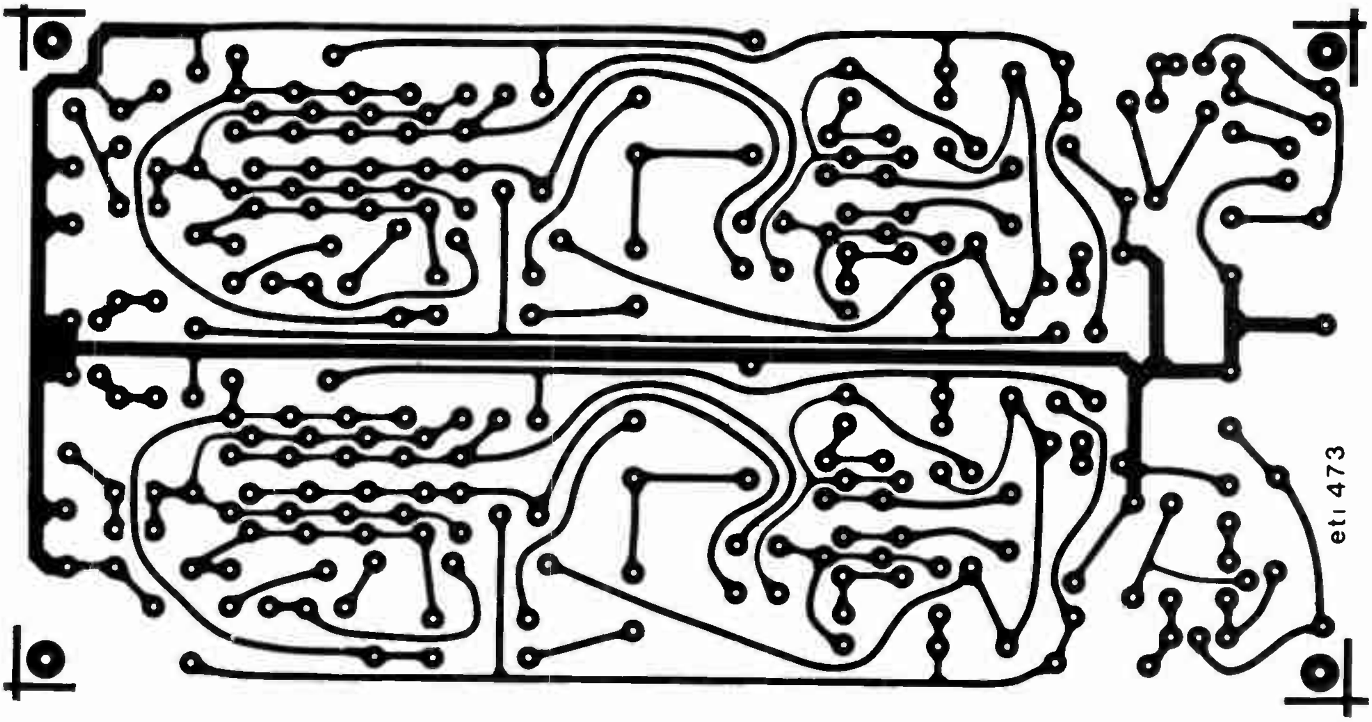
LED1, LED2 . standard red LED

Potentiometers

RV1, RV101 . 100R wirewound linear

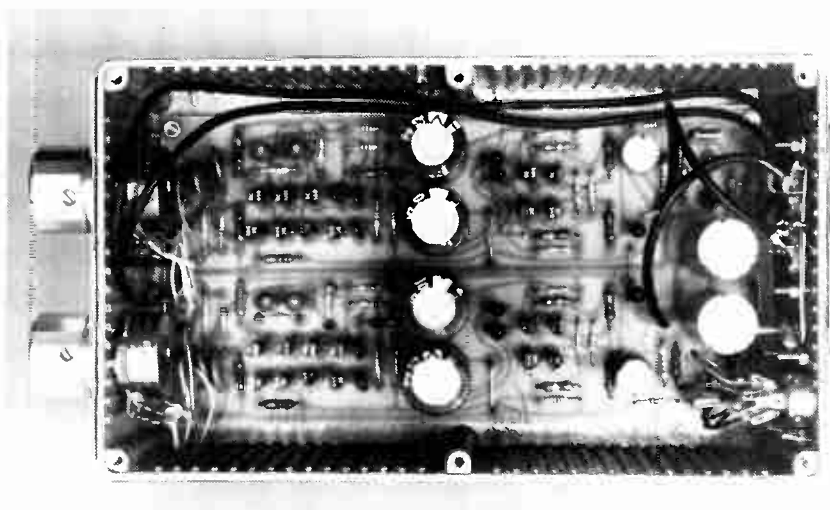
Miscellaneous

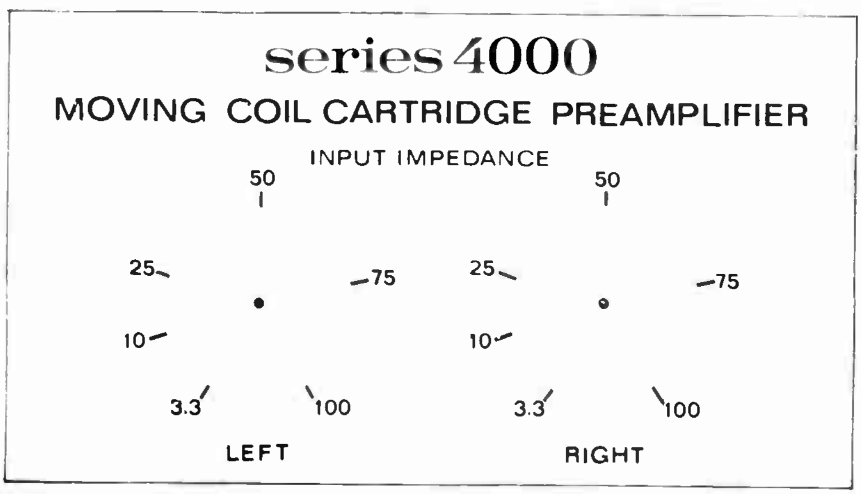
SK1, SK2 . . . 5 Pin DIN socket
Four RCA sockets (insulated from case), One black terminal, mains lead, plug and mains cord securing grommet, two knobs, box to suit, 190 x 60 x 110 mm.



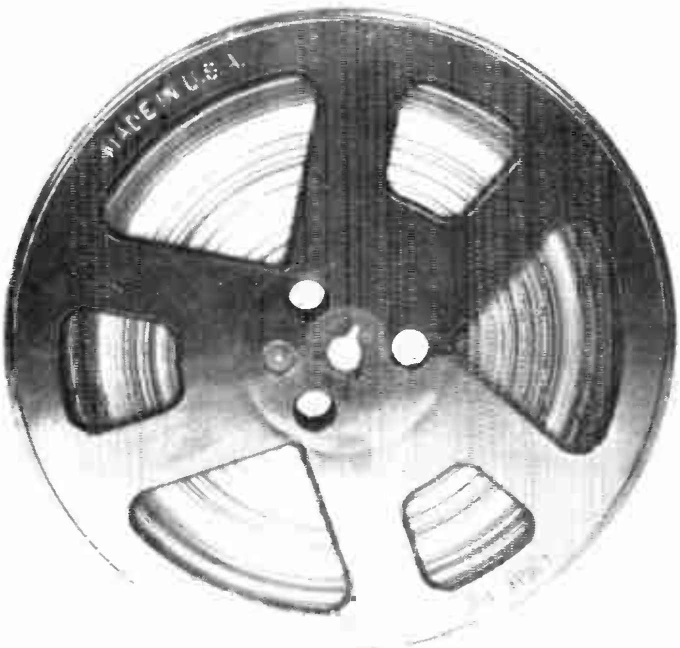
preamp's regulator should come on immediately. I used standard RCA to RCA cables from the output of the preamp to the phono input and had some trouble with hum induction into the leads. Fortunately, we had been sent a set of Audio-Technica type AT620 cables for evaluation several days before and these cured the problem completely.

Perhaps I am biased, but the sound quality of this preamp is extremely good! Using a Nakamichi MC1000 cartridge, this preamp showed distinct improvement over the transformer I was using previously. There is an openness that never existed before and the bass end showed a great improvement being firmer and much more defined. I trust you'll be as satisfied with your project as I have been. ●





Top AMPEX REEL to REEL TAPE at one-third normal price!



The USA Ampex Corporation has made available a substantial quantity of 'off-cut' tapes from their highest grade material. All tapes are 1800 ft (549 m) by ¼", 1 mil ferric oxide on standard 7" reels.

There's a slight gamble involved — but one in which you either win a lot — or a hell of a lot!

Here's why:
The tapes offered are of differing types and you take pot luck on which you receive.

BUT, The lowest quality is Ampex' superb Ampex Plus series! The highest is Ampex' Grand Master series!

SO. If you draw the Ampex Plus' you'll be paying about one-third the usual price. If you score the Grand Masters you'll be paying about a quarter usual price.

YOU CANNOT LOSE. If you are not totally and completely satisfied with your purchase, Dindy guarantee to return the full purchase price without question provided the tapes are returned within 14 days in the original packing.

Identical tapes to those offered are marketed in the USA by Ampex, using the trade name 'Shamrock'. This trade name is also used for those offered here.

$39 for 10 reels

Plus $2.00 for post and packing

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Owing to the exceptionally low offer price, the minimum ordering quantity is ten tapes (total $39).

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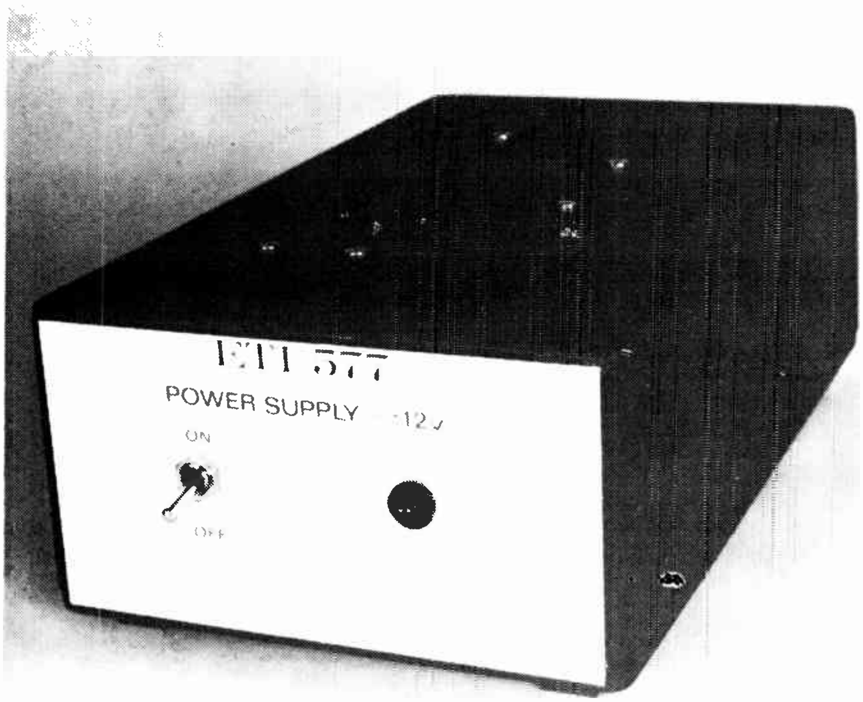
A general purpose, dual 12 V supply

David Tilbrook

Whilst this supply was designed specifically to power the Series 4000 moving-coil cartridge preamp it should find application in many electronic projects.



Our prototype was housed in a diecast box to match that used for our Series 4000 moving-coil cartridge preamp, although any suitable box may be used if the power supply is intended for another application. Scotchcal front panels should be available from kit suppliers or separately from Radio Despatch Service in Sydney.

THIS POWER SUPPLY provides the +/-12 volts needed by the Series 4000 moving coil cartridge preamplifier. We intend designing a range of hi-fi system 'add-ons' like the M.C. preamp and rather than have a power supply in each unit they will be powered from this supply. This decreases the cost of of building the units and just as importantly removes the major source of hum from within the chassis.

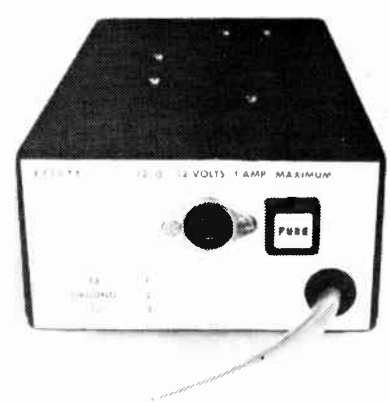
The supply delivers positive and negative 12V dc at 1A while the IC series regulators provide short circuit and temperature protection. These regulators have a tendency to oscillate at around 3 MHz and for this reason must have their output pins bypassed to ground through an appropriate capacitor. If they are allowed to oscillate the device quickly overheats and its thermal protection cuts in.

The regulators are mounted onto the chassis which acts as a heat sink. If the recommended power transformer is used, the voltage after rectification is approximately 17 volts. The regulators must drop 5 volts at a worst-case current of one amp, so they are dissipating a maximum of five watts which is well within their ratings.

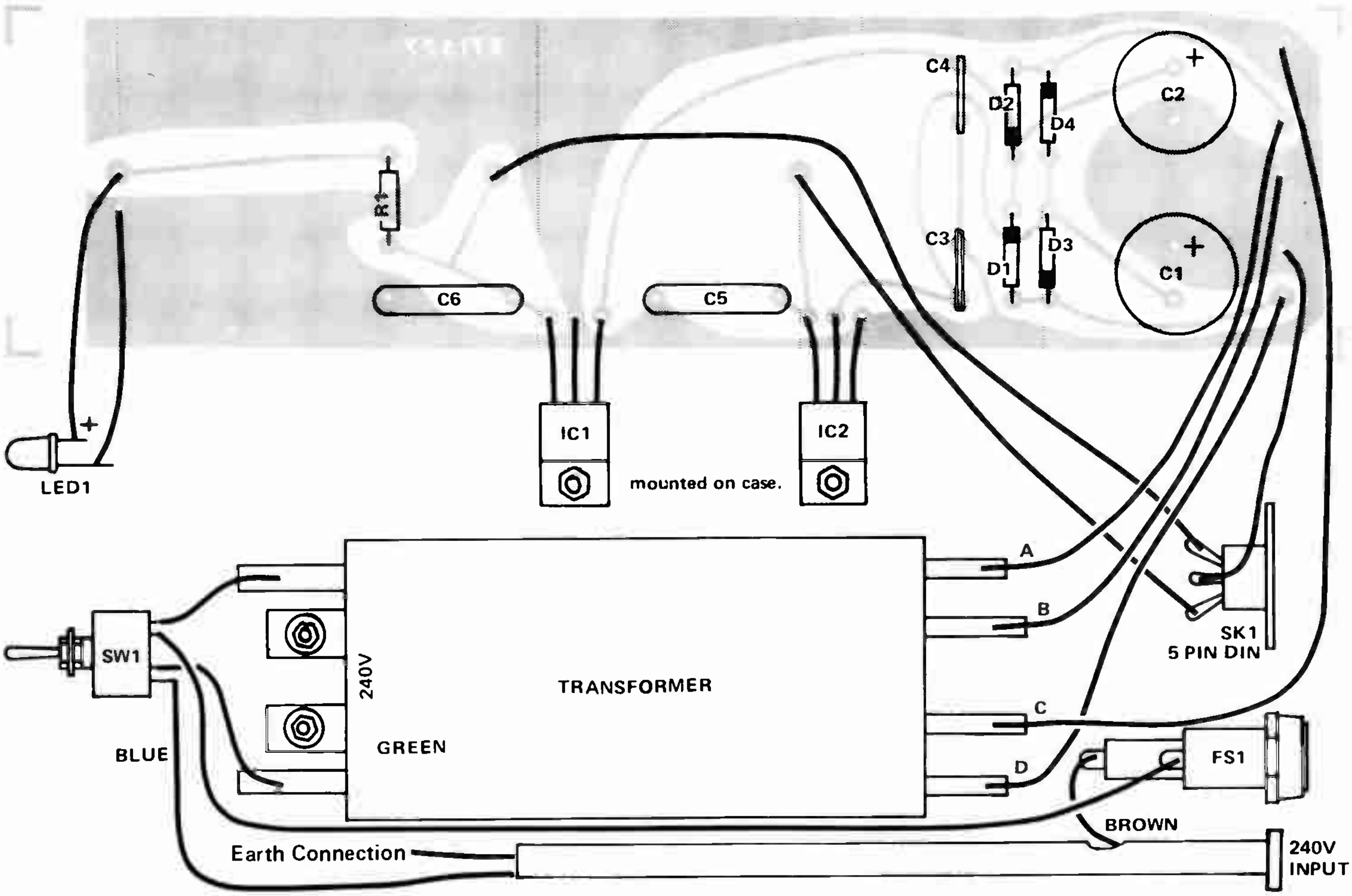
Construction

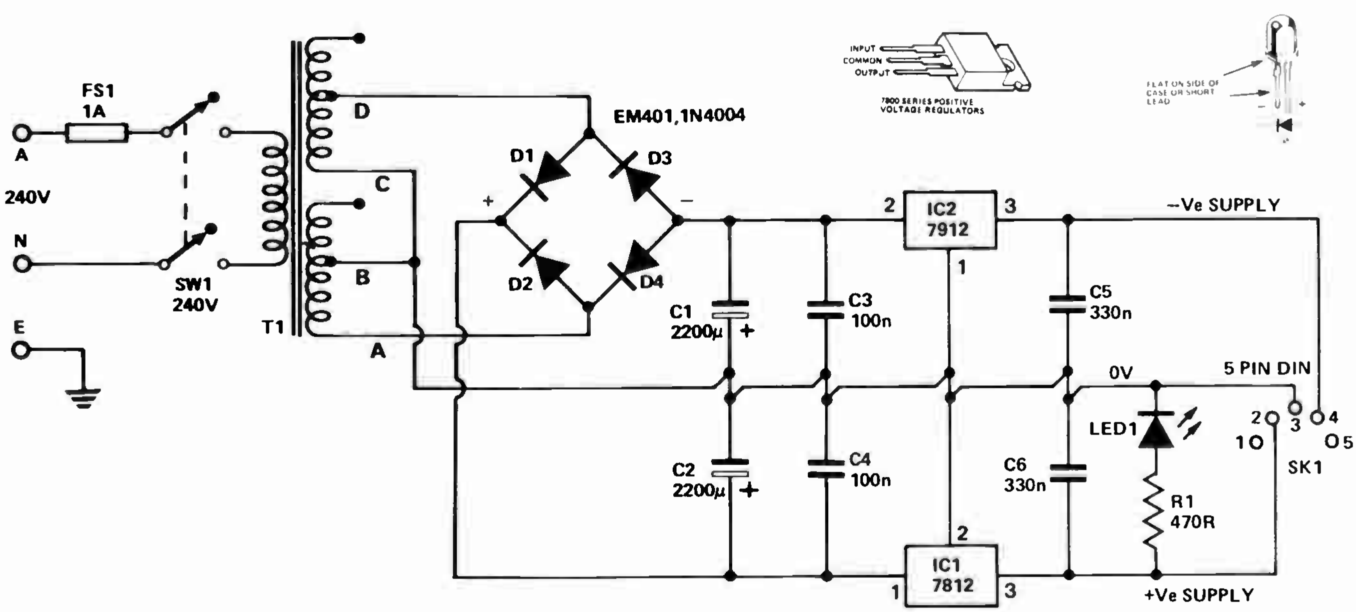
The power transformer used in the prototype was a Ferguson type PL30/40 VA. This is one of their low profile transformers and fits easily into the die-cast aluminium box. The printed circuit board has been designed to slot into the grooves in this box.

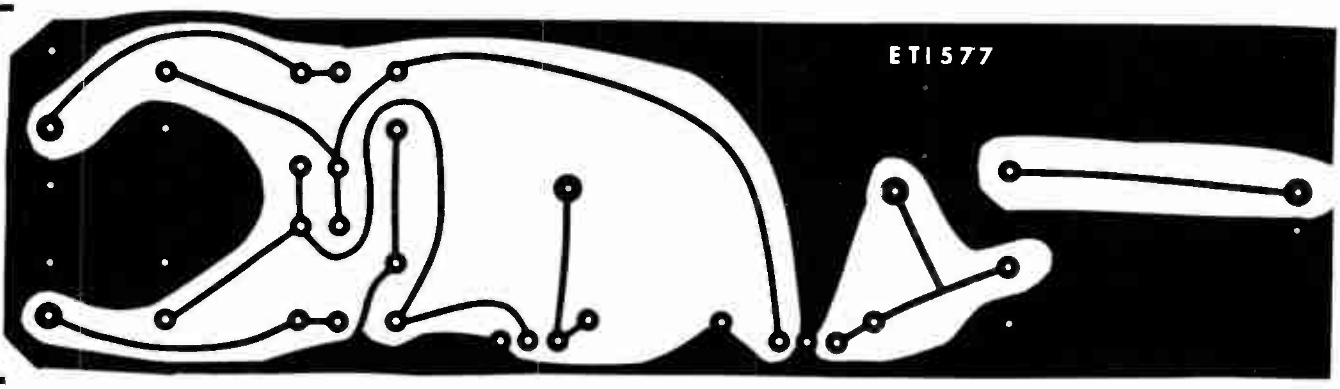
Assembly of the pc board is not difficult as it has relatively few components. If you are using the same box we did it is easier to solder pc board pins onto the board, slot the board into place, bolting the regulators down, and then make the necessary wiring interconnections. Both regulators must be insulated from the case using the appropriate mounting hardware. The case of these regulators is connected to pin 2. For the 7812 this is the ground connection, and accidental connection to case will cause a hum loop when the unit is connected to the moving coil cartridge pre-amp. In the 7912, pin 2 is the input to the regulator and as such has 17 volts directly from the bridge rectifier connected to it. Accidental connection of this to ground will probably damage the rectifier diodes, so check with a multimeter that the case of this regulator is well insul- ▶

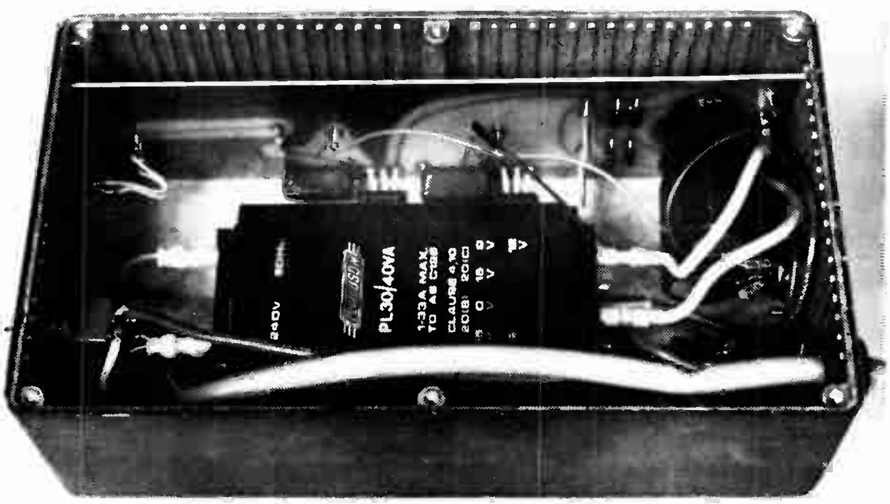


Rear view of the power supply showing placement of the major components.


C4
D2
D4
C2
R1
C3
D1
D3
C1
C6
C5
LED1
IC1
IC2
mounted on case.
SW1
240V
TRANSFORMER
GREEN
BLUE
A
B
C
D
SK1
5 PIN DIN
FS1
BROWN
Earth Connection
240V
INPUT


INPUT
COMMON
OUTPUT
7800 SERIES POSITIVE
VOLTAGE REGULATORS
FLAT ON SIDE OF
CASE OR SHORT
LEAD
FS1
1A
A
240V
N
E
SW1
240V
T1
D
C
B
A
EM401,1N4004
D1
D3
D2
D4
IC2
7912
−Ve SUPPLY
C1
2200μ
C2
2200μ
C3
100n
C4
100n
C5
330n
C6
330n
0V
5 PIN DIN
LED1
R1
470R
SK1
IC1
7812
+Ve SUPPLY





Internal view of the power supply showing how the pc board was mounted, the position of the power transformer and the general wiring arrangement. General parts placement is not at all critical and a variety of layouts is possible. Be sure to insulate the regulator ICs.

ated from the chassis before powering up.

The LED is mounted onto the front panel with a standard LED mounting grommet and connected to the board by two short lengths of hook-up cable.

Make absolutely certain that all 240 volt connections are secure and that the mains cable ground lead is connected to chassis as shown in the wiring diagram. The mains flex must be secured to the chassis, either with a clamp-type grommet where it enters the box or with a cable clamp on the inside.

Before applying power to the unit make a final check of the board and all connections to the power transformer. Check the 240 volt connections and ensure that the regulators are satisfactorily insulated from the chassis. If all is correct, turn the power supply on. The LED on the front panel should come on immediately. Check the voltage present on the output DIN socket which should be very close to 12 volts (certainly within 0.25 V). Make sure the positive and negative supply connections terminate on the correct DIN socket pins. ●

HOW IT WORKS – ETI 577

Mains 240 Vac is applied to the primary of the transformer via a 1A fuse. The transformer secondary consists of two 15 V windings with tappings at 12 V. The 12 V tapping of one is joined to the 0 V of the other – this junction (effectively a centre-tap) forming the volt rail.

A bridge rectifier D1-D4 rectifies the ac voltage from the transformer and supplies around 17 volts to the inputs of the regulator ICs. Capacitors C1-C4 filter the input to the regulators while C5 and C6 ensure high frequency stability of the regulators.

The IC regulators provide a stable, regulated output very close to the specified 12 Vdc and can supply up to one amp of dc current. Overload and thermal protection is provided internally on the IC chip. These regulators are convenient, inexpensive and require the minimum number of components.

PARTS LIST - ETI 577

Resistors	all ½W, 5%
R1	470R
Capacitors	
C1, C2	2200µF 25V electro
C3, C4	100n greencap
C5, C6	330n greencap
Semiconductors	
D1–D4	IN4004, EM401 or sim
LED1	Red led, TIL220R or sim
IC1	7812 or LM340-12 voltage regulator (positive)
IC2	7912 or LM320-12 voltage regulator (negative)
Miscellaneous	
T1	transformer, 15V-0-15V, 1.3 amps (Ferguson PL30/40VA)
SW1	DPDT 240V switch
F1	1A, 3AG type fuse
SK1	Chassis mounting 5 pin DIN socket

Chassis mounting 3AG fuse holder, 5 pin DIN plug, 240V mains plug, 240V/3 core cable, rubber mains cable grommet, Diecast aluminium box 190 x 60 x 110 mm.

High-to-low impedance 'interface' to suit the ETI-470 60 watt amp

The popularity of our 60 watt low distortion amplifier module (May '79) has exceeded all expectations. To achieve the amplification 'accuracy' these power amps are capable of, the drive impedance must be very low — in the order of five to ten ohms. Our previous preamps, the 422 and 482, and many preamps available, generally have a medium to high output impedance and will not properly mate with the 470. This interface provides the necessary impedance conversion, allowing these amps to be used with many existing preamp designs.

Phil Wait

DESIGNED primarily for use with our Series 4000 stereo amplifier, the 470 low TID 60 watt amplifier module has found its way into the most surprising applications – from a dc motor drive to discos in central Africa. Thousands of the modules have been built, occasional output transistor shortages not withstanding, in Australia, New Zealand, Europe, Africa, Canada and the UK.

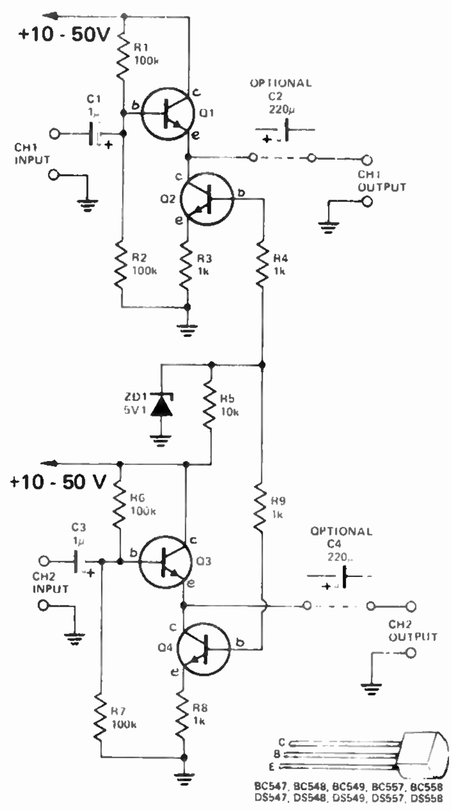
Although the 470 module was designed to be driven from a low impedance source, it is obvious from readers' letters that there are many who want to use it with existing equipment having a preamp with a high output impedance.

This project describes a two-channel (stereo) interface for driving up to two 470 modules (per channel) from a high impedance source, and can in fact be used in any application requiring a very low impedance drive at audio frequencies.

The input stage of the 470 consists of an emitter – coupled darlington pair with the input signal fed to the non-inverting input and the feedback connected to the inverting input. To reduce high frequency intermodulation the slew rate of this stage is limited by placing a 470n (0.47μ) capacitor between the two bases.

The input impedance varies with frequency, from a few thousand ohms at quite low frequencies to hundreds of ohms at the high frequencies, where the effect of the slew limiting capacitor becomes apparent.

If the stage is driven from a high impedance source, the output of the driving current will be loaded down at high frequencies by the reduced input impedance of the amplifier, causing high frequency distortion. This is why we specified a low impedance driving source for the 470, and designed our preamplifier accordingly.



Interface design

The circuit for our interface uses two emitter followers (one per channel) with constant-current generators in the emitters referenced from a zener-regulated supply voltage.

The easiest way to convert from a high impedance to a low impedance with little attenuation is with an emitter follower. The input signal is fed into the base of a transistor and the output taken from the emitter, the collector being tied to the supply. Emitter followers have a high input impedance and very low output impedance. The output impedance is roughly the value of the emitter resistor divided by the beta of the transistor.

To allow the circuit to be used with the power amplifier or with the driving source the circuit must be able to operate over a very wide range of dc supply voltages as found in graphic equalisers, organs, preamplifiers and such.

To limit the supply current and dissipation of the emitter follower when

HOW IT WORKS – ETI 474

The circuit consists of two emitter followers, Q1 and Q3, with constant current generators in their emitters. The constant current generators share the same voltage reference, ZD1.

The reference voltage, 5.1V is derived from ZD1, and fed to the bases of Q2 and Q4. The voltage on their emitters is then set at 4.4V. The transistors will always pass the exact amount of current required to maintain this voltage on the emitters, regardless of supply voltage.

The input signal is fed to the bases through dc blocking capacitors C1 and C3, and the output is taken from the emitters directly or via the optional blocking capacitors C2 and C4. The gain of the circuit is a little less than unity.

ERRATA: A second colour is missing from diagrams on pages 133 and 141 of some copies of this book. Here is the corrected version. Our apologies for any inconvenience.

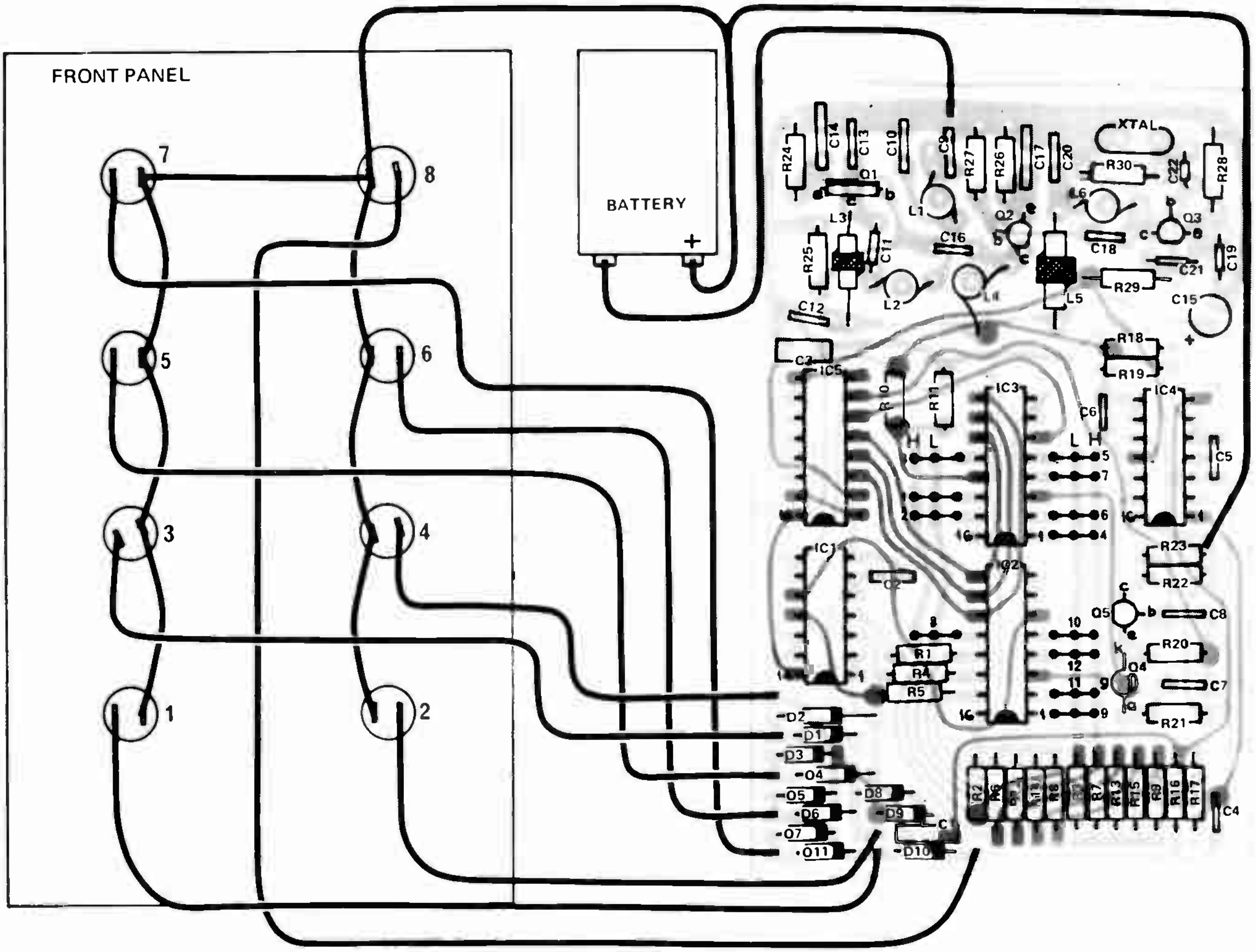


Fig. 7. Component overlay and wiring diagram. Note the links from IC2 and IC3 to the 'H' or 'L' lines. You must decide on the code word to be used and link to one or the other as detailed in the text. Overlay is shown larger than full size for clarity.

PARTS LIST ETI 711

Resistors

R1	100k	¼W	5%
R2	82k	"	"
R3	27k	"	"
R4,5	100k	"	"
R6,7	39k	"	"
R8	82k	"	"
R9,10	39k	"	"
R11	120k	"	"
R12	82k	"	"
R13	39k	"	"
R14	82k	"	"
R15	39k	"	"
R16	2M2	"	"
R17	100k	"	"
R18	3M3	"	"
R19	27k	"	"
R20	100 ohms	"	"
R21	330k	"	"
R22	10k	"	"
R23	47k	"	"
R24	5.6 ohms	"	"
R25	220 ohms	"	"
R26	12 ohms	"	"
R27	270 ohms	"	"
R28	330 ohms	"	"
R29	22k	"	"
R30	1k	"	"

Capacitors

C1-C3	33n		polyester
C4	15n		"
C5	56n		"
C6 – C8	10n		"
C9	47p		ceramic
C10	330p		ceramic
C11	270p		"
C12	10n		"
C13	68p		"
C14	10n		"
C15	33μ	16V	electro
C16	120p		ceramic
C17	10n		"
C18	220p		"
C19	39p		"
C20	10n		"
C21	33p		"
C22	470p		"

Semiconductors

D1 – D11	1N914 or similar
IC1	4001
IC2, 3	4051
IC4	4001
IC5	4520
Q1	BD139
Q2, 3	BC549
Q4	2N6027
Q5	BC548

Switches

PB1 – PB8	Miniature push buttons

Coils

L1,2,4,6	10 turns of closely spaced 24 gauge tinned copper wire wound on 5 mm diameter, 18 mm long coil formers (Neosid 722/18) with 6 mm long coil slugs.

Note L2 has no slug (Neosid 4 x .05 x 6/F29)

3 PTFE Locking Strips

L3, L5	150μH R.F. chokes

Miscellaneous

PC board ETI 711
Aluminium bracket to Fig. 4
Plastic box
Front panel to fig 10
Telescopic antenna
9 volt battery
2 6BA x 3/8 bolts & nuts
Battery clip
27 MHz crystal in the band 26.975 MHz to 27.282 MHz.

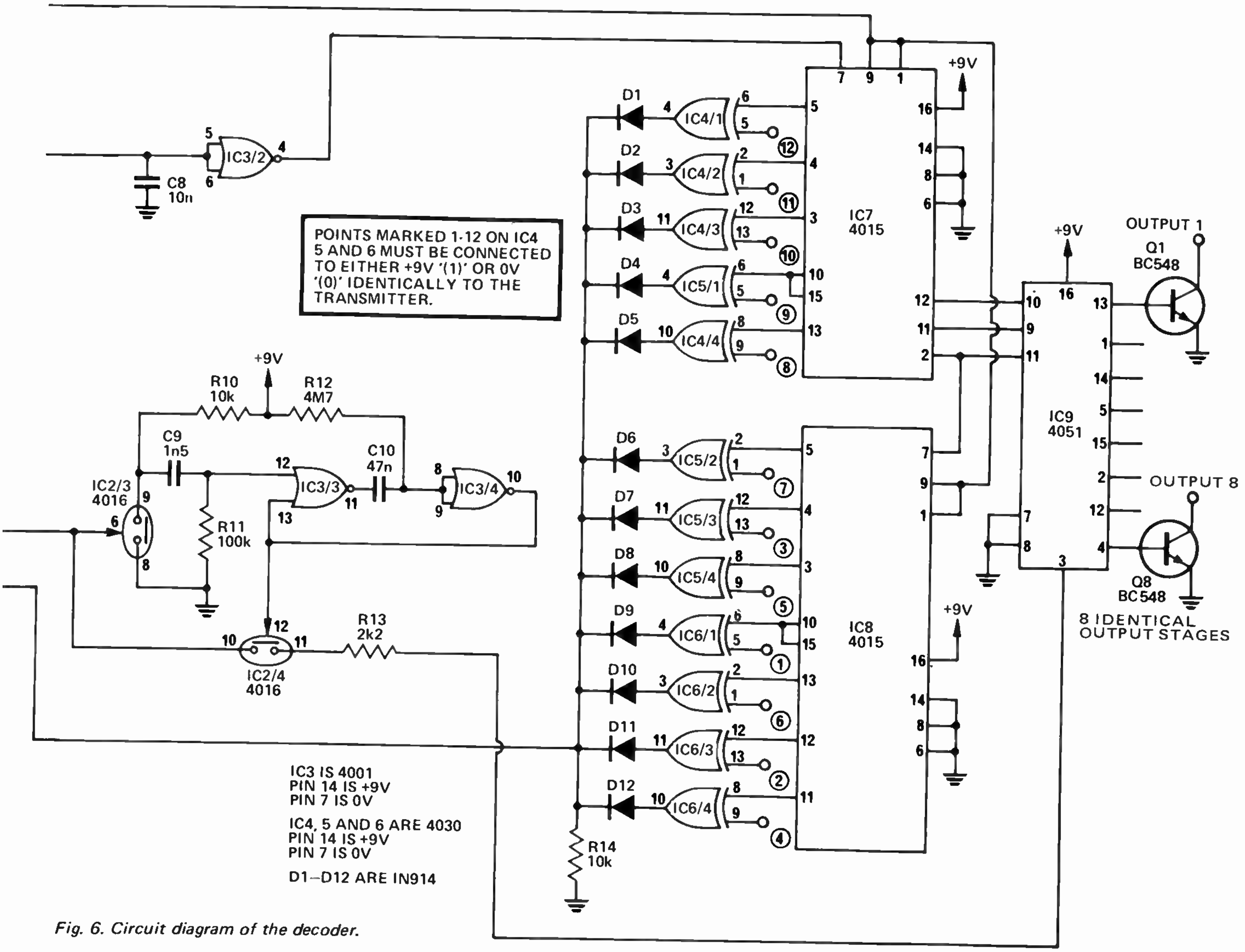


Fig. 6. Circuit diagram of the decoder.

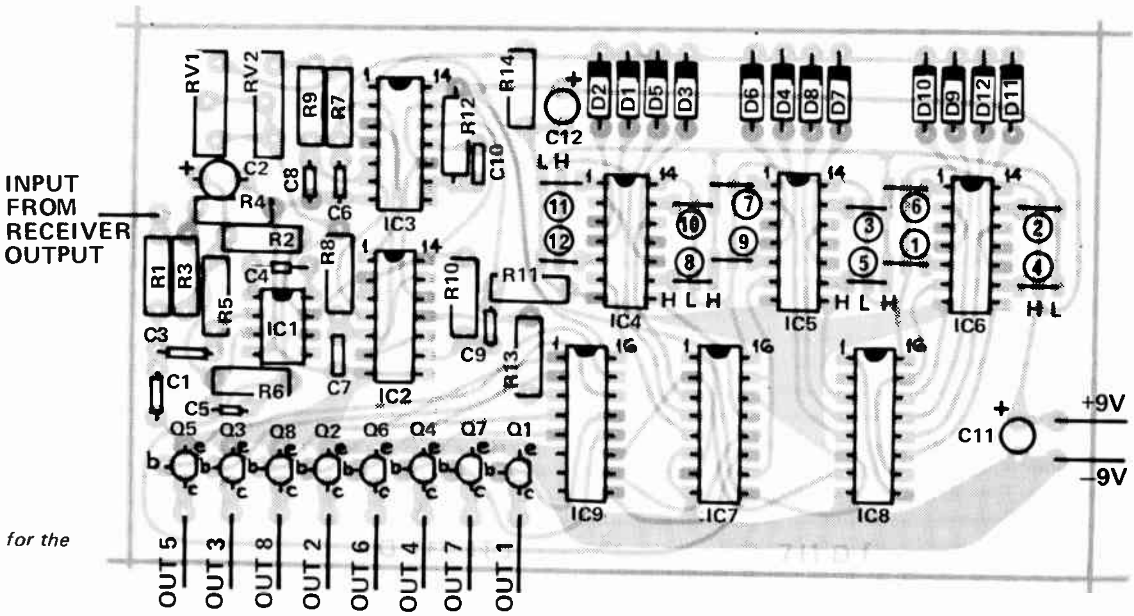
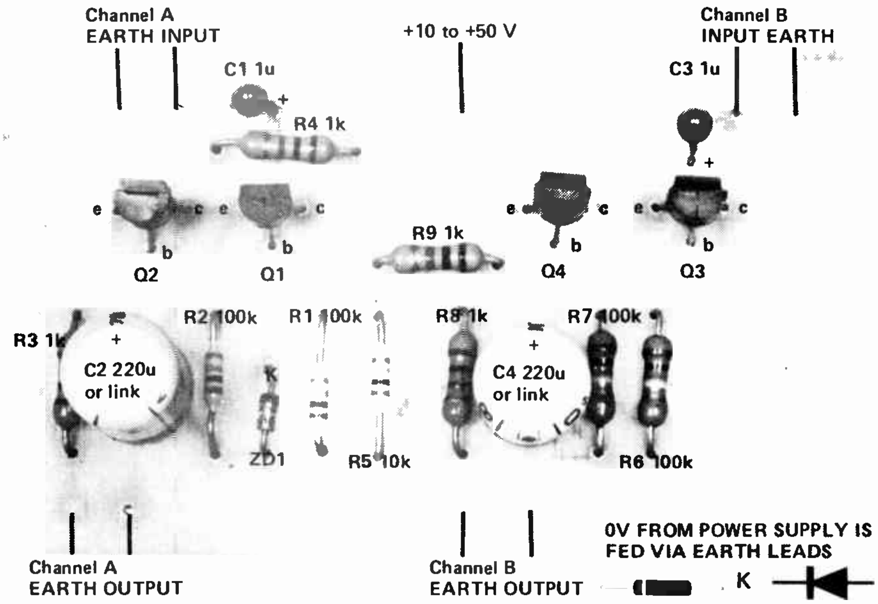


Fig. 7. Component overlay for the decoder.



PARTS LIST - ETI 474

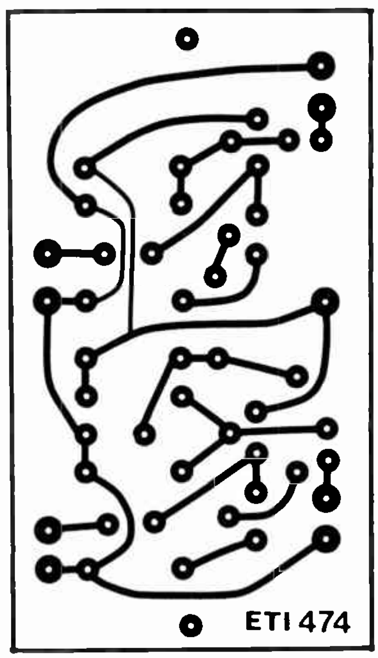
Resistors all ½W, 5%
R1, R2 . . . . . 100k
R3, R4 . . . . . 1k
R5 . . . . 10k
R6, R7 . . . . . 100k
R8, R9 . . . . . 1k

Capacitors
C1. . . . . 1μ 35V tantalum
C2. . . . . 220μ 35V electro (optional)
C3. . . . . 1μ 35V tantalum
C4. . . . . 220μ 35V electro (optional)

Semiconductors
ZD1. . . . . . . 5V1 400mW zener diode

Q1–Q4. . . . . BC107, BC547, DS547 or similar

Miscellaneous
ETI 474 pc board.



used with a high supply voltage we used a constant current generator (Q2, Q4) in each of the emitters in place of the normal emitter resistor. The use of a constant current generator also increases the input resistance and decreases the output resistance. A current of about four milliamps flows through the transistors for all supply voltages above five volts.

The output capacitors (C2, C4) provide dc isolation for the output, but since the 470 modules already have an isolation capacitor (C1), they can be left out and the pc board bridged with a length of tinned copper wire. If any other connection is made from the output, for auxilliary equipment, the capacitors should be left in.

If the capacitors are removed it will be necessary to replace the input capacitor on the 470 power amplifier (C1) with a 220μ, 35 volt electrolytic oriented with its positive lead towards the input terminal.

Construction

Construction is straightforward, the only thing to watch is the orientation of the transistors and the zener diode. The unit can be mounted with the power modules and run from their supply or mounted with the driving circuit. Input and output connections should be via shielded cables which also carry the power supply earth on the braid to avoid earth loops.

If only one power module is to be driven, as with an electronic organ, the pc board can be cut in half and only one channel assembled. ●

Hints and tips for the ETI-470 60W Module

MOST PEOPLE haven't had problems with their 470 module, but inevitably there are some who do. From calls and letters to our reader enquiry service we have identified five areas of trouble.

1) The earth rail on the amplifier must be returned to the 0V rail on the power supply. If this is not done the input transistors and their current source (Q1-Q5) will be destroyed. This is probably our failing as, although it is obvious to most people, it was not indicated on the circuit given on page six but was indicated in the wiring diagram of the Series 4000 amplifier.

2) It can be seen from the overlay that the base lead of Q5 must be slightly bent to fit the pc board. The transistor can easily be inserted the wrong way round. Watch this.

3) The darlington output transistors **must** have a good heatsink. Always make sure the thermal contact between the transistor and the heatsink is good. Use a thermal compound (such as Bevaloid GS13), but not too much — just a smear on either side of the mica washer. Use a metal, rather than a nylon screw with an insulating bush, to fasten the transistor — a nylon one will stretch under tension. Make sure the heatsink is smooth and flat, curved or sandblasted heatsinks will not make good thermal contact with the transistor body.

4) Make sure that the transistor Q8 has a good thermal contact to the heatsink. It must be the same heatsink as the output transistors.

5) Never, never run the amp without a heatsink, even if only to set the bias.

Overheating of the output devices due to poor heatsinking will result in thermal run away which will blow the fuses but will probably not damage the output transistors provided the two amp fuses are in circuit. Faults where the amplifier operates correctly for a while then blows fuses, will probably be due to poor heatsinking.

Most transistors in the amplifier are designed to run quite warm in normal operation.

No problems have become apparent with the preamplifier (ETI-471).

Series 4000 four-way loudspeaker

David Tilbrook

This project is the first in a series of loudspeaker projects designed to complement our Series 4000 range of quality hi-fi projects.

LOUDSPEAKERS still remain the weakest link in the hi-fi chain and the total sound of any system will depend more on the loudspeakers than any other single hi-fi component. So it is important to get the best loudspeakers, even if this means accepting a slightly lower performance amplifier or turntable. In most systems the performance of the cartridge, turntable and amplifier greatly exceeds that of the loudspeakers so an improvement in the loudspeaker department will often yield a radically improved system.

Unfortunately, there are very few really good kit loudspeakers. This project is an attempt to rectify that situation by providing a loudspeaker suitable for home construction that rates amongst the best available. This is not an inexpensive project – the driver and crossover cost being around $400 – but the finished project will rival commercial units at three times the price.

Choosing the drivers

In order to build a good loudspeaker it is obviously important to use good drivers, but availability is just as important a criterion as performance. For this reason we had a close look at the drivers commonly available in Australia and finally decided to use drivers from the huge range of Philips loudspeakers, some of which were not available in this country at that time. Philips agreed to stock the drivers we decided on and these form the basis of the 4000 series of loudspeakers.

The 4000/1 is a four-way sealed enclosure loudspeaker using 12 dB/octave crossover slopes. The original design for our prototype used an 18 dB/octave M-derived crossover (see 'Principles and problems in loudspeaker design' in Jan and Feb 1980 issues of ETI) but it was enormously expensive and complex and would have contributed little to the overall sound finally achieved with the 12 dB/octave crossover. The four-way approach allows closer control over the final frequency response than does a three-way. More importantly a major part of the mid-range normally handled by the woofer can be dedicated to a separate mid-range driver. The basic design idea was to use the woofer only up to 150 Hz. A separate mid-range driver would then take over up to 750 Hz where a second mid-range would come in. The lower mid-range driver, crossing in at 150 Hz needs a usable response down to around 60 Hz (i.e. one octave) so that the crossover region will have a reasonably flat response. Similarly, the woofer crossing out at 150 Hz needs to have a usable response to at least 300 Hz.

After a great deal of testing it was finally decided to use the Philips AD12250/W8 unit for the woofer. This is a 100 watt driver with a free air resonance of 26 Hz. When mounted in the enclosure the fundamental resonance rises to around 31 Hz, an excellent figure. This driver seems to have a bad hole in its response at 350 Hz but this is unimportant in this loudspeaker.

The AD70601/W8 unit was chosen as the lower mid-range as it has a free air resonant frequency at 45 Hz. This driver is actually a woofer and does not have the integral sealed enclosure common to many mid-range drivers. The enclosure must be provided by the cabinet construction and the volume chosen in the 4000/1 increases the 45 Hz fundamental resonance of this driver to around 55 Hz, which is ample.

The response between 750 Hz and 3 kHz, where the tweeter takes over, is handled by the latest Philips dome (AD02161/SQ8) mid-range. This driver has a 50 mm textile dome giving a good frequency response and wide dispersion at higher mid-range frequencies.

Above 3 kHz the AD01610/T8 tweeter is used. We tested a large range of Philips tweeters and this was the best, followed closely by the AD01605/T8, which suffered a little from roll-off of the frequencies above 10 kHz.

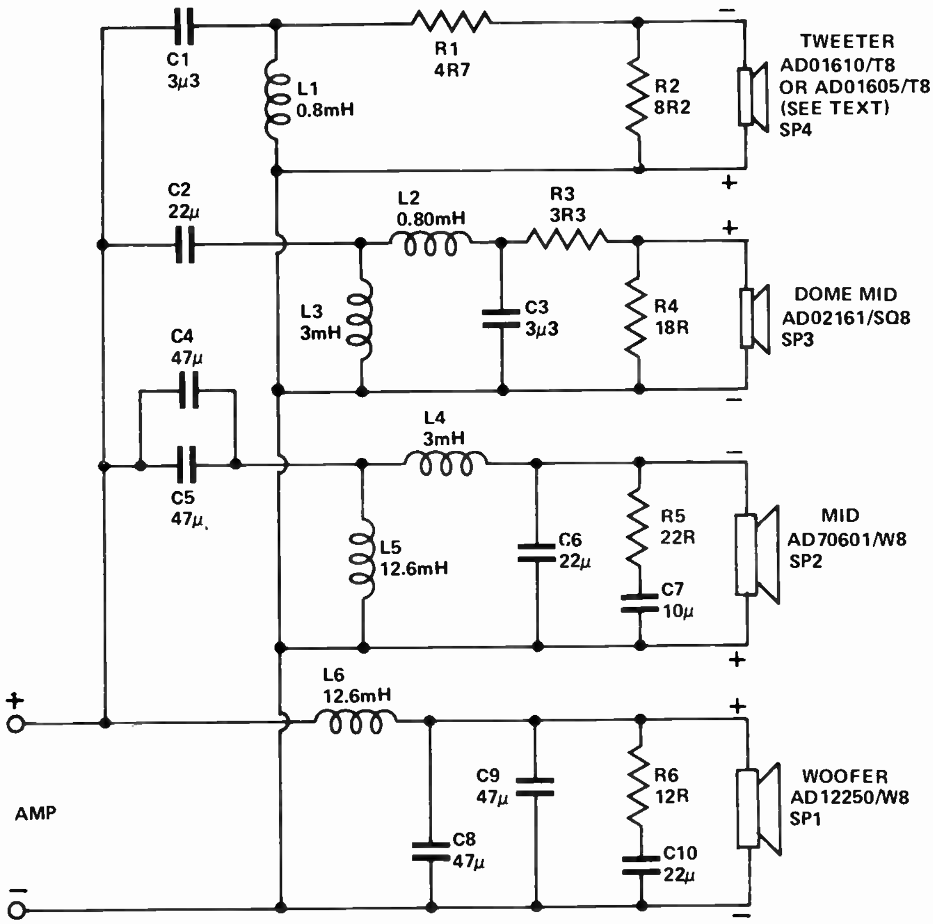
The 4000/1 loudspeaker, without the front grille, showing the drivers. It stands about one metre tall.

Construction

If you are constructing the boxes yourself start by assembling the sides, top, bottom and back of the cabinet. The bottom panel is placed 100 mm above the bottom of the box and the cavity formed under the box can be used to mount the crossover instead of putting it inside the box as is the usual practice. Now insert the two pieces of timber that form the mid-range enclosure. It is essential that there is a perfect seal between the bass and mid-range chambers, as well as between these two chambers and the outside air. Line every joint carefully with caulking compound

HOW IT WORKS.

The input signal from the output of the amplifier is fed to the 4 way crossover that divides the signal into the 4 different frequency bands covered by each of the drivers. The loudspeaker cabinet is divided into two sections, the larger one forming the bass chamber for the woofer and the smaller one forming the midrange chamber. These two chambers are sealed from each other so that interactions cannot occur between the back radiations of the woofer and lower midrange. The other two drivers have their own enclosures as an integral part of the driver. For a detailed account of the design approach and the problems that occur in loudspeaker design, read 'Principles and problems in loudspeaker design' in the Jan and Feb 1980 issues of Electronics Today International.



Circuit diagram for the four-way system. Driver polarity is important. Note that the "dome mid" driver, AD02161/SQ8, is available in two models, the other being AD02160/SQ8, which is different in appearance but electrically equivalent.

or glue so that no possiblity of an air leak exists. This is probably the best stage of the construction to drill the holes for the wiring to the loudspeakers. I used two cores of 240 volt three-core mains cable for this purpose, mainly because a round hole could be drilled and the cable squeezed through it to make a reasonable seal. Three holes need to be drilled in the bottom of the midrange chamber to allow for cables for the two midrange drivers and the tweeter. Cut suitable lengths of 240 V mains cable and insert these through the holes. Seal between the cables and the holes with sealing compound or a glue like Silastic. If the crossover is to be mounted under the loudspeaker, drill four holes through the bottom of the box and run the cables exactly as with the mid-range enclosure. Drill the holes so that they are closer to the rear of the box to allow ample room for mounting of the crossover. The input terminals should be mounted on the back of the enclosure, below the bottom panel if the crossover is mounted under the loudspeaker.

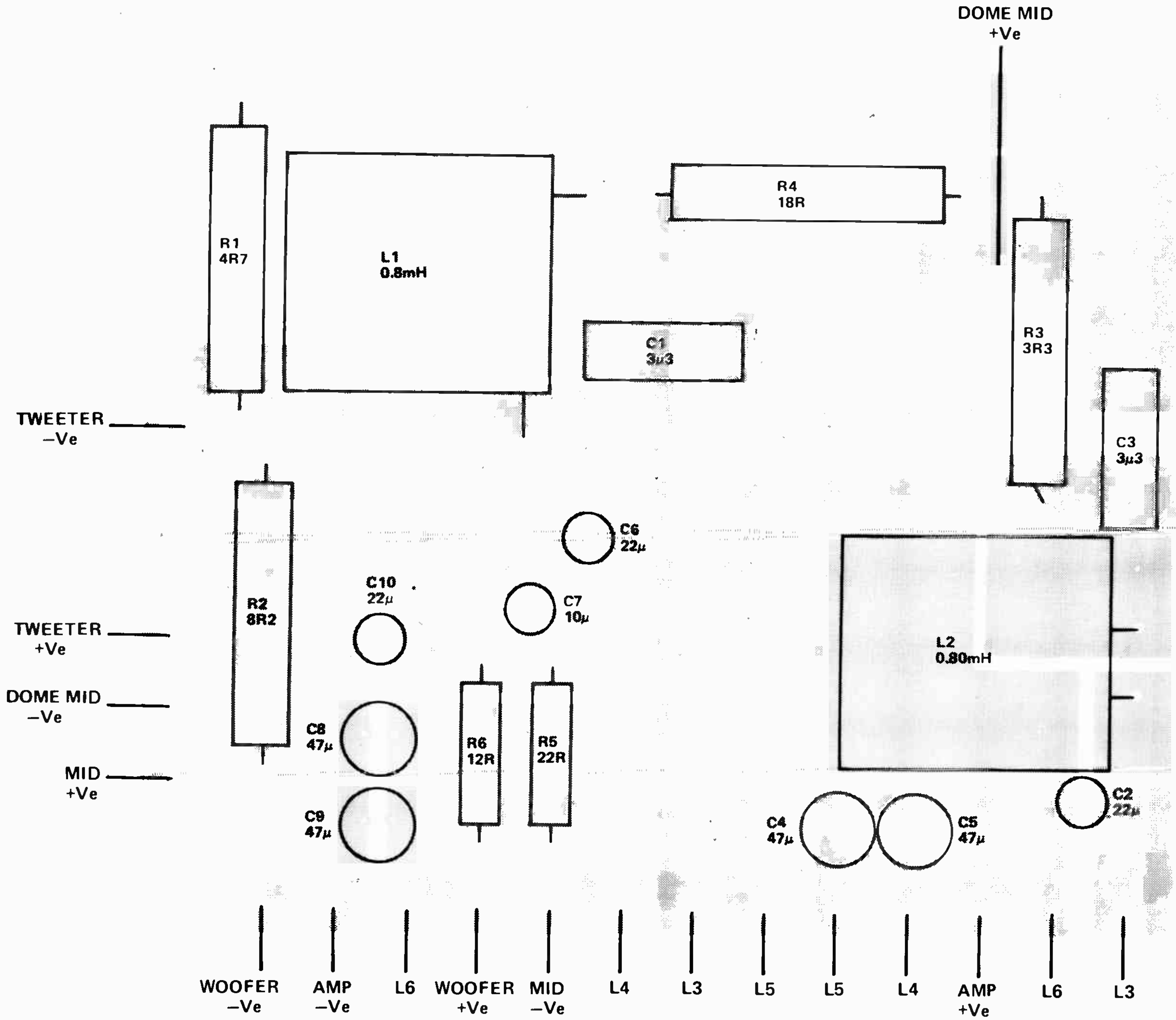
It is not necessary to have the front baffle removable since the drivers are external mounting types. It is probably easier to cut the holes for the drivers before mounting the baffle onto the front of the cabinet. The base panel and midrange enclosure panel should have been cut so that 38 mm remains between these and the front edge of the side and top panels. When the front panel is fitted, 19 mm should remain between the front of the baffle and the front edge of the sides and top. This space will be taken up by the grill cloth frame. Seal the remaining joints between the front baffle and the rest of the box. The only remaining part of the box construction is to attach the small 100 mm high wooden panel to the bottom of the box. The front grill is made by constructing a rectangular frame that fits into the remaining cavity on the front of the baffle. Stretch the grill cloth (use proper speaker grill material to avoid absorption of the treble) tightly over the frame.

If you have purchased a kit of ready made boxes it will still be necessary to drill the holes for the cables and to seal the box thoroughly with some sealing compound. If the slightest leak exists between the bass and mid-range chambers the large pressure increases created in the bass chamber will force the mid-range to vibrate, causing distortion.

The last stage before mounting the drivers is to line the box with 25 mm thick loudspeaker innerbond. Line the back, sides, top and bottom of both the bass and mid-range chambers. Attach the innerbond firmly to the sides of the box using tacks or thin nails and glue.

The tweeter and dome mid-range drivers are supplied with mounting washers so that good seals can be made between the drivers and the baffle. Use adhesive foam tape available from most hardware stores, to make a good seal around the lower mid-range unit and the woofer. Stick the tape to the front of the baffle around the edge of the holes cut for the woofer and mid-range so that when the drivers are mounted a good seal results.

Solder the wires to each of the drivers making sure you know which wire is connected to the positive terminal on the loudspeaker. This terminal is marked on the driver either by a red terminal or a red dot near one of the terminals. Mark the other ends of the cables so that it is clear which cables connect to which drivers. *This is important;* if the outputs of the cross-over are connected to the wrong drivers ▶


DOME MID +Ve
R1 4R7
L1 0.8mH
R4 18R
C1 3μ3
R3 3R3
C3 3μ3
TWEETER –Ve
TWEETER +Ve
DOME MID –Ve
MID +Ve
R2 8R2
C6 22μ
C10 22μ
C7 10μ
L2 0.80mH
C8 47μ
C9 47μ
R6 12R
R5 22R
C4 47μ
C5 47μ
C2 22μ
WOOFER –Ve
AMP –Ve
L6
WOOFER +Ve
MID –Ve
L4
L3
L5
L5
L4
AMP +Ve
L6
L3

this could result in damage to the drivers.

Once all of the drivers are mounted the final stage is the construction and mounting of the crossover. If the crossover is mounted inside, instead of under the box it will be necessary to leave mounting of the woofer until last. After all of the drivers have been mounted connect a 1.5 volt battery to the woofer wires and watch the lower mid-range cone. If it moves, the seal between the bass and mid-range chambers is not complete.

The inductors used in the crossover are too big to be mounted on the pc board. All the other crossover components are on the pc board. Start construction of the crossover by mounting and soldering the capacitors to the pc board. Next solder the resistors into place spacing them approximately 10 mm off the board. This is necessary to prevent charring the pc board should these resistors get hot when the speaker is used with high power amplifiers. The remaining two inductors should be glued onto the pc board and then the leads soldered.

The prototype crossover was mounted on a sheet of aluminium 200 mm by 330 mm, but this is optional. If you elect to use this method of construction screw the remaining four inductors onto the aluminium sheet and solder the leads from these onto the pc board. Solder the leads from the drivers and input terminals onto the pc board and mount the pc board onto the aluminium base using 6 mm spacers. Finally, the whole crossover can be screwed to the bottom of the loudspeaker box. If you are not using the aluminium base the pc board and inductors are mounted directly to the bottom of the loudspeaker box. The advantage of using the aluminium base is so that the crossover can be handled as one complete unit.

PARTS LIST - ETI 496

The following is a parts list for one only loudspeaker so two of every component will be needed for a stereo pair.

Drivers

SP1	Philips AD12250/W8
SP2	Philips AD70601/W8
SP3	Philips AD02161/SQ8 Philips AD02161/SQ8 or AD02160/SQ8
SP4	Philips AD01610/T8 or AD01605/T8, see text.

Inductors

L1, L2	0.8 mH max dc resistance 0.5 R
L3, L4	3.0 mH max dc resistance 0.5 R
L5, L6	12.6 mH max dc resistance 0.7 R

Capacitors

C1	3μ3 polycarbonate
C2	22μ bipolar electrolytic 50 V
C3	3μ3 polycarbonate
C4, C5	47μ bipolar electrolytic 50 V
C6	22μ bipolar electrolytic 50 V
C7	10μ bipolar electrolytic 50 V
C8, C9	47μ bipolar electrolytic 50 V
C10	22μ bipolar electrolytic 50 V

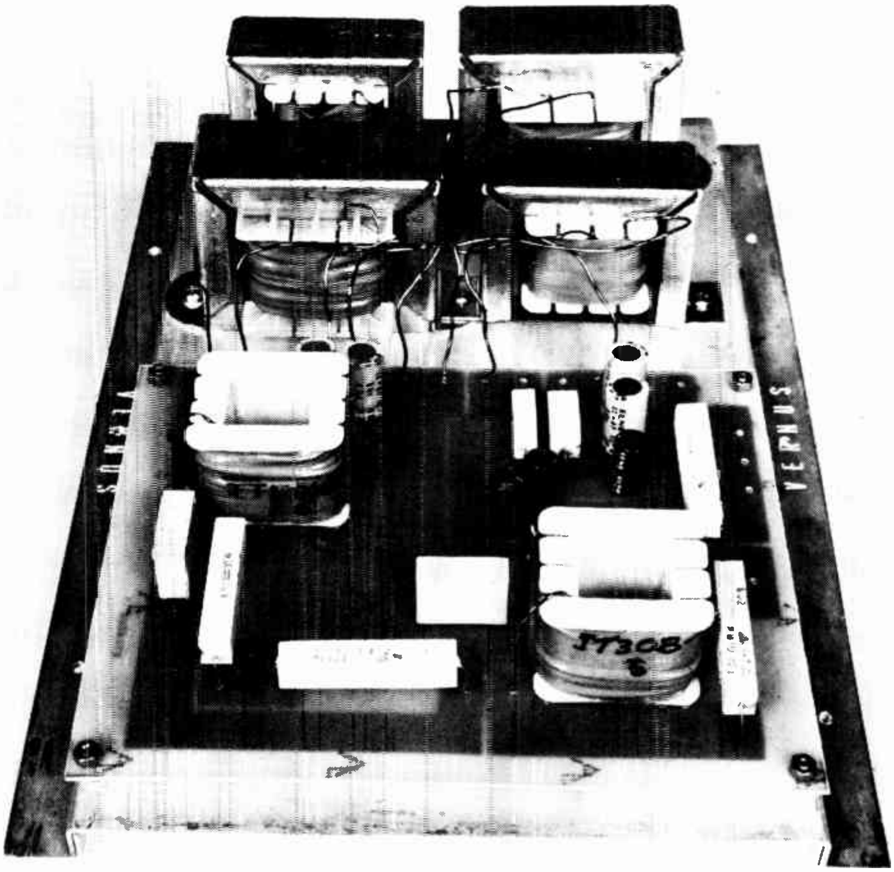
Resistors

R1	4R7 10 W 5%
R2	8R2 10 W 5%
R3	3R3 10 W 5%
R4	18R 10 W 5%
R5	22R 5 W 5%
R6	12R 5 W 5%

Miscellaneous

pc board .... ETI 496

Wire, one pair of spring terminals, particle board, screws, glue, etc. Speaker grill cloth, innerbond.



We mounted the crossover network assembly on an aluminium plate, bent as shown. The whole assembly was then screwed to the bottom of the loudspeaker and each driver connected as per the overlay.

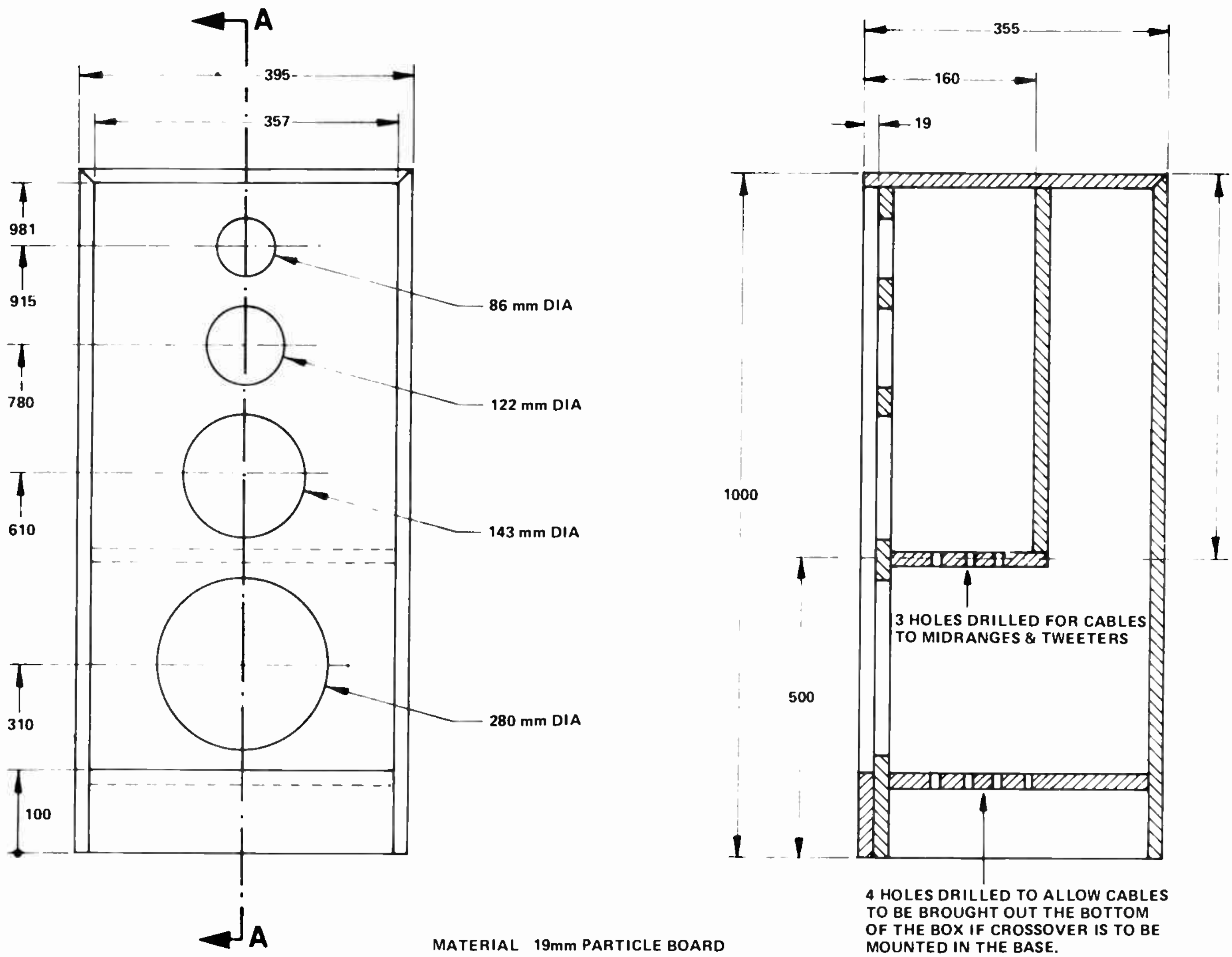
Powering up

Before connecting the loudspeaker to an amplifier touch the input of the loudspeaker to a *single 1½ volt* penlight battery. With the positive of the battery connected to the positive input (red terminal) of the loudspeaker the woofer cone should move forward and the loudspeaker should make a loud thump. Listen to all the drivers separately while connecting and disconnecting the battery to check that all of the drivers are operating. Don't use a battery any bigger than 1½ volts for this test or you could damage the woofer.

If all is well, connect the speakers to an amplifier and turn the volume up slowly.

Performance

Power handling figures for loudspeakers ▶



Complete cutting and assembly details for the four-way loudspeaker box. It is important that all joints be well sealed.

ALL DIMENSIONS ARE IN MILLIMETRES

NOT TO SCALE

SECTION AA

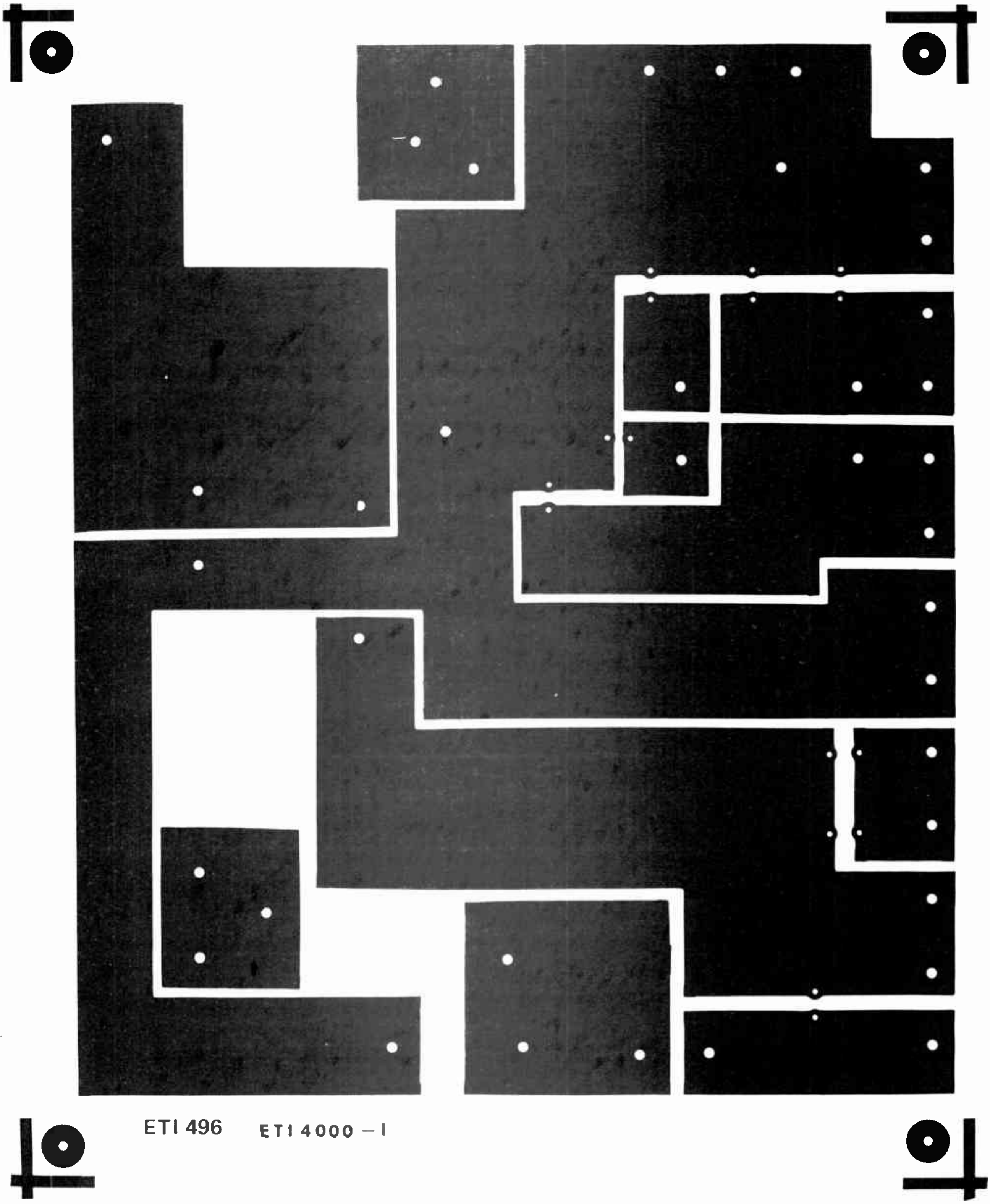
are a very dubious quantity. Some manufacturers (not many) quote continuous sine wave power handling at a particular frequency, but it is doubtful that this is a really meaningful figure. Probably the best way of measuring power handling is with pink noise. This is a type of noise which contains equal energy per octave over the entire audio range. Using this technique, these loudspeakers are rated at 100 watt power handling. The bipolar electrolytic capacitors used in the crossover are rated at 50 volts. This corresponds to 156 watts into an 8 ohm load so this should be considered the *absolute maximum* power for the loudspeaker. It is sometimes mistakenly thought that the power handling figure represents the power below which the loudspeaker cannot be damaged. The most dangerous condition for any loudspeaker is a heavily clipping amplifier. In this state the output of the amplifier approaches dc and even a 20 watt amplifier can do irreparable damage if operated incorrectly.

Your ears are the best indication that the loudspeakers are operating safely. If the sound becomes distorted or unpleasant at higher power levels, turn down your amplifier. Nine times out of ten it will be the amplifier and not the loudspeaker that is running out of power.

The 4000/1 loudspeaker has been designed in accordance with extensive tests that reveal the "ideal" frequency response characteristics for most listening environments. This response is not flat but has a tapered top end, so that the extreme treble is attenuated slightly with respect to the mid-range and bass.

The subjective test revealed just how good the loudspeakers are. The frequency response is smooth and extended and the bass and treble are present only when they should be!

Above all, the sound is clean and easy to listen to for extended periods, even at very high listening levels. I hope you get as much enjoyment from your 4000/1 speakers as I have. ●


ETI 496
ETI 4000 – I

'The Brute' — develops 300W into 4 ohms, 200W into 8 ohms!

Barry Wilkinson

For many audio applications there's no substitute for sheer power — low efficiency speakers, outdoor sound systems, or maybe you like the full flavour of the dynamic range afforded by a high power amp. Whatever your requirement — this 'super power' module should fill the bill.

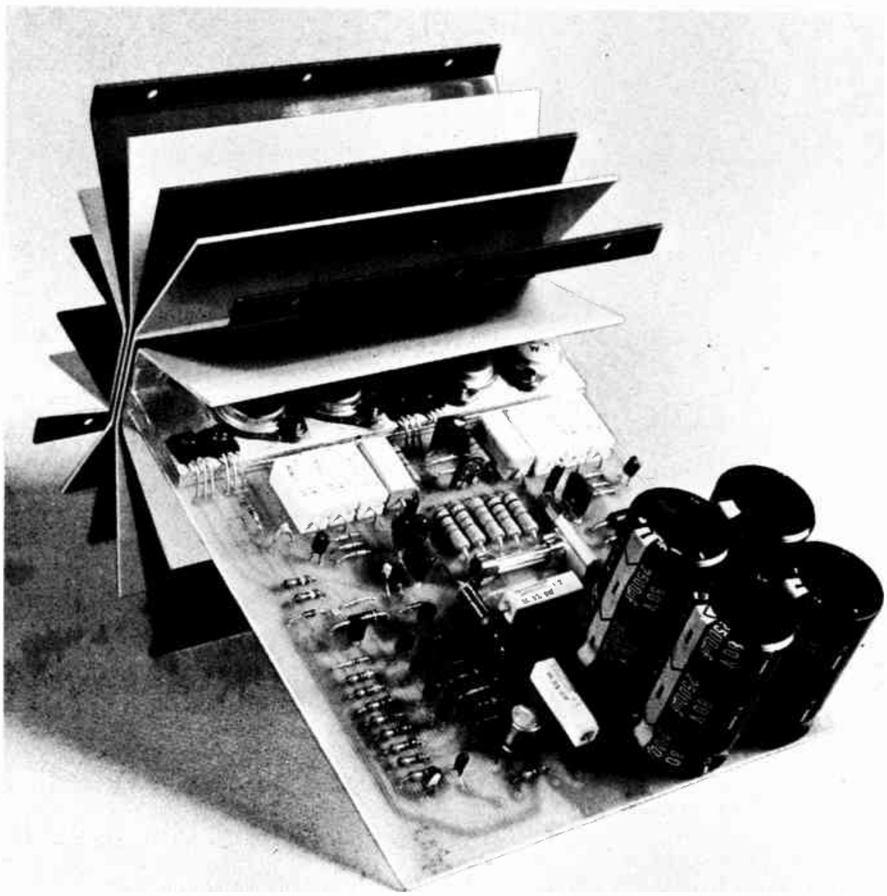
START HERE

Do not pass 'go', do not spend $200

THIS IS a relatively expensive project, compared to our previous amplifier modules, the ETI-480 and the more recent ETI-470. It is not recommended for beginners or inexperienced constructors. Although we have included protection for the output devices in the design it is obviously impossible to protect against circumstances which we cannot forsee. Follow the assembly details and advice given in this article — especially regarding heatsinks and power supplies etc, and you'll be well assured of success. We must *stress* that any deviation from this design, other than the variations suggested, you do at your own risk.

If this is your first experience with such high power don't be embarrassed to follow the instructions slavishly until you are familiar with the unit and get the 'feel' of the technology. Check *everything* as failures can be disastrous, not to mention spectacular, if something goes wrong.

If we haven't put you off by this stage — read on !



SPECIFICATIONS — ETI 466

Power output	
8 ohm load	200 watts RMS
4 ohm load	310 watts RMS
Frequency response	
20 Hz to 20 kHz	+/- 0.5 dB
Hum and noise	
re 200 W into 8 ohm	- 105 dB
Input sensitivity	
8 ohm load	1 V for 200 W output
4 ohm load	1 V for 300 W output
Total harmonic distortion	see graph
Damping factor	
20 Hz - 3 kHz	65
5 kHz	55
10 kHz	45
20 kHz	35

HI-FI AMPLIFIERS are becoming more and more powerful, and with good reason. Modern recordings, especially direct-cut discs, have a useful dynamic range approaching 40 dB between the quieter musical passages and the peaks of the crescendos. If the quieter passages are played at a power output of 100 mW, which is not untypical in a domestic environment, to faithfully reproduce the full recorded dynamic range of a good record without clipping the peaks would require an amplifier capable of delivering 1000 watts! This, coupled with the current trend amongst some manufacturers to build speakers having quite low efficiency, plus the number of people who like their music loud (*and* undistorted) makes the case for high power amplifiers very strong indeed.

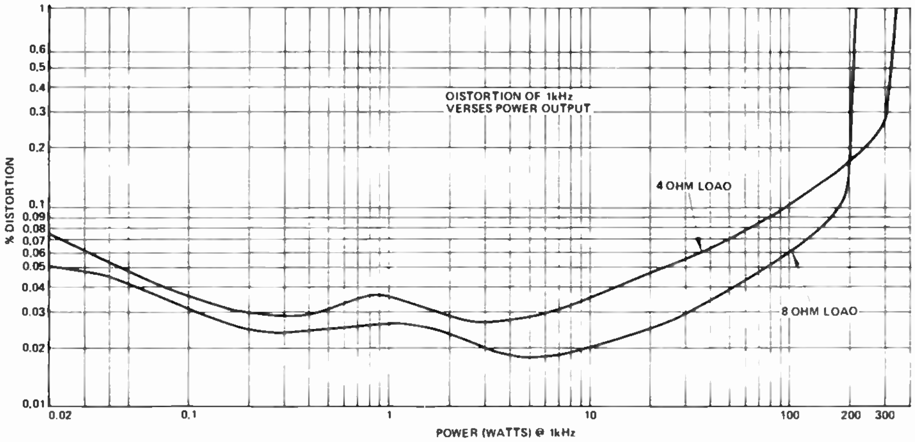
Past amplifier projects have generally been limited to output powers of 50 watts or so. Designed around cheap, readily available transistors, they have proved very popular. We have done the occasional 100 watt amplifier and once described a 'bridge' amplifier capable of delivering 200 watts into an eight ohm load, rather than design an amplifier using expensive, hard to get transistors for that power level.

To gain a worthwhile improvement in subjective performance over an amplifier of 50 watts output, we must go for a four times increase at least, to 200 watts, as the ear has a logarithmic response, and anything less is barely noticeable. That might be stating the case a little simply, but it conveys the general idea.

Over the past six or seven years we've had many requests for a *high* power amplifier, but for the reasons stated previously, we have decided against it. It would have been possible to design a unit using a large number of readily available power transistors in the output – in fact, one design we have seen used a total of 24 devices in the output stage! Difficulties for the home constructor in this approach are obvious, regardless of expense.

For various reasons, a bridge amplifier was ruled out when the design of this amplifier was considered. Hence, a plentiful source of suitable output transistors was first sought.

There are really not too many transistors available that meet the requirements. Firstly, adequate safe operating area (SOAR) is of prime importance. Next, and probably of equal importance, is availability. Let's have a look at the SOAR problem first. Some high power transistors don't compare too well with the ubiquitous 2N3055 (and its complement, the MJ2955) when operated as an amplifier. Take a look at the set of curves plotted on the accompanying diagram. This compares the safe operating area curves of a number of power transistors. Operation of any power device must be confined to the area inside the device's curve at worst case. If the current/voltage operating point is allowed to fall outside the area of the SOAR curve during any part of the operating cycle for the device, it will be destroyed – with amazing rapidity. Now, the 2N3773 and MJ802 transistors have been around for some time and at first glance would seem good choices for a high power amp, but note that their SOAR characteristics are not much better than the 2N3055. In fact, at 40 V (Vcc) the MJ802 is actually worse. In contrast, the MJ15003 is quite a long way outside the curve for the 2N3055 and therefore has a much higher power rating when used in an amplifier. Hence, the MJ15003 and its complement – the MJ15004, were chosen as the output devices for this design. Secondly, these transistors are widely used in industrial applications and are available from a number of sources, thus they meet the availability requirement. See Shoparound on page 160 for more information.

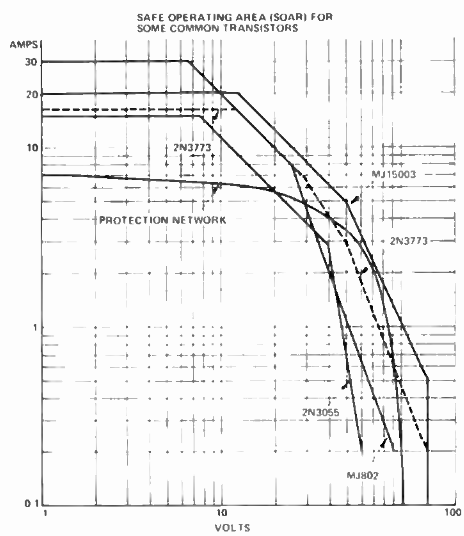


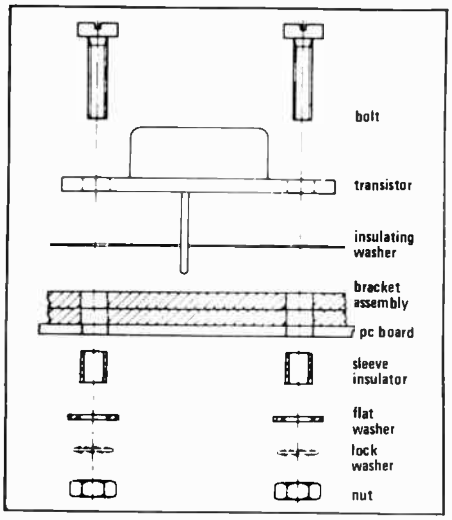
Total harmonic distortion versus power output at 1 kHz. The 'bump' at around 1 W is due to the output stage changing from Class A operation to Class AB operation.

Another problem that arises with a design such as this is protection for the output devices. Amplifiers using transistors such as the 2N3055/MJ2955 can easily be protected with a fuse. In high power amplifiers where supply rails of 60 – 70 volts are necessary, the energy available (from the filter capacitors) will easily destroy the transistor *and* the fuse – in that order. The answer is to use electronic current limiting in the output. This adds complexity, but is cheap insurance against accidental (or deliberate!) abuse. The curve showing the limiting effect on the SOAR characteristics of the MJ15003 for the protection network used in this amplifier is shown on the diagram with the other SOAR curves.

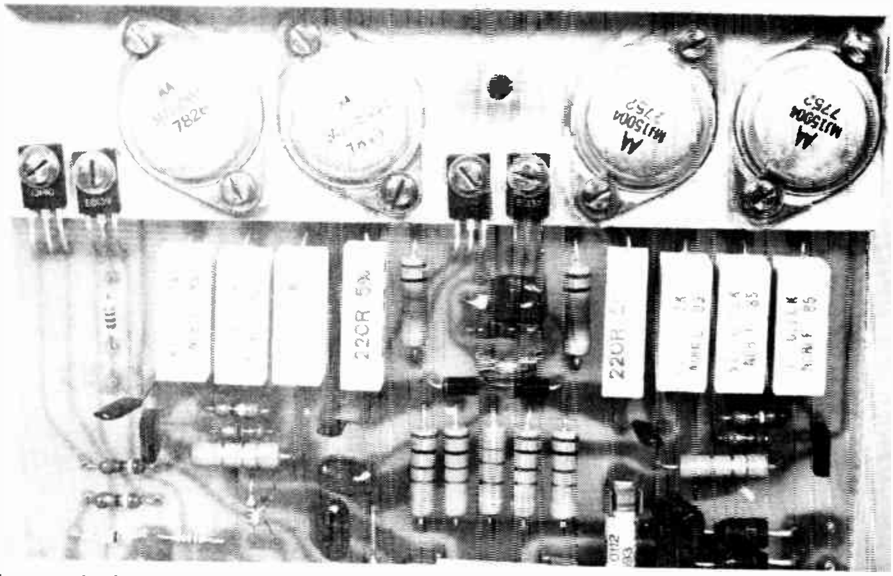
The main cost of the amplifier is in the output stage, transformer and heatsink. We therefore decided to go to a slightly more complex input stage to improve the performance. This type of amplifier usually uses a Class A driver which introduces second harmonic distortion. By using a complementary-differential input circuit we have been able to eliminate the Class A driver and therefore kept the second harmonic distortion very low indeed. The distortion curve shows the distortion is well under 0.1% until almost full power output. The 'bump' in the curve around one watt is the point where the output stage changes from Class A (peak output being less than the bias current) to Class AB operation. ▶

Comparison between the Safe Operating Area characteristics of a variety of transistors, including the MJ15003 used in the output stage of this amplifier.

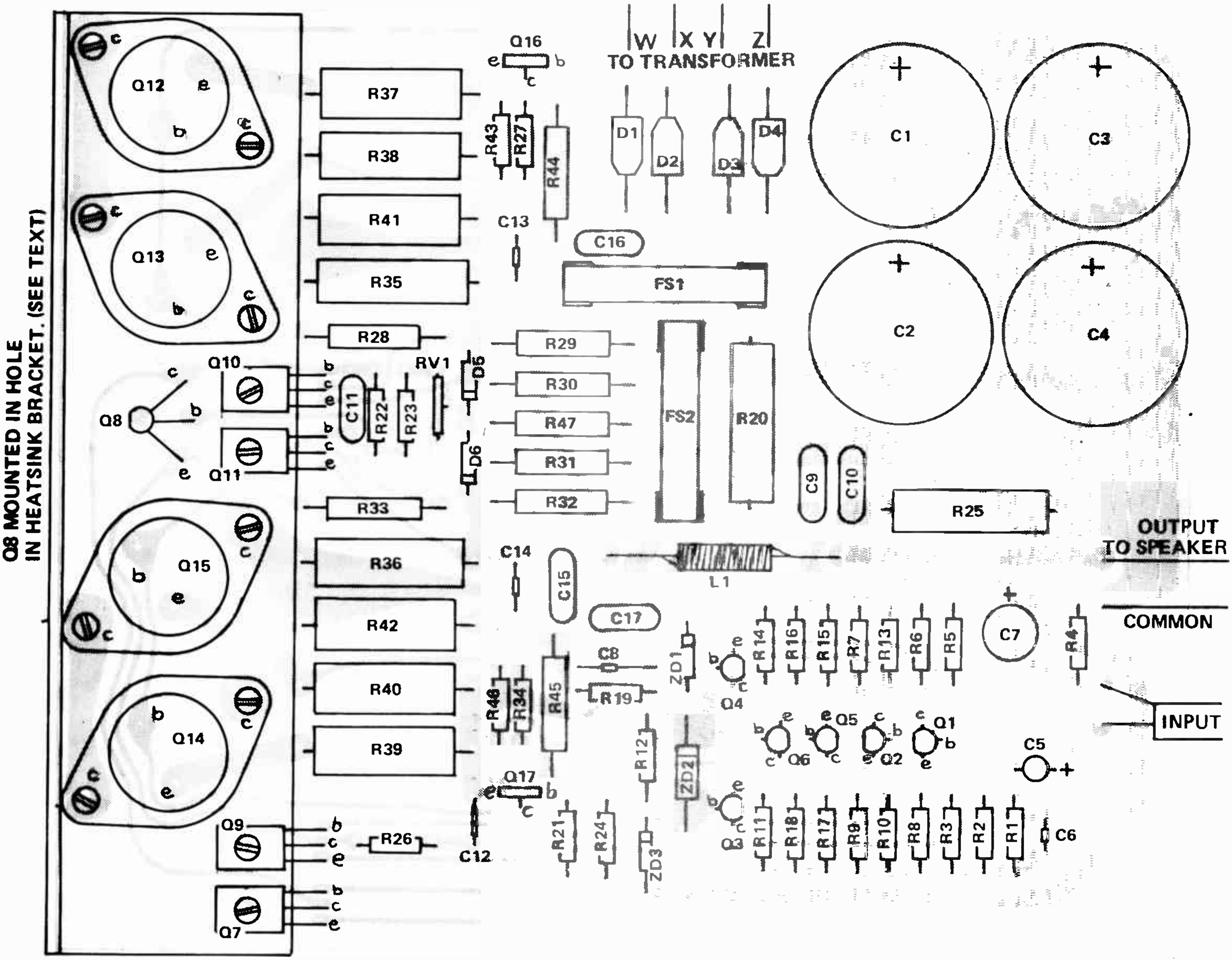




Exploded view of how the TO3 output transistors are assembled to the angle brackets and pc board.



Photograph of the completed output stage, prior to mounting to the heatsink assembly.



The complete amplifier, including the power supply components and output transistors, is assembled on a single pc board. An aluminium bracket holds the output transistors conducting heat from the output stage to the heatsink. Only three sets of external connections are made to the pc board; input, output and power supply ac input from the transformer.

Start the construction by making the aluminium bracket shown on page 49. We used two length of 3 mm angle which may be purchased from Alcan Handyman stores. This bracket is 3 mm thick and two must be placed back to back to make the required 6 mm thickness for adequate thermal conduction to the heatsink assembly. If you elect to use a Philips 65D6CB heatsink (see the box on 'Heatsinks'), a single 6 mm thick angle extrusion can be used, fixed to the flat side of this heatsink.

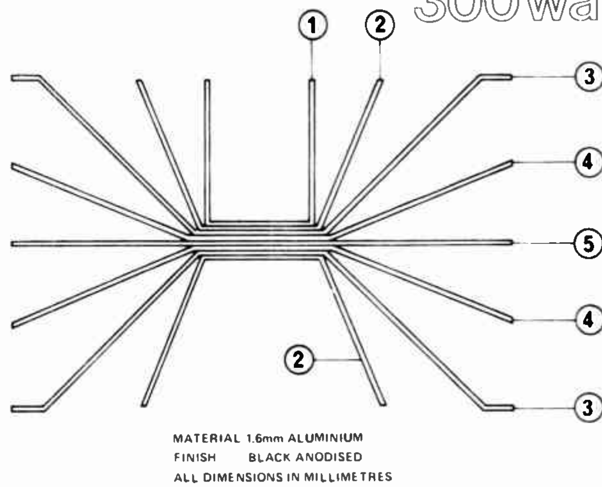
The easiest way to make the bracket assembly and ensure correct alignment of all the holes is to cut the two lengths of angle somewhat longer than necessary. The extra length will be cut off later. Clamp the two pieces back to back and drill a small hole at each end so that they can be clamped together with nuts and bolts through this excess. This allows you to shift the bracket assembly in a vice or what have you without getting them out of alignment. Next, mark out the position of the transistor holes (use the pc board as a guide if you have it to hand already) on the broad side of one bracket and then the holes in the narrow side – the latter secure the bracket assembly to the heatsink. Use a scriber or other sharp-pointed instrument. Then drill the holes.

The hole for the thermal feedback transistor (Q8) *must* be a neat fit. The best way to accomplish this is to drill a slightly smaller hole and carefully enlarge it with the correct size drill. A reamer gives a conical hole and is not really suitable. Those holes marked 'C' on the bracket drawings can be tapped to take a 4 BA bolt if you plan on using the sheet metal heatsink described later.

Once you have drilled all the holes in the bracket assembly, cut off the excess at each end and file the edges smooth. Also, ensure that no 'burrs' are left on the lips of each hole. Chamfer then with a large drill held in your hand.

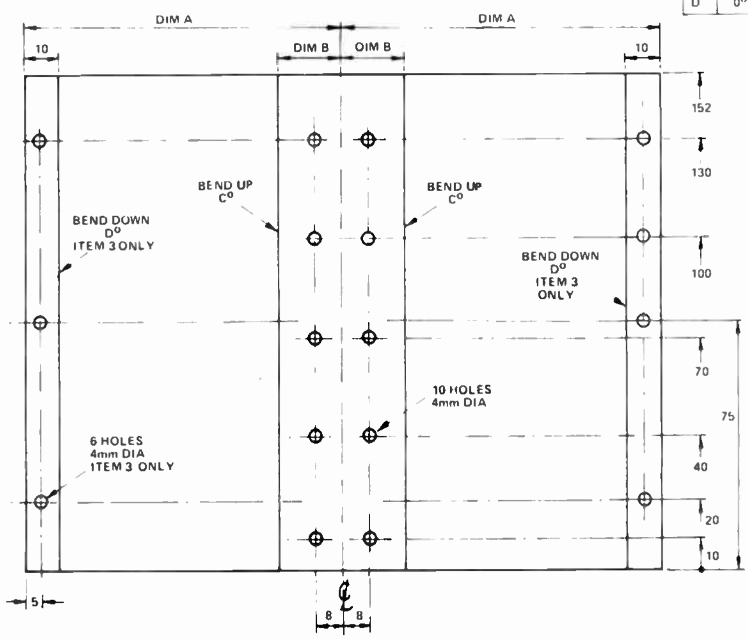
The next step is to make the heatsink assembly – that is, if you're not using one of the commercially-made alternatives suggested.

If you have access to a sheet metal ▶



Dimensions and bending details for the sheet metal heatsink assembly we used.

	ITEMS				
	1	2	3	4	5
A	58	65	95	80	75
B	15	17	19	21	–
C	90°	67.5°	45°	22.5°	0°
D	0°	0°	45°	0°	o



HEATSINKS

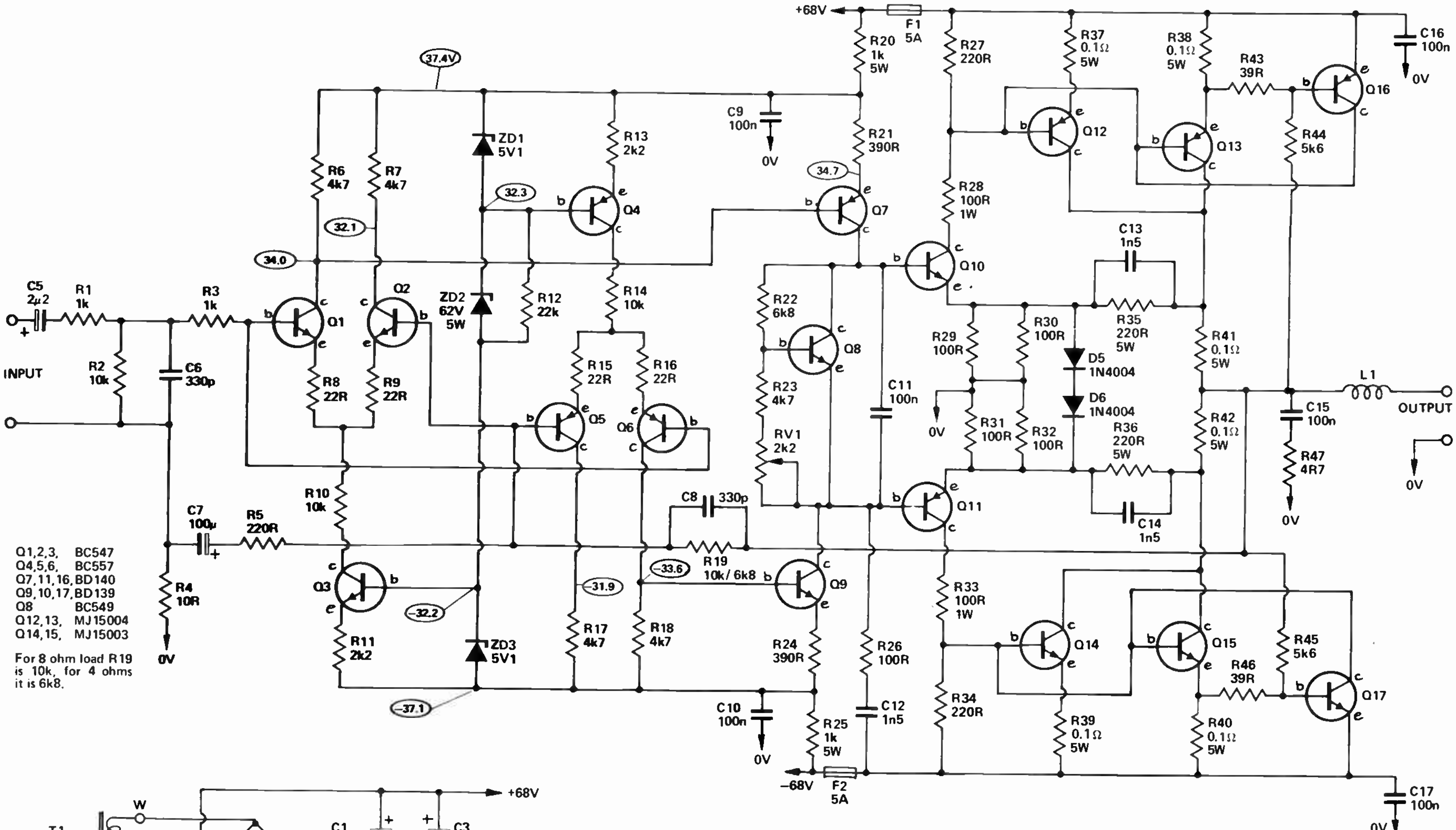
There are several alternatives you can choose from for heatsinking the amplifier output stage. The heatsink described, and shown in the front cover photograph, was made from sheet aluminium and has a thermal rating of 0.55°C/watt. This is the rating we recommend for any heatsink if the amplifier is to drive a four ohm load, particularly for pop group use. If it is driving an eight ohm load in typical domestic use, half the fins may be left out (every second one – the yellow ones!) resulting in a thermal rating for this heatsink arrangement of 0.75°C/watt.

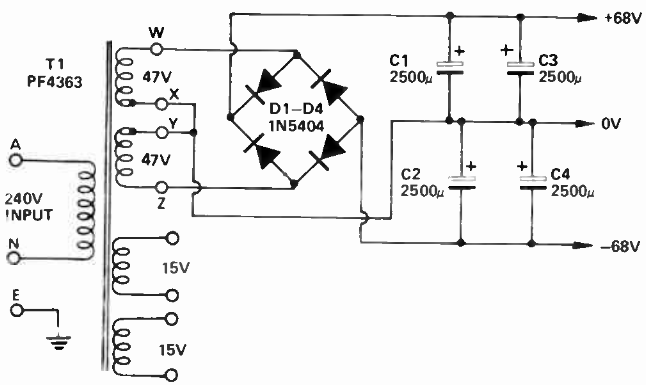
The nearest equivalent in a commercially-made heatsink is a 140 mm length of Redpoint R type – which nobody (to our knowledge) has had the foresight to stock in this country. Tch, tch.

The Philips 65D6CB heatsink has a rating of 0.65°C/watt and would be suitable for this amplifier in most applications, except for a pop group with four ohm loudspeakers, unless fan cooling is added.

A heatsink with about 1°C/watt rating and substantial fan cooling is another alternative.

Remember that dissipation in the heatsink will be about 200 watts at full power output. That means a temperature rise of 110°C above ambient if the amplifier is run continuously. Poached eggs anyone? Temperature rise with music or intermittent use is considerably less, of course, as average power dissipated is much lower.





Complete circuit diagram of the amplifier. Note that L1, not listed in the parts list below, is wound on a 1 W resistor – see text. Voltage readings are included as a guide.

The power transformer shown will power a pair of amplifiers (stereo) driving 8 ohm loads in typical domestic situations, but only a single module under other circumstances, particularly if driving a 4 ohm load.

When supplying two modules from a single transformer simply parallel W, X, Y and Z on each pc board and connect these to the transformer.

For stereo applications use separate earth returns for each speaker to the common on the pc board and separately join the two commons.

If the module is to be used in applications other than a domestic hi-fi set up and driving a 4 ohm load, we recommend you add another MJ15003/MJ15004 pair and associated components. The angle bracket and heatsink assembly will need to be extended.

bender, making your own heatsink is certainly the cheapest way out. The complete drawings are given back on page 45. Referring to these, note that dimension 'A' and dimension 'B' varies for each fin, the appropriate measurements being given in the table accompanying the drawings together with the angle of bend for each fin. Don't forget to allow a small angle for the 'spring' in the metal. Angles can be within a few degrees as they aren't that critical to heatsink efficiency. Don't be too sloppy though.

We used 1.6 mm thick aluminium sheet to construct the heatsink – *do not substitute a thinner gauge.* The bolts which secure the heatsink assembly to the bracket assembly also hold the whole heatsink assembly together.

It is easiest to drill the heatsink fins *before* bending them up, but you *must* mark out and drill the holes *accurately.* Mark one outer fin very carefully. Assemble the fins in order, making sure they are carefully aligned, then clamp the whole assembly and drill right through. Carefully de-burr all the holes.

At this stage you can do a trial assembly of the heatsink and bracket assemblies to see how it all mates – or not. If you have taken care with the drilling, then all should be well. Having confidence in your ability, we shall press on.

If you decide to paint the heatsink rather than having it anodised black, the mating surfaces should all be masked before spraying.

If you intend to use a Philips 65D6CB heatsink, the bracket holes may be marked on the heatsink using the already-drilled 6 mm thick bracket as a template. The holes can be drilled to the root diameter of a 4 BA bolt and suitably tapped.

The whole heatsink 'business' is not assembled at this stage, final assembly comes later. Be patient my little chickens !

The next part is the easy part (! . . . . Ed.). Having got the mechanicals off your chest, the electronics needs attention.

The components may be assembled to the pc board starting with the smaller resistors and capacitors. Carefully follow the overlay drawing. When you come to the 0.1 ohm, 5 W resistors note that they should be mounted about 2 - 3 mm off the board to allow a free air flow around them. Next mount the power supply electrolytics. Note that the recommended types have three pins projecting from the base. This is to provide mechanical rigidity. All three pins are soldered to the board and the capacitors can only be inserted one way round. The inductor L1 is made by winding a layer of 26 swg enamelled wire (or the nearest equivalent gauge) along the body of a 1 W resistor. The number of turns is not critical, just wind enough wire on the resistor to cover the body with one layer. The value of this resistor may be anything over 100 ohms. Two 5 A fuses are mounted on the pc board, held in place with fuse clips.

Next comes the semiconductors.

▼

HOW IT WORKS – ETI 466

The amplifier can be divided into three separate parts. These are: the input stage – which consists of Q1 - Q9, a high gain, low power driver; the output or power stage – which only has a voltage gain of four but enormous power gain; and the power supply.

The input stage is a complementary-differential network, each with its own current source. Each transistor in this stage is run at a collector current of about 0.7 mA. Emitter resistors are employed to stabilize the gain and improve linearity. The output of Q1 - Q6 drives Q7 and Q9. The latter are virtually two constant-current sources run at about 7 mA collector current. With an input signal these 'current' sources are modulated out of phase – the collector current of one decreases while the other increases. This configuration provides quite an amount of gain.

In between the bases of these two transistors is Q8, the thermal sensing - bias transistor. The voltage across Q8 may be adjusted by RV1, thus setting the quiescent bias current for the output stage.

The output stage, Q10 - Q15, has a gain of about five, set by R39 and R29 plus R30. Diodes D5 and D6 prevent reverse biasing of Q10 and Q11 (otherwise the output would be limited.

Protection of the output transistors is provided by Q16 and Q17 which monitor both current and voltage in the output transistors and bypass the base current if the limit is exceeded.

The power supply is a full-wave rectifier, with a centre-tap on the transformer giving the 0 V rail, providing +/- 68 volts. A total of 5000 uF is used across each supply rail for filtering. The amplifier input stage works on a reduced supply rail, derived from ZD1-ZD3 via R20 and R25.

Frequency stabilisition is provided by capacitors C8, 13, 14 and the RC networks R26/C12 plus R47/C15. Frequency response of the amplifier is set by C5 and C7 (lower limit), C8 sets the upper frequency limit.

The transformer has two additional windings of 15 Vac each. These are not used here but are suitable for powering a preamplifier.

PARTS LIST - ETI 466

Resistors all ½W, 5% unless noted

R1	1k
R2	10k
R3	1k
R4	10R
R5	220R
R6, R7	4k7
R8, R9	22R
R10	10k
R11	2k2
R12	22k
R13	2k2
R14	10k
R15, R16	22R
R17, R18	4k7
R19	10k (6k8 for 4 ohm loads)
R20	1k 5W
R21	390R
R22	6k8
R23	4k7
R24	390R
R25	1k 5W
R26	100R
R27	220R
R28–R33	100R 1W
R34	220R
R35, R36	220R 5W
R37–R42	0.1 ohm, 5W
R43	39R
R44, R45	5k6 1W
R46	39R
R47	4R7 1W

Potentiometers

RV1	2k2 trim

Capacitors

C1–C4	2500µ 80V RTP electro
C5	2µ2 35V tantalum
C6	330p ceramic
C7	100µ 25V RB electro
C8	330p ceramic
C9–C11	100n polyester
C12–C14	1n5 polyester
C15–C17	100n polyester

Semiconductors

Q1–Q3	BC547
Q4–Q6	BC557
Q7	BD140
Q8	BC549
Q9, Q10	BD139
Q11	BD140
Q12, Q13	MJ15004
Q14, Q15	MJ15003
Q16	BD140 or BC640
Q17	BD139 or BC639
D1–D4	IN5404
D5, D6	IN4004
ZD1	5V1 300 mW (IN751A)
ZD2	62V 5W (IN5372B)
ZD3	5V1 300 mW (IN751A)

Miscellaneous

ETI 466 . . . . pc board
Heatsink - see text
Transformer PF4363 (47 + 47V - 300 W)
4 fuse clips, 2 x 5A fuses

Leave Q7, 8, 9, 10 and Q11 plus the output stage devices Q12, 13, 14 and Q15 until last. Be *careful* with the orientation of the diodes.

Now you can assemble the heat-sink bracket to the pc board, plus Q7 to Q15 inclusive.

First smear heatsink compound on the two mating surfaces of the bracket assembly. Note that insulating washers are used on all the transistors, Q7 to Q15, mounted on the bracket assembly (except Q8 of course). Smear both sides of each washer with heatsink compound. Place the bracket pieces on the board — component side — and secure Q7, Q9, Q10 and Q11 with nuts and bolts. Only tighten the nuts finger tight at this stage. Now, take the whole board and place the bracket ends against a flat surface — such as the flat heatsink fin — and juggle the brackets until the end faces are flush. Check that all holes line up and then tighten the nuts and bolts.

The TO3 power transistors Q12, 13, 14 and Q15 may now be assembled to the bracket and pc board using the accompanying assembly diagram as a guide. We used spaghetti insulation to sleeve the bolts but pieces of heat-shrink tubing would be better.

Don't solder any leads yet.

Allow time for the heatsink compound to spread under compression and finally tighten all nuts. Last of all insert Q8. Smear the inside of the hole it sits in with heatsink compound to ensure good thermal contact.

Now you can solder all the transistor leads.

Check the component placement against the overlay now, just to ensure all is in order. If you wish, you can test the amplifier up to the driver stages for correct operation before assembling the unit to the heatsink. Remove the fuses before applying ac input from the transformer. Refer to the 'powering up' procedure. If there are any problems, look for errors in component placement or orientation — particularly with diodes. If all is well, assemble the module to the heatsink and you're ready for the big test.

Powering up

The set of output transistors is expensive to replace, therefore we recommend you follow this test procedure in the interest of conserving supplies of same.

The power supply ac input should be connected to the transformer (see the overlay) but no power applied. You'll need a multimeter of at least 20k ohms/V sensitivity.

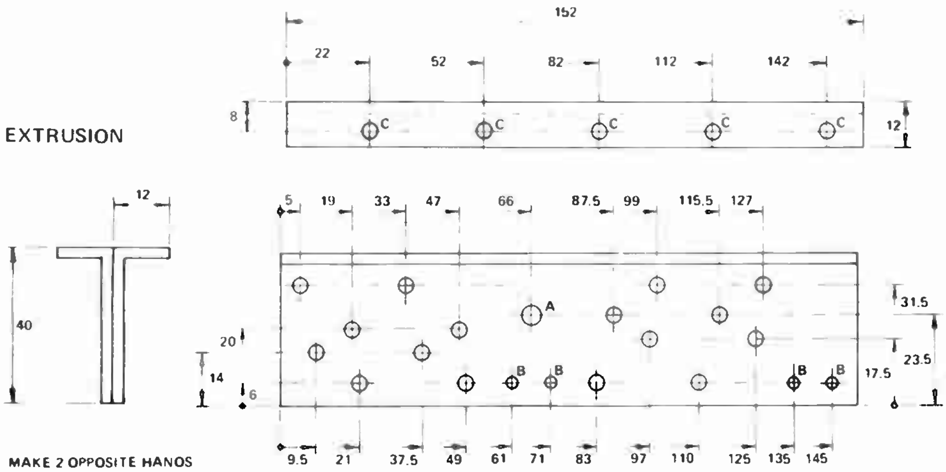
1) Remove the two fuses.
2) Solder a small link across C11.
3) Solder a wire between this link and the output pad.
4) With no load connected and no input signal, switch the power on.
5) Check the supply rail voltages. These should be about 68 volts each (plus and minus).
6) Check the voltages on the cathode of ZD1 (should be about +37 V) and the anode of ZD3 (about -37 V) with respect to 0 V.
7) If these two voltages differ with respect to each other by a volt or so, check other voltages around the input stage to determine the reason.
8) Check the dc voltage on the output (with respect to 0 V). It should be within 20 mV of zero.
9) Inject a sinewave signal into the input at a level of about 20 mV (RMS). Don't use a higher input level. Output should be 1 V RMS.
10) Switch off the main power and allow the filter capacitors to discharge. Remove the input signal.
11) Solder a 10 ohm ½W resistor across each fuse holder. Rotate the trimpot RV1 such that it is set at maximum resistance. Remove the short across C11 and the link from there to the output pad.
12) Switch on. . . . . if the 10 ohm resistors immediately vaporise you either have a short or some fault in the output stage!
13) If all is well, check the dc output voltage. It should be near zero.
14) Measure the voltage drop across one of the 10 ohm resistors placed across the fuse holders and adjust RV1 to give a reading of 1.0 V.
15) Switch off, allow the filter capacitors to discharge and remove the two 10 ohm resistors. Replace the fuses.
16) Connect suitably rated loudspeakers, warn the neighbours, connect a signal source to the input (turn down the volume), switch on the power and put the amp through its paces.

At this stage we'll leave the applications of this module up to you. No doubt you have plenty in mind already. We are preparing a follow-up article to be published in Electronics Today International in which we may cover such things as preamps, bridge operation, design parameters and variations etc. For the moment, our existing preamp designs, such as the ETI-422 and ETI-471 will drive this module quite well.

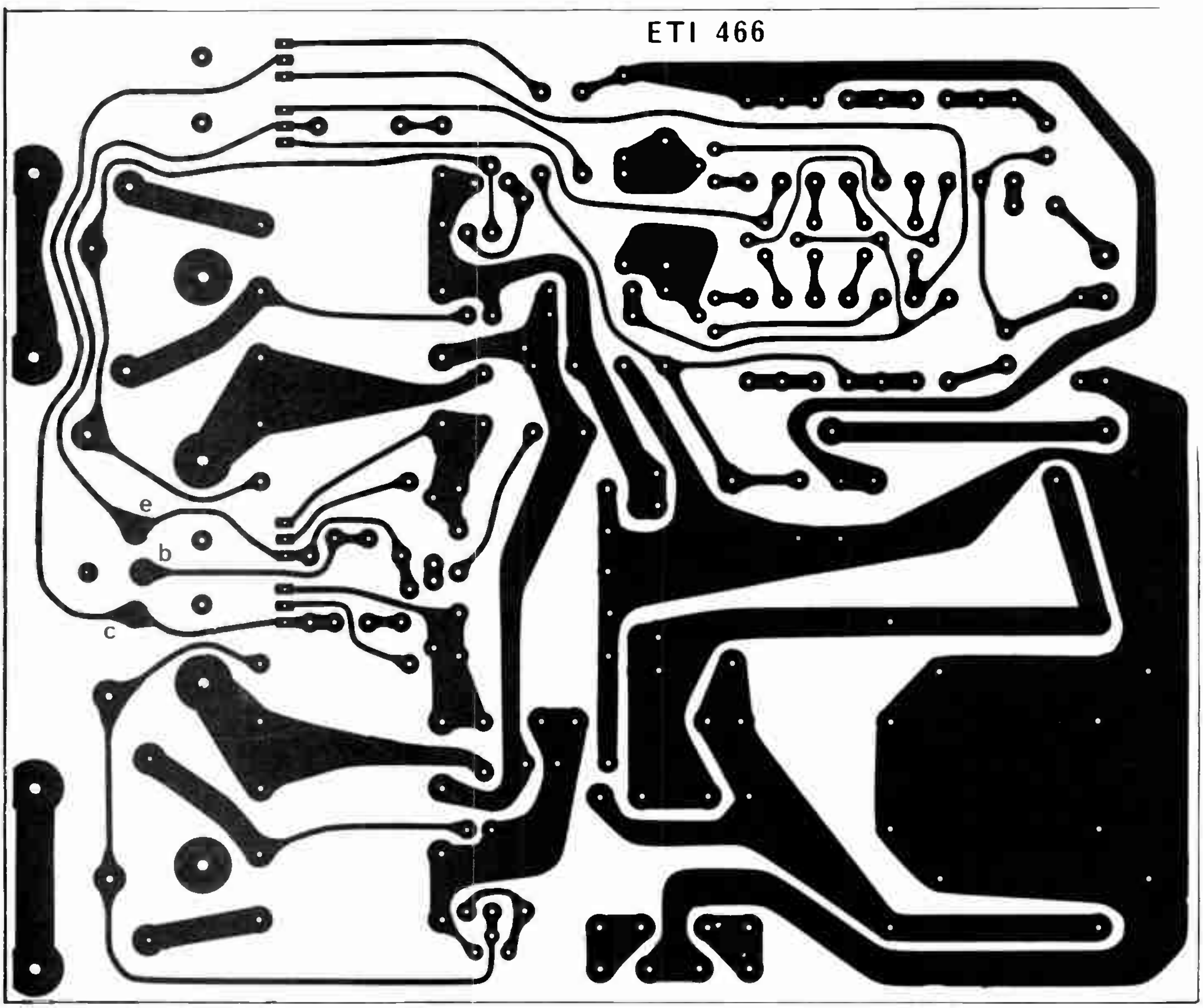
Keep reading.

HOLES MARKED A 4.5mm DIA
HOLES MARKED B 3mm DIA
HOLES MARKED C TAP 4BA OR 4mm DIA
ALL OTHERS 4mm DIA

MATERIAL 40 x 12 x3 ALUMINIUM ANGLE EXTRUSION



Drilling details for the heatsink bracket assembly. All dimensions are in millimetres. Suitable aluminium angle stock is available from Alcan Handyman stores.



Guitar practice amplifier

Simple construction, low cost, good performance and superb neighbour relations are the features of this project!

David Tilbrook

THIS PROJECT has been designed to enable guitarists to put in long hours of practice and still keep that high power amp in the cupboard, where it belongs! It is a compact amp capable of about 7W into a 4 ohm load. This is enough power for practice purposes and just think of the greatly improved relations you will have with your neighbours.

We were in a considerable quandary as to how to present the project, whether it should be done as a complete practice unit with inbuilt speaker or simply as an amplifier to be connected to an external speaker. Finally we chose a compromise. The pc board has been designed in such a way that it can be used as a totally self-contained unit. The heatsinks for the output stage have been mounted on the pc board so that the only components separate to the board are the power transformer, 240 volt power switch controls, input and output jacks. We have shown the project mounted in its own box with power transformer but it should be a simple matter to construct the whole unit inside a small loudspeaker cabinet.

The unit has two inputs so that two guitars can be mixed together using the relative settings of the two input level controls. A pre-amp output enables your main high power amp to be driven from the guitar practice amp using the practice amp as foldback.

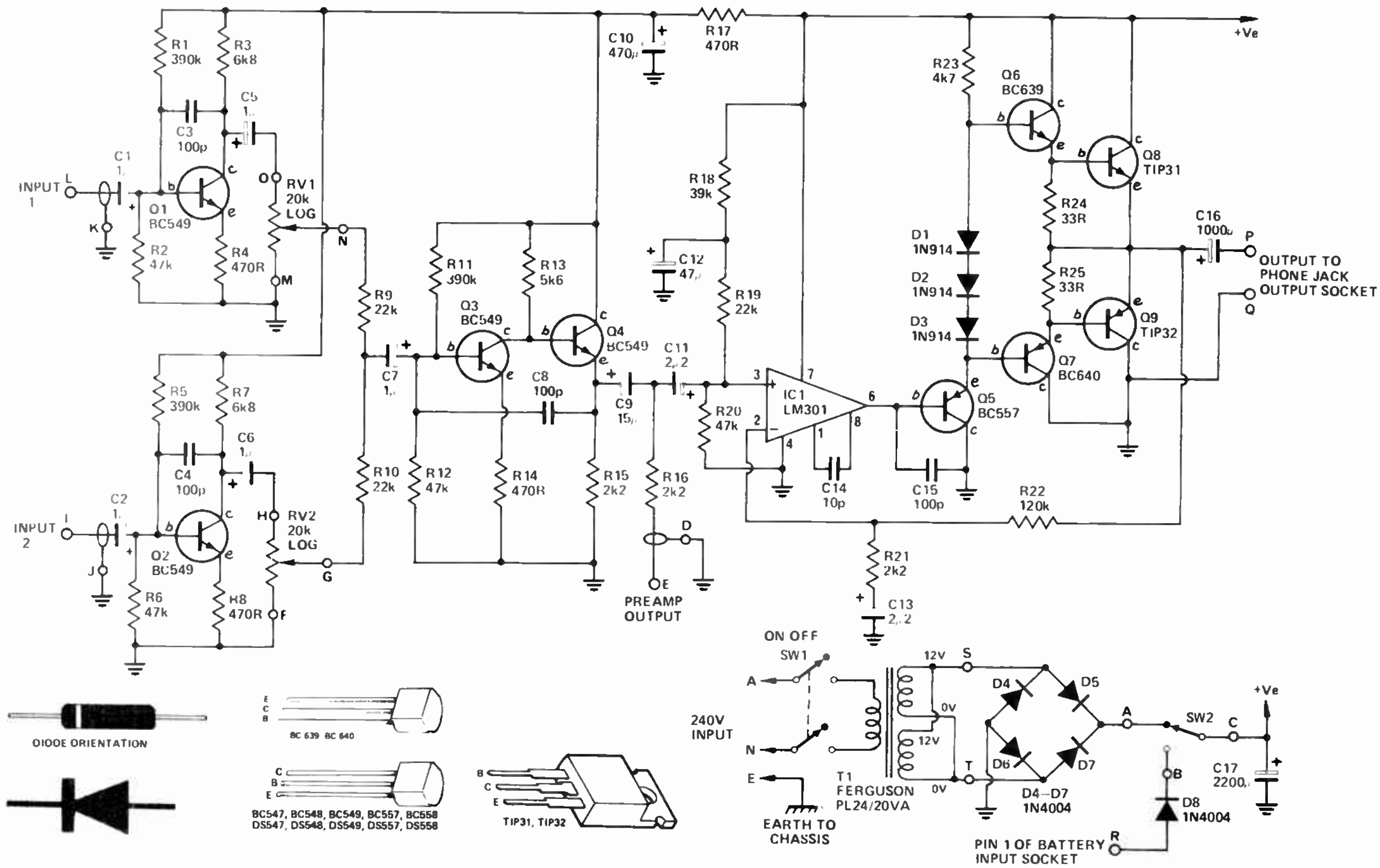
We provided the pc board with the necessary circuitry for a battery input but you might elect not to use this feature. If so diode D8 and the battery switch can be omitted with points 'A' and 'C' connected together by a wire link.

Construction

Construction of the project is reasonably simple since it is almost entirely devoted to construction of the pc board. Start as always by mounting the resistors and non-polarised capacitors. Mount the tantalum and electrolytic capacitors next, being careful to orient them correctly. These components could be irrepairably damaged if inserted the wrong way around. Mount the LM301 IC transistors and diodes, again being careful to insert these the correct way round. Finally the output devices can be mounted. Cut the centre (collector) lead off. This lead is connected to the case of the transistor internally, so in this case, electrical connection is made through the mounting screw that also serves to hold the heat sink in place. Place the heatsinks on the pc board and secure with the lower nut and bolt (not used to mount the transistors). Bend the leads of the output transistors and, using a small amount of thermal compound (non-toxic, such as Bevaloid GS13), mount the transistors with the leads protruding through the pcb.

Secure each transistor with a nut and bolt through both the transistor 'flag' and heatsink. Use a star washer between the head of the bolt and the copper pad on the pc board to ensure good electrical contact.

The prototype unit was constructed in a steel box measuring approx. 250 x 210 x 80 mm. Mount the pots and



HOW IT WORKS

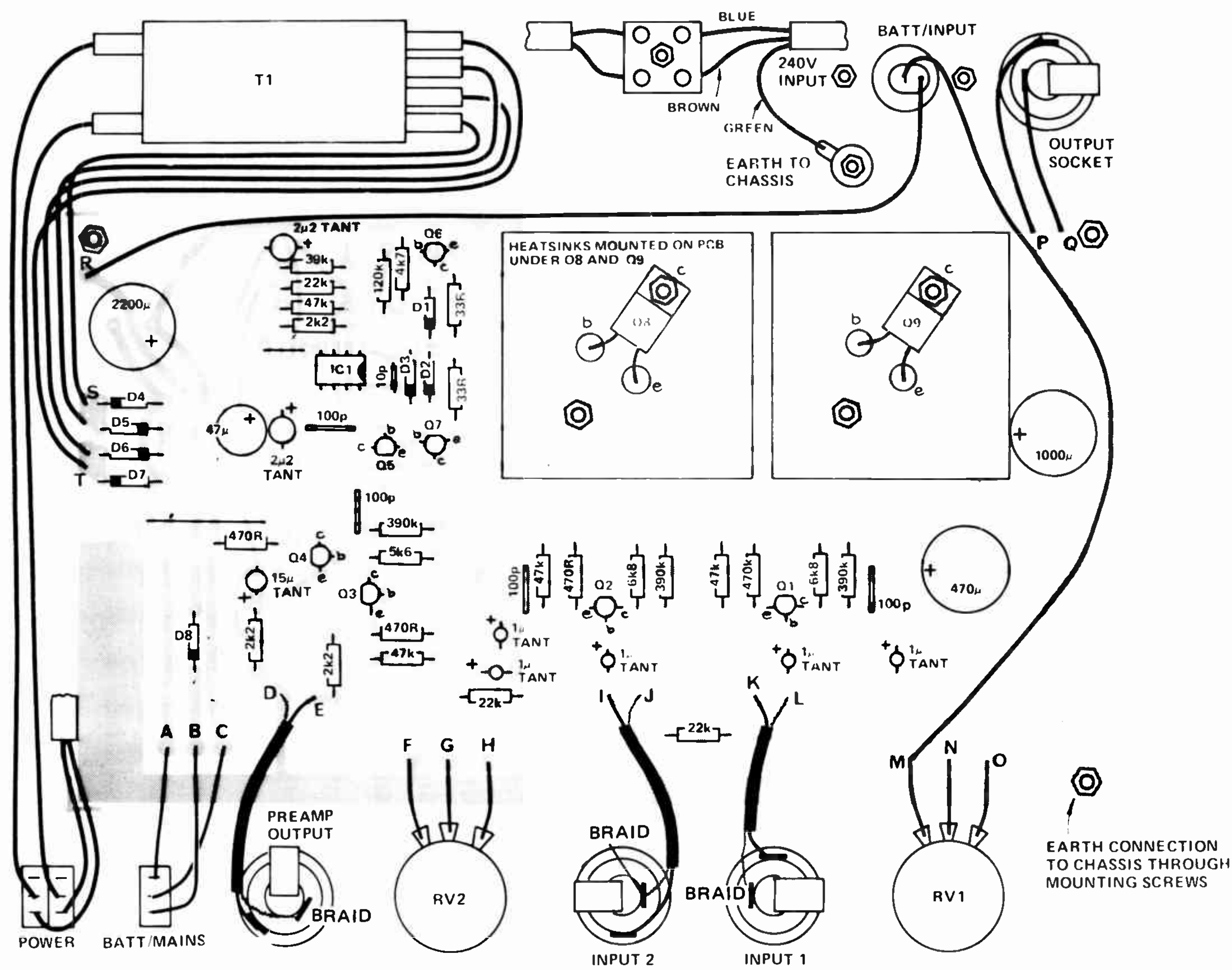
The two input stages formed around Q1 and Q2 are identical. Resistors R1, R2 and R4 form a very stable biasing configuration around Q1. The gain of this type of circuit is determined by the values of R3 and R4 (specifically, the gain is R3/R4). The load impedance on the output of the input stages is in parallel with R3, effectively decreasing the total value of impedance from collector to ground. Remember that, as far as signal is concerned, the positive supply rail is a short circuit to ground, since it is connected to ground through a 2200 uF capacitor. When all these factors are taken into account the gain of the first stage is about 10 since the impedance from collector to ground is about 4k7.

The signal which should be around 200 mV is then applied to the input of the second stage through potentiometers RV1 and RV2. The 22k resistors R9 and R10 prevent the output of one of the stages being shorted to ground when the other is turned right down.

The second stage works in exactly the same manner as the input stages; resistors R11, R12 and R14 forming the bias network for Q3. The voltage present on the collector of Q3 is around 9V which is approximately half the supply voltage. This is used to bias Q4 which is an emitter follower. This type of amplifier has no voltage gain but provides a low output impedance to drive the pre-amp output socket. Q3 has a gain of approx. 10. If the volume controls RV1 and RV2 are used in their middle positions the voltage out will be around one tenth of the voltage at their inputs since these are logarithmic pots. So, the signal voltages into Q3 should be in the order of 20 mV. This will be amplified to a level of 200 mV and applied to the input of the power amp. The power amp has been designed to deliver full power with an input voltage of 300 mV, so the amp should be easily driven to full output.

Since this is a guitar amplifier, it will spend most of its life hard into clipping. The output stage had to be robust! The basis of the output stage is the LM301 IC op-amp. This device gives all of the voltage gain in the power amp. The output of the IC is fed through a voltage follower Q5. This has no voltage gain and, like Q4, serves to decrease the impedance feeding the output stage. The three diodes, D1, D2 and D3, maintain 1.8 volts between the bases of Q6 and Q7. Each of these transistors will drop approximately 0.6 volts across their base-emitter junctions. This leaves a total of 0.6 volts to be dropped by the two 33R resistors, R24 and R25. Since these are of equal value they will each drop 0.3 volts and hold this voltage across the base-emitter junctions of the two output transistors Q8 and Q9. As these transistors require 0.6 volts to turn on they will remain off until the applied signal voltage causes the voltages on their bases to rise above 0.6 V. The extra 0.3 volts needed to turn on the output devices will be supplied by a mere 10 mA of current through the 33R resistors. Resistor R22 forms a feedback loop around the entire output stage to decrease distortion, stabilise the dc output voltage and set the overall gain of the power stage. (A process too difficult to go into here).

The op-amp will at all times attempt to make the dc voltage at the output equal to that voltage set up on its positive input. This voltage is determined by the potential divider formed by R18, R19 and R20. Since this is also the main input to the power amp any noise which might be on the positive supply rail (and supplies can get very noisy sometimes!) will be communicated directly to the input of the power amp, only to be amplified and applied to the loudspeaker. Capacitor C12 prevents this from happening by bypassing to ground any noise above a frequency of around 0.1 Hz.



PARTS LIST - ETI 452

Resistors all ½W, 5%

- R1 . . . . 390k
- R2 . . . . 47k
- R3 . . . . 6k8
- R4 . . . . 470R
- R5 . . . . 390k
- R6 . . . . 47k
- R7 . . . . 6k8
- R8 . . . . 470R
- R9, R10 . . . . 22k
- R11. . . . . . . 390k
- R12. . . . . . . 47k
- R13. . . . . . . 5k6
- R14. . . . . . . 470R
- R15, R16 . . . 2k2
- R17. . . . . . . 470R
- R18. . . . . . . 39k
- R19. . . . . . . 22k
- R20. . . . . . . 47k
- R21. . . . . . . 2k2
- R22. . . . . . . 120k
- R23. . . . . . . 4k7
- R24, R25 . . . 33R
- RV1, RV2 . . . 20k log potentiometer

Capacitors

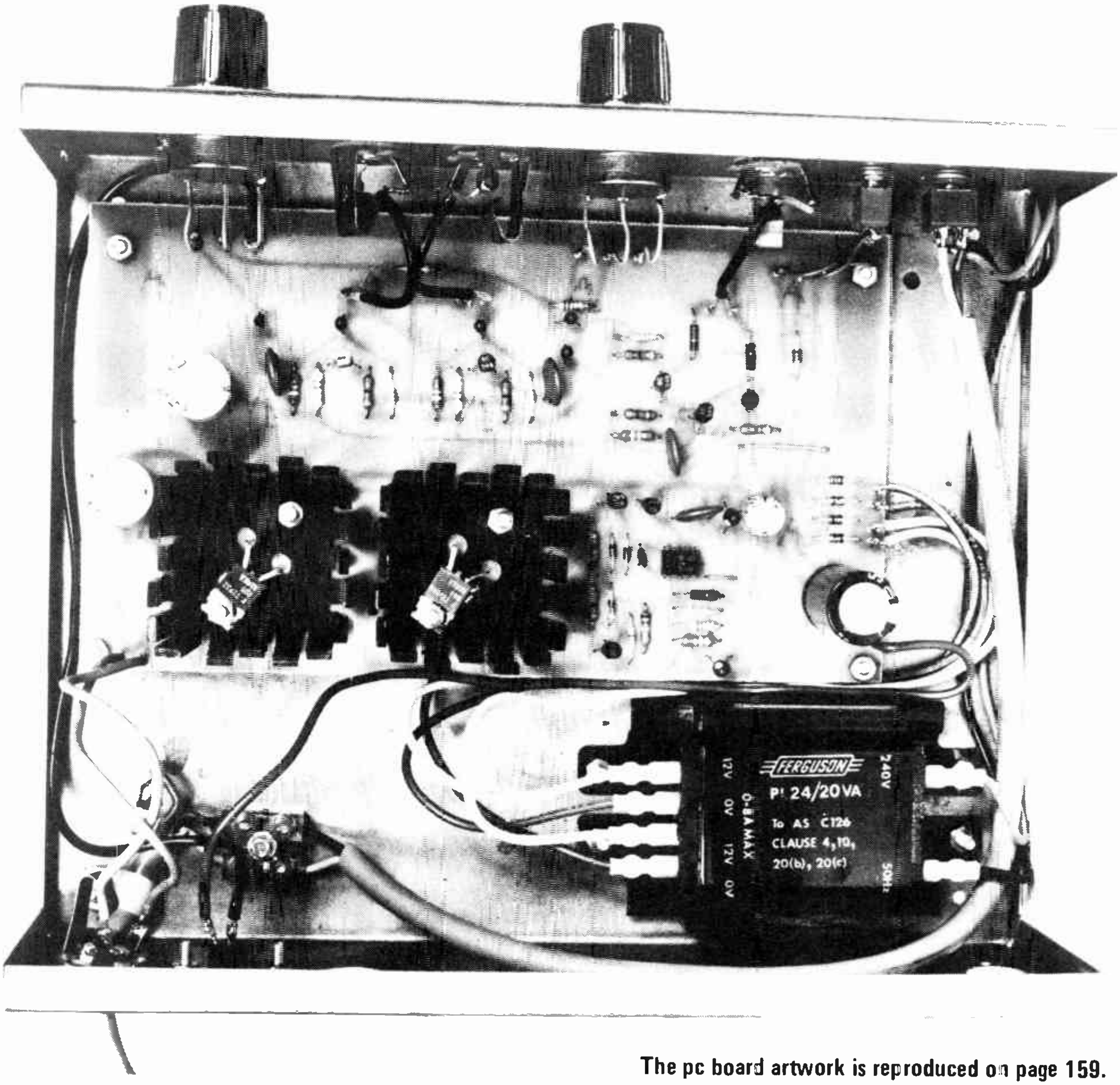
- C1, C2 . . . . . 1μ 35V tantalum
- C3, C4 . . . . . 100p disc ceramic
- C5—C7 . . . . . 1μ 35V tantalum
- C8. . . . . 100p disc ceramic
- C9. . . . . 15μ 16V tantalum
- C10. . . . . . . 470μ 25V electrolytic
- C11. . . . . . . 2μ2 35V tantalum
- C12. . . . . . . 47μ 25V electrolytic
- C13. . . . . . . 2μ2 35V tantalum
- C14. . . . . . . 10p disc ceramic
- C15. . . . . . . 100p disc ceramic
- C16. . . . . . . 1000μ 25V electrolytic
- C17. . . . . . . 2200μ 25V electrolytic

Semiconductors

- Q1—Q4. . . . . BC549, BC109, DS549
- Q5 . . . . BC557, BC179, DS557
- Q6 . . . . BC639
- Q7 . . . . BC640
- Q8 . . . . TIP31
- Q9 . . . . TIP32
- D1—D3. . . . . 1N914
- D4—D8. . . . . 1N4004
- IC1 . . . . LM301 op-amp

Miscellaneous

Box to suit, pc board - ETI 452, power transformer 12V @ 1.5 amps Ferguson PL24/20VA or similar, 2 x TO3 type heatsinks for pc board mounting, mains flex and plug, 2 pin DIN sockets (chassis mounting, speaker socket), DPDT 240V switch (power on/off), DPST switch (battery/mains switch), four phone jacks (mono), two knobs, grommets, nuts, bolts, pc board pins, four pc board mounting spacers.



The pc board artwork is reproduced on page 159.

switches to the front panel, using the pot and switch nuts to secure the front escutcheon if you have one. Mount the output and battery input sockets on the rear panel. If you are using a battery input socket use something different to the output socket (which is usually a two pin DIN socket or a 6.5 mm jack socket) to avoid confusion.

Mount the power transformer and make the 240 volt connections. The mains lead should be terminated immediately inside the case into a terminal block and the earth lead secured firmly to the chassis by a solder lug bolted to the case using a star washer. This lead must be the longest. A length of 240 volt cable should be used between the terminal block and the power switch. The Ferguson transformer specified comes supplied with cables to make its 240 connections. Solder these to the power switch as shown in the wiring diagram, then wrap the whole switch with insulation tape or enclose in large diameter heat shrink tubing so that no 240 volt connection is exposed.

Finally, the fully-loaded pc board can be secured into the case using short metal spacers. If pc board pins are used, all the connections to the board can be made after the board has been mounted. Connect the front panel controls, rear panel sockets and input sockets as shown in the wiring diagram. Use short lengths of shielded cable to make the connections to the two inputs and the pre-amp output.

Powering up

Make a final check of the wiring and pc board. If all is well, apply power. A slight turn-on· thump should be heard at the moment of turn on. If the 'Input 1' volume control is now wound up some hiss should be heard from the loudspeaker. Do the same check on the other input. There is no set up procedure since the power amp stage is operating in class B and requires no bias adjustment. ●

Speaker protection unit saves a saddening experience

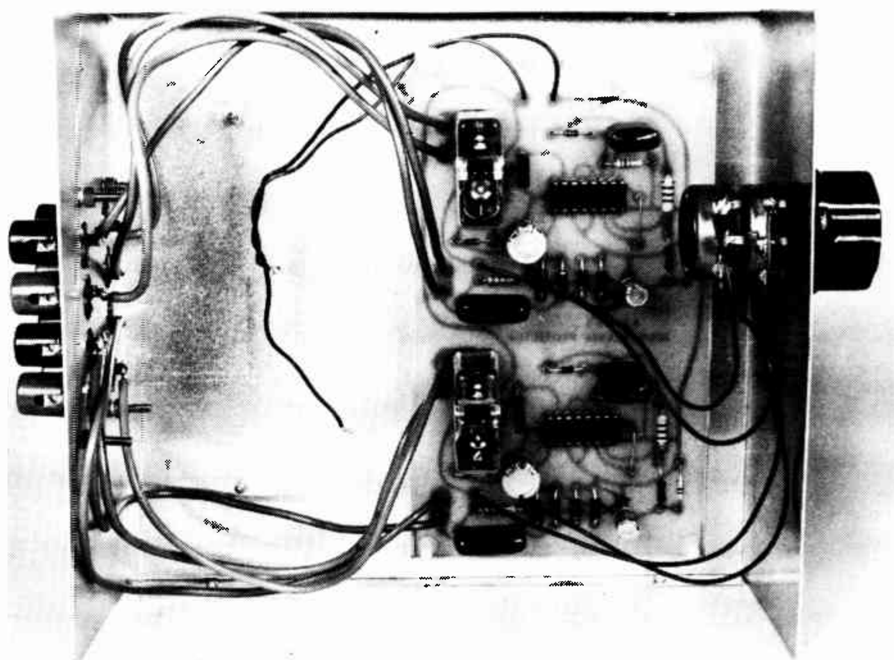
An expensive speaker system can be readily destroyed by a 20 watt amplifier. Carelessness with a high power amplifier (like the ETI-466 for example) can melt voice coils like cheese on toast. We know . . .

David Tilbrook

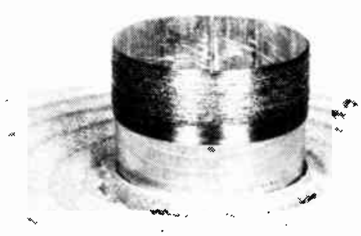
MODERN TRANSISTOR power amplifiers use the technique of dc coupling between the low level amplifier stages and between the output stages and the loudspeaker. This has the advantage of removing coupling capacitors from the signal path, decreasing parts count and improving performance at low frequencies.

Older transistor amplifiers used a single supply rail so the transistors operated between the supply voltage and ground. Since an ac signal has both negative and positive excursions the power amp was designed so that a dc voltage was present on the output stage. Positive excursions would cause an increase of this dc voltage while negative excursions decrease the voltage. Since dc cannot be applied directly to a loudspeaker it was necessary to insert a capacitor, called a blocking or output capacitor, between the output stage and the loudspeaker. The load impedance of the loudspeaker is around eight ohms so the capacitor has to be 5000 μF to 10 000 μF before an acceptable low end performance can be obtained.

The solution to these problems was dc coupling. The power amp is run from a 'split supply' so that the output transistors are supplied from a positive and negative supply voltage. The average of these supply rails is zero volts, so the output can be connected directly to the loudspeaker. Both positive and negative excursions are possible due to the split power supply.



Internal view of the speaker protector. We mounted the unit in a 'Deluxe Metal Cabinet" from Dick Smith measuring 184 x 160 x 70 mm, but you can choose any similar size cabinet to suit your equipment or even mount single units in your loudspeaker enclosures with preset controls.



What happens *without* the speaker protector.

Unfortunately, dc coupling also has its disadvantages. The biggest of these is the possibility of damage to the loudspeakers in the case of power amp failure. Since all the stages are dc coupled, a fault anywhere in the power amp can cause the output stage to swing hard against one of the supply rails. The most common power amp fault is a condition in which one or several of the output or driver transistors is destroyed, and this almost always causes the full dc voltage from one of the supply rails to be applied directly to the loudspeaker. The loudspeaker cone is slammed against the suspension and the power dissipation in the voice coil causes a rapid increase of voice coil temperature. In this condition most woofers will survive for only a few seconds. The most dramatic example of this fault I have seen was in a very expensive pair of three-way loudspeakers. They had been connected to a high power tuner-amplifier (150 W/channel) when the output stage had gone faulty. The entire inside of the speaker was one charcoal mass (much to the horror of the owner). The temperature increase in some of the crossover components had set fire to the stuffing inside the box, totally destroying the crossover and drivers.

This type of fault is all too common and is the most expensive fault likely to ▶

occur in a modern hi-fi system. Some top line amplifiers have built in protection circuits with relays that disconnect the loudspeakers should this condition occur, but these are the minority.

This project is an attempt to remedy this situation. The circuit 'looks' at the loudspeaker wires and protects the loudspeakers in two ways. The presence of any dc automatically trips the relay and disconnects the loudspeaker. The protector also looks at the amount of power applied to the loudspeaker. It allows high power transients but will disconnect the loudspeaker if the applied power exceeds the loudspeaker rating for more than about 50 milliseconds. In this way the advantage of the improved high power amplifiers is not lost but the loudspeaker is still protected. The circuit includes a two-second monostable delay circuit so that the loudspeaker is automatically reconnected approximately two seconds after the 'fault condition' has been removed.

The project is designed around two standard CMOS ICs. This ensures a very low current consumption and obviates the need for a power switch. This is important since a fault with an amplifier could well occur at the moment of turn-on and it is essential that the loudspeaker protector is already on. When the relay trips, the circuit pulls around 50 mA for each relay so it is important that battery is capable of supplying 100 mA during relay operation. For this reason, the battery specified for this project is an Eveready 276-P or equivalent. There should be no problem with the battery lasting for its shelf life, providing the relays are not tripped more than very occasionally.

Construction

Start construction with the pc board. Solder the resistors capacitors, diodes and relay first. The diodes and electrolytic capacitors must be inserted the right way round as shown on the pc board overlay. Lastly, solder the transistors and ICs on the board. Again, these devices must be oriented correctly.

The prototype was constructed in a general purpose steel box but this is not critical. The front panel is fitted with a stereo 100k potentiometer. This sets the trip point of the protector so that it can be adjusted for your particular loudspeakers. The rear panel holds the terminals for the wires from the amplifier and loudspeakers. I used two four-way spring terminals. The wiring to the rear panel and to the front potentiometer is shown in the wiring diagram.

Finally, make the connection to the battery. Probably the best way to do this is to screw two self-tapping screws into the battery terminals and solder the wires between these and the pc board. The pc board should be mounted on spacers in the case. Plastic pc board stand-offs are ideally suited for this project as the pc board is small.

Testing

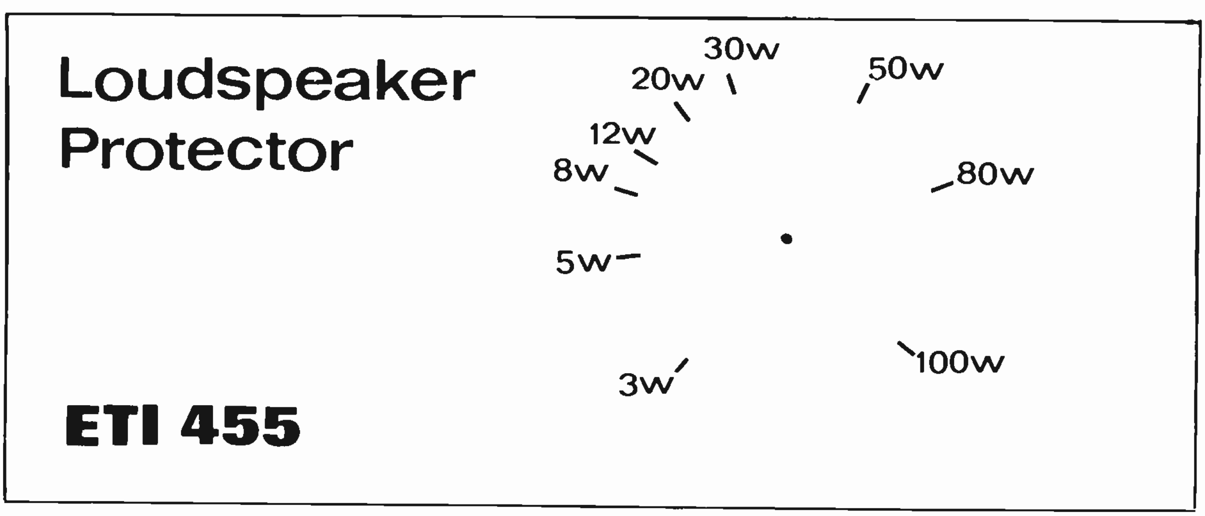
Check the orientation of all polarised components including the transistors and ICs. If all is well cut two short lengths of speaker cable and connect the output of the amplifier to the input of the loudspeaker protector. Connect the speaker cables to the output of the protector. Now switch on the hi-fi system. Choose music with reasonably even amplitude for this test. Turn the front panel level control on the loudspeaker protector for the lowest power and slowly increase the amplifier volume. When the power to the loudspeakers exceeds that set by the potentiometer the protector should trip in and disconnect the loudspeakers.

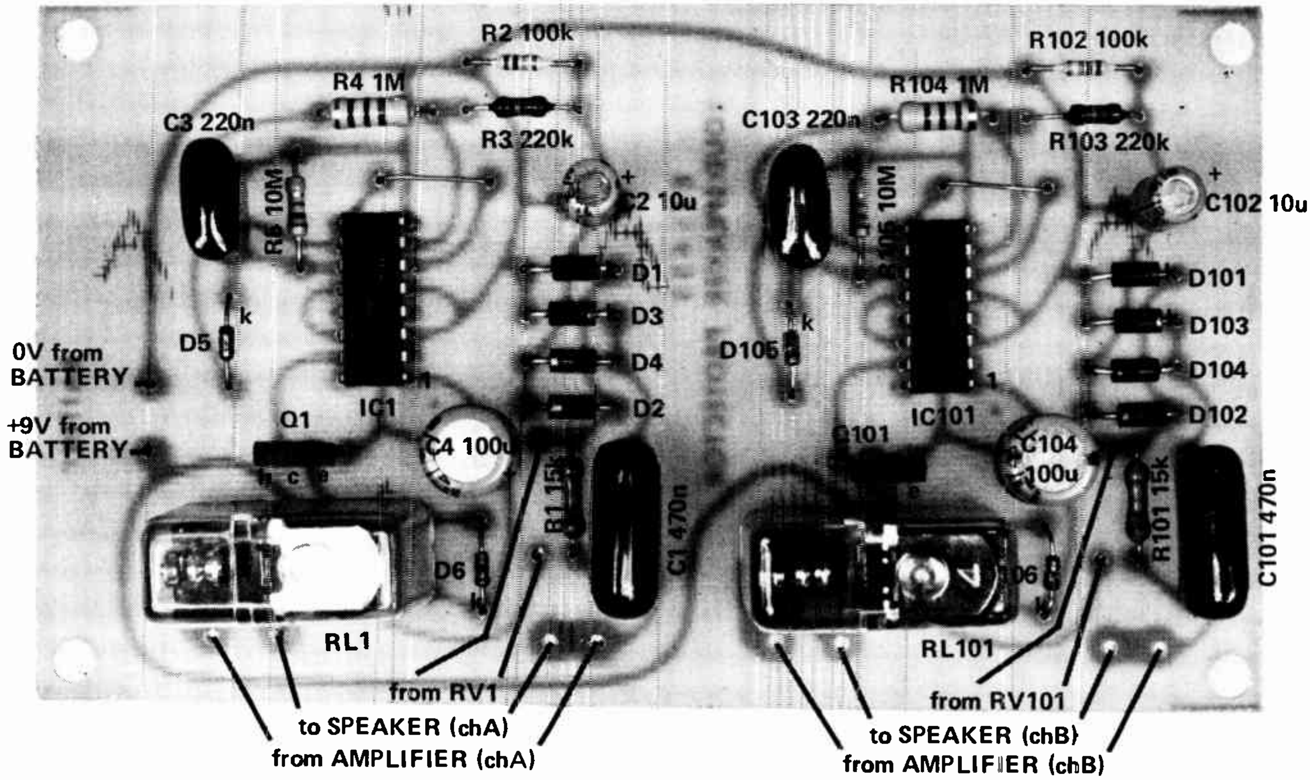
Turn the amplifier down, and the loudspeakers should be reconnected after about two seconds. Since loudspeaker power figures are a rather dubious quantity, it is probably best to establish the correct setting for the

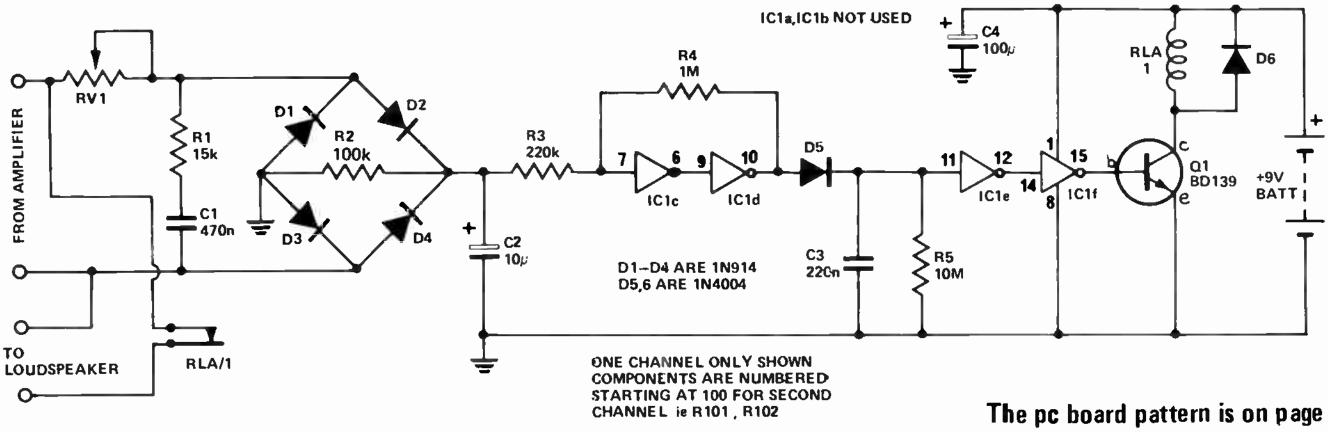
HOW IT WORKS – ETI 455

The signal voltage from the amplifier is rectified by a full-wave bridge consisting of diodes D1, D2, D3 and D4. The potentiometer RV1 and the resistor R1 and capacitor C1 form a potential divider that determines the sensitivity of the circuit. At normal signal frequencies C1 has a relatively low impedance and the resistance across the diode bridge becomes that of resistor R1, i.e: 15 k. As the frequency approaches dc however, the impedance of this capacitor increases, increasing the sensitivity of the circuit. If a dc voltage is presented to the input C1 acts as an open circuit and the protector is therefore at its most sensitive.

Signal voltages from the full wave rectifier are averaged by the capacitor C2 and R2, and then applied to a Schmitt trigger. The Schmitt trigger is formed from the resistors R3, R4, ICIc and ICId. This circuit will only respond to a voltage level greater than a preset amount. When this voltage is exceeded (around 6.5 V in this case) the output goes positive charging C3 through diode D5. This diode prevents C3 from being discharged by the Schmitt trigger when its output goes low again so the capacitor can only be discharged by the 10 M resistor R5. This takes about two seconds so this circuit is in reality a simple and effective monostable. Another two stages of the IC drive the transistor which is in series with the relay coil. Diode D6 protects the transistor from large back-EMF voltage spikes produced when the relay is turned off.







The pc board pattern is on page 74.

loudspeaker protector experimentally rather than just setting it to the rated power handling of your loudspeakers. Your ears are the best indication that the system is being strained. Set the loudspeaker protector so that it trips just below that volume where distortion starts to occur.

We have done extended tests on the protector, even to the point of connecting expensive loudspeakers and inducing power amp faults that would otherwise destroy a loudspeaker in seconds. In all of these tests the loudspeaker protector has performed well and it is a comforting thought that should a power amp fault occur, it will not take your loudspeakers with it. ●

PARTS LIST - ETI 455

Two of each of the following is required for stereo.

Resistors all ½W, 5%
- R1 . . . . . . 15k
- R2 . . . . . . 100k
- R3 . . . . . . 220k
- R4 . . . . . . 1M
- R5 . . . . . . 10M

Potentiometers
- RV1 . . . . . 100k lin. (dual for stereo)

Capacitors
- C1. . . . . . . 470n greencap
- C2. . . . . . . 10μ 25V electrolytic
- C3. . . . . . . 220n greencap
- C4. . . . . . . 100μ 25V electrolytic

Semiconductors
- Q1 . . . . . . BD139
- D1–D4. . . . IN4002, EM402 or similar
- D5, D6 . . . . IN914 or similar
- IC1 . . . . . . 4049B Hex inverter

Miscellaneous
Only one of each of the following is required.

- ETI 455 . . . pc board
- 12V relay with one C/O, Pye 265/12/C2, four terminals, case - Dick Smith H-2744, knob(s), screws, nuts, pc board spacers.

A hum filter for hi-fi systems

There are few things more annoying in life than attempting to track down and remove all sources of hum from a hi-fi set up only to be partially successful, no matter how hard you try. This project should remove the last vestige of that 50 Hz pest from your system. Go 'notch' that nasty!

David Tilbrook

SO YOU'VE just spent most of your spare money, unpacked everything from the boxes, connected it up and turned it on. What on earth is that awful noise?

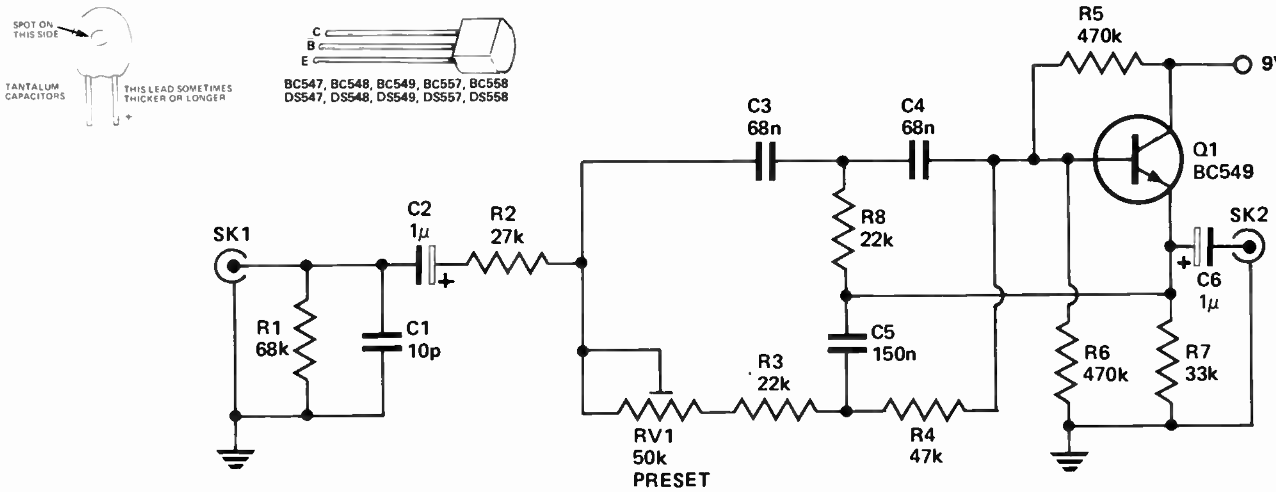
Maybe this is a bit of an exaggeration, but it does illustrate the problems some of us have with mains induced hum. Often it's necessary to position the various components of a hi-fi system close together and this can cause problems.

The magnetic field around the transformer in the power amplifier can couple to the preamp or tape deck. Also, the location of nearby 240V mains wiring can cause problems that can be very difficult to overcome. In theory, if the equipment and leads have been properly shielded and earthed this problem shouldn't exist. In practice it's a very different story.

This project aims at overcoming some of the problems of mains induced hum by using a notch filter at the hum frequency of 50 Hz. At this frequency any signal present will be attenuated. At frequencies either side of the notch the response should return to the unattenuated input level.

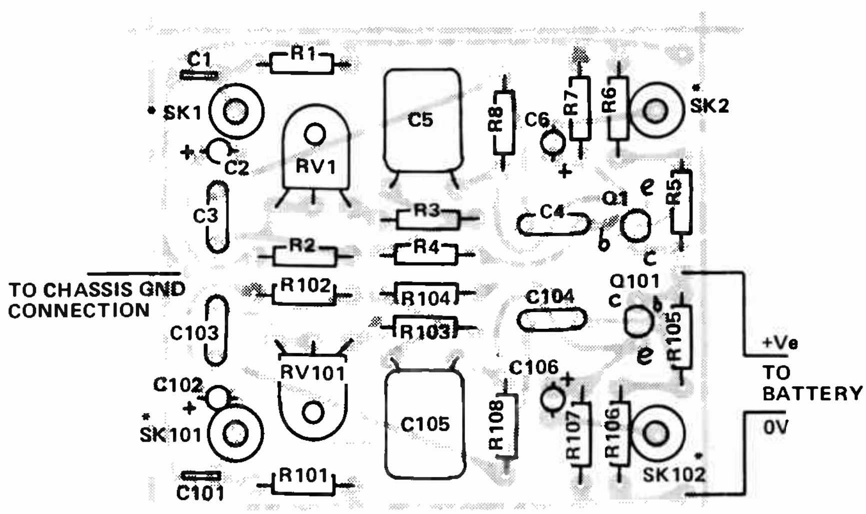
The 'Q', or Quality Factor, of a tuned circuit — which the RC network in this circuit forms, determines the bandwidth, or narrowness, of the amplitude response of the circuit (see the diagram). As this circuit forms a notch filter, the Q of the circuit determines the narrowness of the notch.

With a high-Q notch the frequency response of the circuit will dip suddenly around the notch frequency. Frequencies ▶

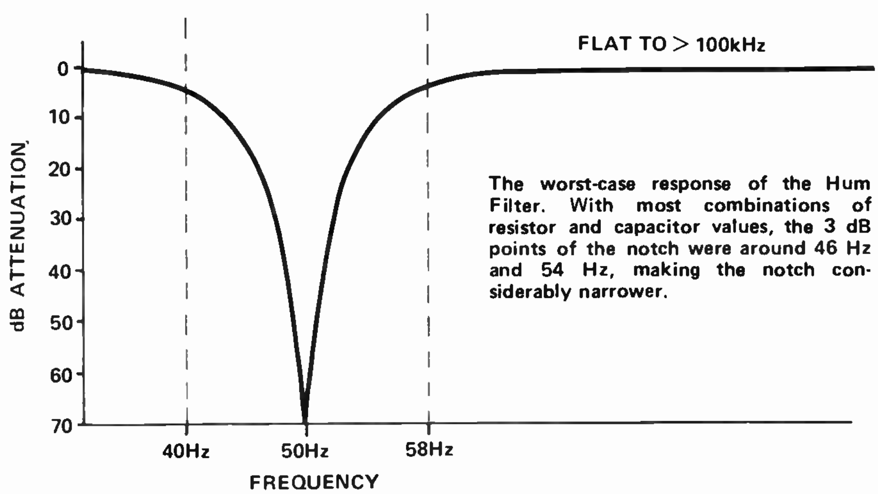


NOTE
ONLY ONE CHANNEL HAS BEEN SHOWN FOR CLARITY. THE COMPONENT NUMBERING OF THE OTHER CHANNEL BEGINS at 101 i.e. R101 R102 etc.

The printed circuit board artwork is reproduced on page 157.



*RCA SOCKETS POSITIONED HERE ON FRONT PANEL OF CHASSIS



The worst-case response of the Hum Filter. With most combinations of resistor and capacitor values, the 3 dB points of the notch were around 46 Hz and 54 Hz, making the notch considerably narrower.

PARTS LIST - ETI 451

Resistors all ¼ W, 5%
- R1, R101 . . . 68k
- R2, R102 . . . 27k
- R3, R103 . . . 22k
- R4, R104 . . . 47k
- R5, R6, R105, R106 . . . . . . 470k
- R7, R107 . . . 33k
- R8, R108 . . . 22k

Capacitors
- C1, C101. . . . 10pf ceramic
- C2, C102. . . . 1μ tant
- C3, C4, C103, C104 . . . . . . 68n greencap
- C5, C105. . . . 150n greencap
- C6, C106. . . . 1μ tant

Potentiometers
- RV1, RV101 . 50k min preset

Semiconductors
- Q1, Q101 . . . BC549, BC109, DS549, etc.

Miscellaneous
- ETI 451 pcb, box to suit, 4 panel mounting, RCA sockets.

Components for 100 Hz operation
- R4, R104 . . . 22k
- R8, R108 . . . 10k

Replace R3 with wire link.

a little either side of the notch centre frequency will be little affected. If the Q is low, frequencies some way either side of the notch frequency will be attenuated. The actual attenuation at the notch frequency is greater with a high-Q circuit than with a low-Q circuit.

High-Q circuits have the disadvantage that slight changes in component values, due to temperature changes etc, will affect the centre frequency. Tuning of the circuit to frequency is also quite critical. Lower-Q circuits do not suffer so much from this disadvantage.

The design Q chosen for this project was a compromise between the constraints of critical tuning and drift effect and good attenuation at the notch with little affect on nearby frequencies. Peak attenuation at the notch centre frequency of 50 Hz is around 80 dB while attenuation of only 3 dB is obtained at 40 Hz and 58 Hz. There is some audible effect on the bass response of a system, but this is minimal.

Construction

Mount the resistors and capacitors on the board first. Be sure the orientation of the tantalum capacitors is correct. These are polarized and can only be installed one way round. Next, install the preset pot. If you elect to use the same case we did, the preset must lie flat on the board. This is best done by bending the pins 90° first and then soldering onto the printed circuit board. Finally, solder the transistor in place.

The input and output connections are best made by mounting the four RCA sockets directly above the input and output pads on the pc board. Strong wires can be soldered onto the RCA sockets and the entire board slid onto the four wires. This serves the purpose of holding the board in place as well as forming the input-output connections. A short insulated wire should be connected to the gound point provided on the pc board (see overlay diagram) and to the chassis. The RCA sockets are grounded by their mounting nuts, so be sure to use a metal case.

The circuit is run from a single No. 216 nine volt battery. The current consumption of the prototype was 200μA so the battery life should be good for several months. If it is found that battery life is not long enough a power switch could be fitted.

The filter can be used almost anywhere in the amplification chain since its overload margin is very high (typically 8 V p-p). It should obviously be placed after the point where the hum is being picked up. If the hum is in the turntable it can even be placed between the turntable and the magnetic phono input of the amplifier since the input impedance is 47 k shunted by 10 pF, which should suit most magnetic cartridges.

Once the filter is in place, the presets are adjusted so that the hum is brought to a minimum by adjusting each channel independently.

Installation

Before connecting the battery, check the pc board thoroughly. Check the orientations of the tantalum capacitors and the transistor. If all is right, plug in the battery and seal the base.

In the unit we built, holes were drilled in the chassis immediately above the preset pots. This allows the filter to be fine-tuned after it has been connected into the circuit. The presets themselves are connected to the base of the transistors via some resistance, so the transistor bias voltage is present on the preset. If the pot is to be adjusted through a hole in the chassis this voltage will probably be shorted out by the screwdriver touching the earthed chassis. Although this won't damage the circuit, it could damage the loudspeakers if the filter is being used in the magnetic phono line. It certainly makes the adjustment meaningless, so either use a non-metal adjustment tool or use LED mounting grommets to insulate the holes.

If the hum problem you are experiencing is 100 Hz instead of 50 Hz the filter is easily adapted. Simply replace resistor R3 (22 k) in each channel with a wire link. Remove R4 (47 k) and replace with a 22 k resistor. Remove R8 (22 k) and replace with a 10 k resistor. ●

HOW IT WORKS

The circuit consists of a "Twin-T" notch filter formed by capacitors C3, C4 and C5 and resistors R3, R4, R8 and preset PR1.

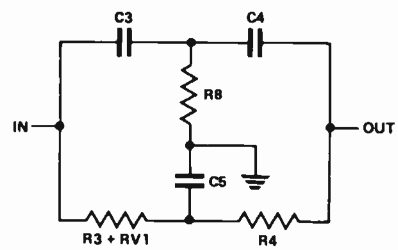
The operation of the Twin-T requires that $C_3 = C_4 = \frac{C_5}{2}$ **and** $R_3 + PR1 = R_4 = 2R_8$

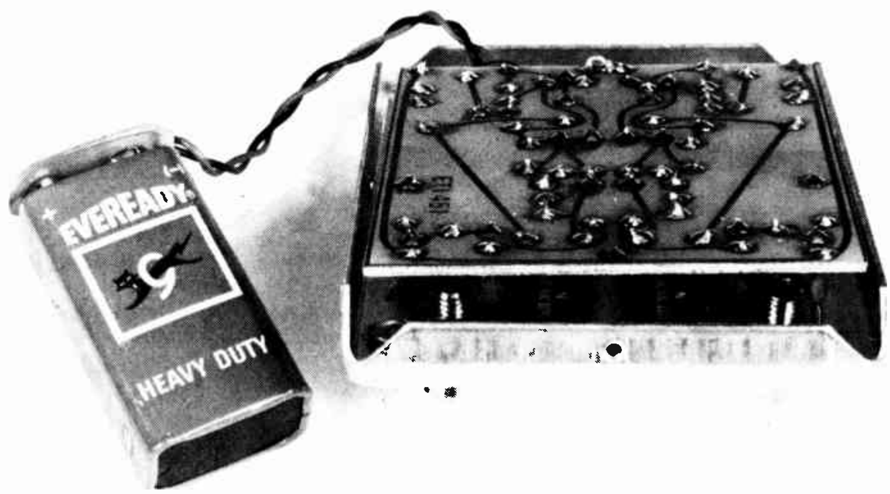
These conditions must be met with reasonable accuracy if a good, deep notch is to be obtained. The preset corrects to a certain extent for errors due to component mis-match and assumes that the notch can be adjusted to the exact frequency of the hum to be rejected.

The frequency of the notch is then given by

$$f = \frac{1}{2\pi R_4 C_4}$$

The transistor is operating as an emitter follower, giving zero voltage gain, but providing feedback into the notch to increase the Q to acceptable limits.

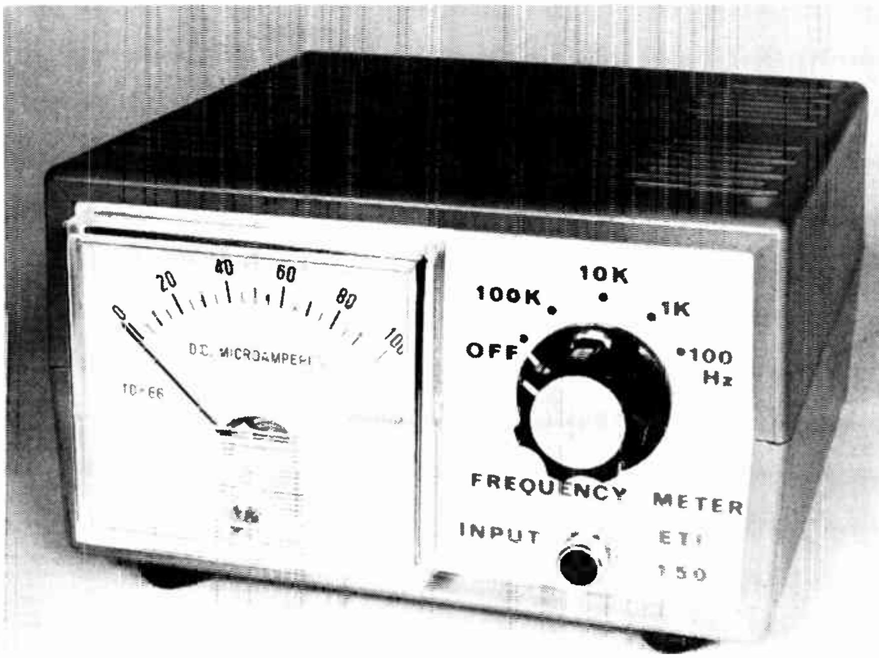




Simple analogue frequency meter features linear scale

This simple project is easy to build, inexpensive and should find many uses in the hobby workshop.

Phil Wait



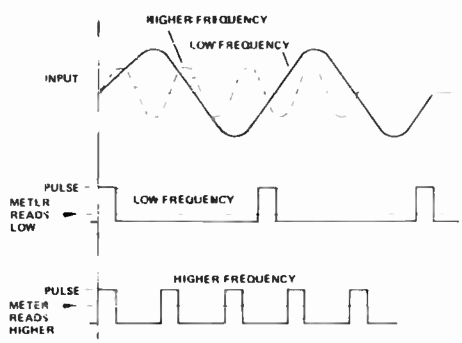
THERE ARE MANY applications in the home workshop where simple audio frequency measurements are required. When experimenting with oscillators, building or repairing function generators etc, it is often handy to have some means of measuring frequency — accuracy to the last Hertz is not always required and thus a full-blown digital counter is not warranted.

This project will enable you to measure frequency from around 100 Hz right up to 100 kHz with an accuracy of a few percent. It is inexpensive to build but performance is quite adequate to meet a large number of needs in any hobbyist's workshop. Accuracy is unaffected by the waveshape of the signal being measured and the unit will accept signal levels as low as 200 mV. The input is fully protected against high signal levels and against dc voltages up to the rating of the input capacitor, C1. The input is also fully floating above earth — a useful feature.

The frequency meter may be powered from an internal No. 216, 9 V battery or from a Plugpack battery eliminator. A suitable dc socket may be installed on the rear of the cabinet. All components are readily obtainable, the moulded plastic case in which we housed the prototype is an item supplied by A & R Soanar and is available from many suppliers.

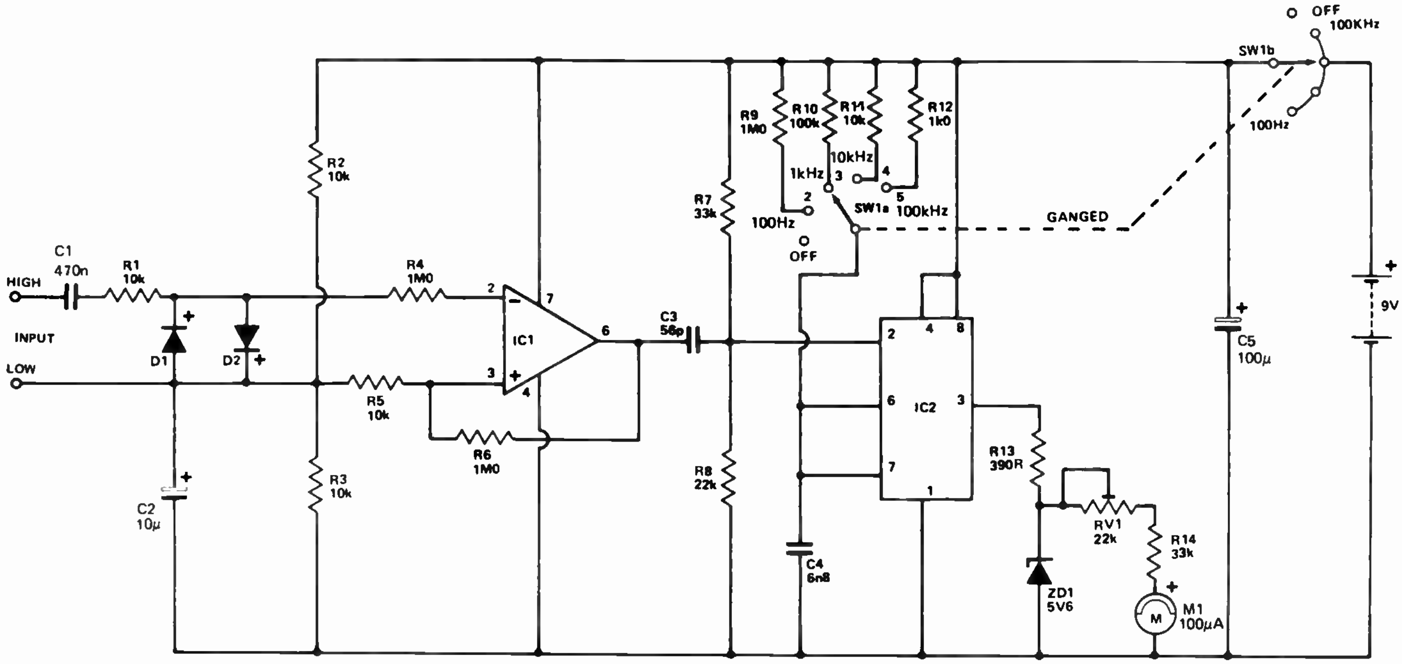
Circuit features

The circuit generates a series of short pulses at the same frequency as the input. These pulses drive a moving-coil meter the current through which will be the average amplitude of the pulse waveform; that is, it will integrate the pulses. This average will be proportional to the ratio of time the pulse is on to the time it is off. The time the pulse is on, that is — the pulse width, is fixed. At low frequencies, the time the pulse is off will be much, much longer than the time the pulse is on. Thus, the average current through the meter will be quite low. At higher frequencies, the time between pulses will be quite short and the average current through the meter will be quite a bit higher (As shown in the diagram). Thus, as the frequency of the pulses is proportional to the input frequency, the pulse on/off ratio, and therefore the meter current, will be proportional to the input frequency. The meter can be calibrated directly in frequency as the relationship is a linear one. We have used a 100▶



SPECIFICATIONS ETI 150

Frequency	10 Hz to 100 kHz in four decade ranges
Minimum input	200 mV RMS
Maximum input	250 V peak AC or DC (dependent on voltage rating of C1)
Supply voltage	9 Vdc battery or Plugpack battery eliminator



microamp movement for convenience as it does not have to be re-scaled. The lowest range is 100 Hz full-scale deflection, the highest, 100 kHz.

Only two cheap IC's are used in the whole design a 3140 op-amp and a 555 timer. The 3140 amplifies and squares the input signal and was selected for its high slew rate, wide frequency response and high input impedance. The output of this stage will be a square wave of the same level for all input signal levels and waveforms.

The pulses are generated by a 555 timer connected as a one-shot monostable giving a single pulse output for each input cycle. The monostable has four ranges giving decade scales on the meter. A fifth position on the switch is used as a power switch.

Regulation of the output pulses by a zener diode preserves the accuracy of the unit with falling battery voltage.

HOW IT WORKS – ETI 150

The circuit consists of an op-amp operated as a Schmitt trigger to amplify and square the input signal, followed by a 555 timer wired as a monostable, giving a short output pulse of fixed width for each cycle of input signal. This pulse drives a moving-coil meter, the reading being an average of the pulse amplitude, which is proportional to the pulse frequency. As the pulse frequency is directly related to the input frequency, the meter reading is directly proportional to the input frequency.

The input signal is coupled into IC1 via C1, which provides dc blocking. Protection from overload caused by high amplitude input signals is provided by a diode clipper consisting of D1, D2 and R1. The diodes are connected in an inverse-parallel arrangement so that both positive and negative peaks, above the diode forward conduction voltage, are clipped.

IC1 is a fast op-amp connected as a Schmitt trigger with amplification, as mentioned above. Resistors R5 and R6 provide hysterisis, a 'dead band' in the action of the Schmitt, centred on zero input level. This dead band ensures that the Schmitt ignores noise pulses.

As the unit is required to operate from a single supply, for convenience, R2 and R3 bias the input of IC1 at half the supply voltage.

The output of IC1 is a train of square waves at the same frequency as the input. The output of IC1 is differentiated to provide short trigger pulses for the 555 timer, IC2. The differentiating network consists of C3, R7 and R8. This network is arranged to provide a trigger pulse that is always shorter than the output pulse of the 555. Capacitor C3 is selected to give the shortest possible pulse to the 555 consistent with reliable triggering.

The output of the 555 monostable will be a pulse of fixed width, determined by the range resistors, R9 to R12, and capacitor C4. The ranges are arranged to give a 75% output duty cycle at frequencies of 100 Hz, 1 kHz, 10 kHz and 100 kHz on the input.

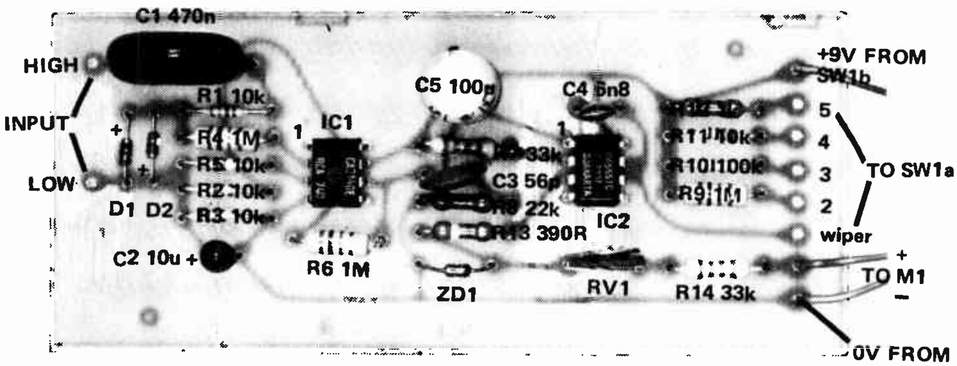
The output pulse from the 555 is clipped at 5.6 V by a zener diode, ZD1, to avoid inaccuracies caused by falling battery voltage (as the battery ages). The meter responds to the average value of the clipped pulses. As the frequency increases, the duty cycle (on/off ratio) of the pulse train increases, increasing the average voltage and thus the meter current in direct proportion. Thus the reading on the meter will be linearly related to frequency.

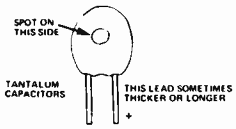
Construction

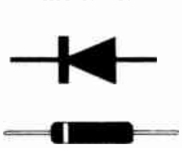
Even though this project is relatively simple, we strongly recommend you use the pc board – saves possible hassles!

As mentioned previously, we constructed our prototype in a commonly available plastic box. This has the advantage that the unit can be operated fully floating from earth – handy in some situations. Check placement of components on the front panel and the positioning of the pc board inside before commencing major assembly. It's probably best to assemble the components on the pc board first. Take care with the orientation of the ICs, diodes and tantalum capacitor.

The input capacitor, C1, can be obtained in several voltage ratings. Greencaps are available in ratings of 100 V, 250 V and 630 V. If all your work is with solid-state circuitry, a 100 V type will be more than adequate. If you anticipate using your unit with say, valve equipment, the highest rating type for C1 is recommended. The rating applies to the combined







The pc board pattern is on page 158.

dc voltage that may be present on the input, *plus* the possible peak value of the input signal.

A 630 V rated capacitor will be physically larger than a 100 V type and the leads may have to be shaped to fit the capacitor on the board.

Once the board is assembled, the major components can be assembled onto the front panel of the case. We made up a Scotchcal overlay for the front panel, to dress it up and give it a bit of a 'professional' look. Kit suppliers will probably have these available shortly after this book goes on sale. Radio Despatch Service in Broadway, Sydney offer a special Scotchcal front panel service for projects so, if you are using a similar case you may have on hand, then they will be able to supply a front panel.

The meter (we used a University TD66 – but many other types are suitable), was mounted in a circular cutout on the left hand side of the panel. The range switch should be mounted next, followed by the input socket. After much discussion around the office ("A jack socket!", "No, screw terminals", "Rubbish! RCA socket" . . .), we settled on an RCA socket. It's a common item on audio equipment, inexpensive and coax cables terminated in RCA plugs, for input leads, are cheap and readily available.

However, any type of socket to suit your individual requirement will do equally well. If you use a metal box, the input connector earth must be the *only* connection from the circuitry to the case, as the negative rail from the battery is not at earth potential.

The pc board may be mounted anywhere convenient in the case and wires run to the front panel for the input and switch connections. Make sure the board does not get in the way of the meter when the front panel is in place.

The unit may be powered from an internal battery, which makes it a handy portable unit. If you wish to operate the unit from a plugpack battery eliminator, then we recommend you purchase a unit giving a nominal 6 Vdc output. The current requirement for the project is quite modest and the output of these small battery eliminators is dependent on the load. A 6 V unit will typically deliver 9 V or so under a light load.

If you do decide to use one of these units, a socket matching the unit's plug will have to be mounted on the rear panel and leads run to the supply rail pads on the pc board. If you wish to have the option of both battery and mains operation, then a small SPDT toggle switch should be mounted on the rear panel also and wired into the circuit.

Calibrating it

Calibration of the frequency meter is very easy, aided by the fact that it has a very high input impedance.

With the unit switched to the 100 Hz range, touch your finger to the input. There will usually be enough 50 Hz field from the electrical wiring in a building to drive the input. This will cause a deflection on the meter and RV1 should then be adjusted to give a meter reading of 50 (half scale). Move the unit near house wiring to increase the amount of signal to the input if a reading cannot be obtained.

If a signal generator of known accuracy is available the instrument can be calibrated on any range. Only one range need be calibrated as the others will automatically fall into line.

If it is impossible to obtain any reading on the meter, the coupling capacitor (C3) may have to be increased in value to say 100p or 150p. This component has been selected to give a very short trigger pulse into the 555 and has been found to work correctly, using the value shown in the circuit, with several different ICs.

Using your meter

Selecting the 100 kHz range will connect power to the unit and the unknown signal can then be applied to the input. Note the reading and switch to a lower range if required. This procedure avoids the possibility of spurious readings that may be obtained on lower ranges due to re-triggering of the 555 by high frequency signals. There are no other adjustments, so all you need is something to measure.

This is the sort of instrument that, once you have it, seems to find a great many uses for itself! ●

PARTS LIST - ETI 150

Resistors all ½W, 5%

R1–R3	10k
R4	1M
R5	10k
R6	1M
R7	33k
R8	22k
R9	1M
R10	100k
R11	10k
R12	1k
R13	390R
R14	33k

Capacitors

C1	470n greencap
C2	10µ tantalum
C3	56p ceramic
C4	6n8 greencap
C5	100µ 25V electrolytic

Semiconductors

D1, D2	1N914 or similar
ZD1	5V5,400mW Zener diode
IC1	3140 op amp
IC2	555 timer

Miscellaneous

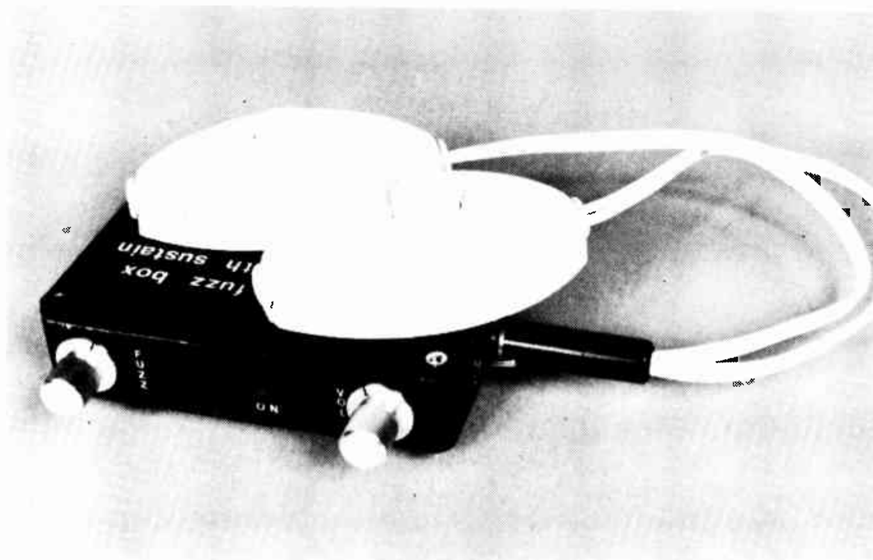
M1	100µA meter, University TD - 66 or similar
RV1	22k min vert mounting trim pot
SW1	two pole five pos wafer switch

Plastic box to suit (approx. 75 mm x 135 mm x 130 mm); input connector chassis mounting RCA socket or similar; knob, ETI 150 pc board.

Fuzz/sustain unit for guitarists

Ron Keeley
Jonathan Scott

For that raunchy sound beloved of electric guitarists the world over, this simple little project is just the thing.



THE INVENTOR of the fuzz-tone is lost in history (rugged country, that), along with the discoverer of the wheel, the first chef, and the architect of square corners. However, his legacy is with us still, to the joy of those who like their music *loud*, and the despair of those who can't stand it that way!

Like the first bar-b-que, the first fuzz-tone was probably an accident — a blown speaker, perhaps, or a badly overdriven amplifier. However, the essential nature of the phenomenon did not long remain hidden, and keen guitarists soon had the fuzz by the short and curlies.

Fuzz-tone is to guitar what salt is to meat — it adds flavour and body. The ETI Fuzz Unit, based on the 'clever fuzz-box' circuit which appeared in the January '79 ETI, has an added bonus in an inbuilt sustain circuit, adding a bit of extra spice to the idea.

The device offers three distinctive sounds, in addition to the 'straight through' option: sustain, fuzz with sustain or fuzz without sustain.

How we did it

To explain how these sounds are realised, we have to consider the circuit diagram.

The input amplifier, IC1, is required to give the system some overall gain, to boost the treble response, and to present the correct load impedance to the instrument. The mid-range gain is set to 5, allowing 1 V peak-to-peak input signals before distortion, and producing the largest possible dynamic range. The frequency response is flat from 20 Hz to about 2 kHz, after which an 8 dB step provides a gentle treble boost up to 20 kHz, where the response is flat from 20 Hz to about 2 kHz, after which an 8 dB step provides a gentle treble boost up to 20 kHz, where the response is rolled-off.

Following the input stage is IC2/1, one half of an NE 571 compander IC configured as a conventional compressor with a fixed compression ratio of 2:1. This compression effectively halves the dynamic range of the incoming signal by attenuating high level signals and boosting low level ones; thus the signal hangs on — "sustains" — for much longer than it otherwise would. The compression also provides a constant ▶

HOW IT WORKS – ETI 562

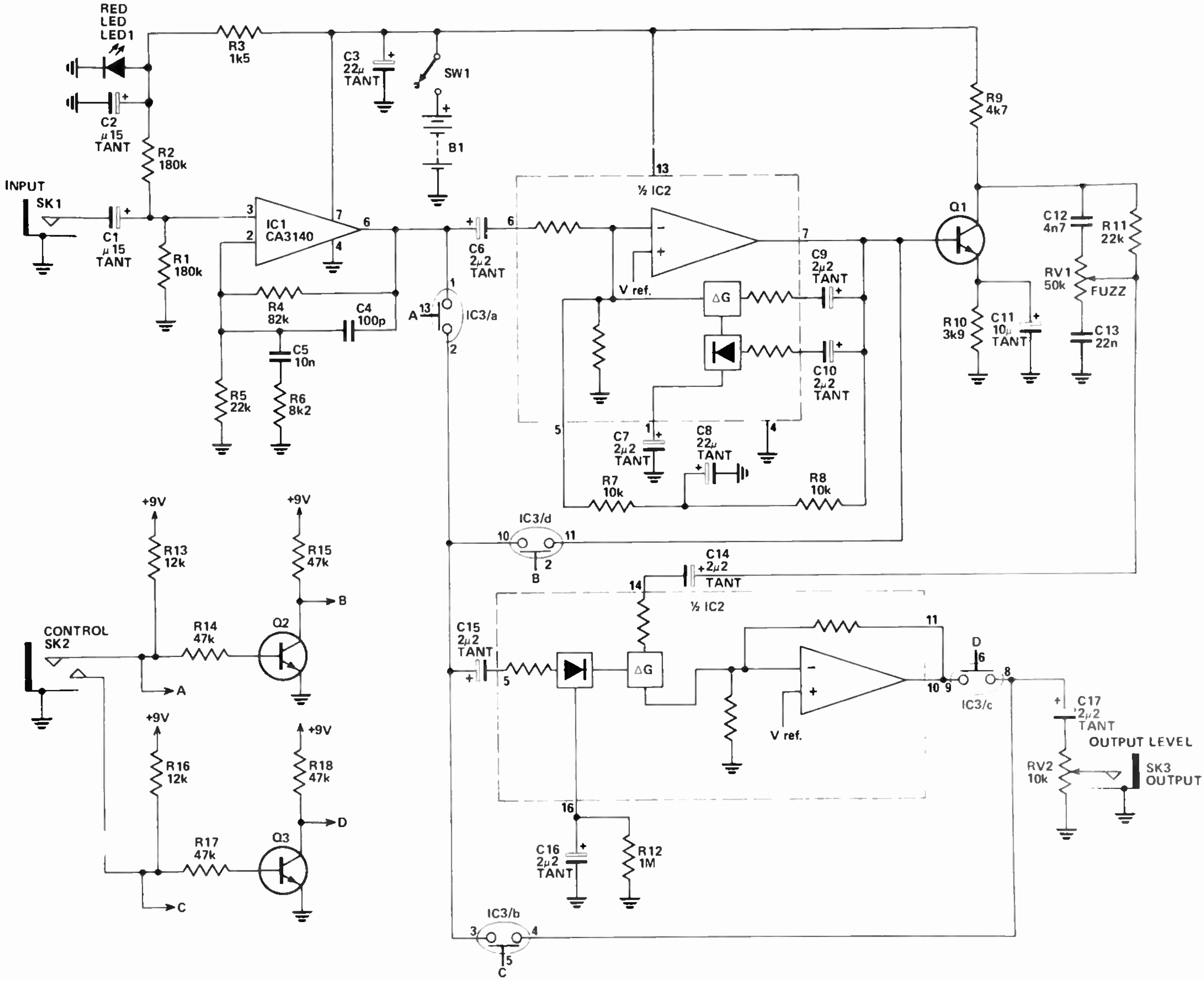
The input amplifier is a CA 3140, chosen for its low noise. The input impedance of the device is quite high, so the effective value is determined by the parallel combination of R1, R2; the values used give an impedance of 90k. R1 and R2 can be as low as 10k or as high as 1M, as long as they are the same and within this range.

The bias for the CA 3140 is filtered and regulated by R3, C2 and LED1; the LED also acts as a 'power on' indicator! The LED must be RED as other colours have a different forward voltage. The stage gain of 5 is set by the ratio of R4 and R5, while C4, C5 and R6 tailor the frequency response as described in the text.

IC2 is a dual gain control IC, NE 571, which may be set-up to implement a number of signal processing functions. Each half of the IC consists of a full wave rectifier acting on the control input, a variable gain cell (signal input), an operational amplifier and a bias system. The blocks may be set-up as, for example, a compressor, an expander, a limiter or an envelope follower. The compression/expansion ratio is internally set at 2:1 while the attack and release times are determined by an external timing capacitor and an internal resistor, the attack-to-decay time ratio is internally set at 1:5.

It is possible to vary both the compression ratio and the attack/decay ratio by the use of complex external circuitry, however the internally set values are adequate for the purpose of this gadget.

IC2/1 is configured as a compressor. The control signal is rectified and fed to an internal summing node. The rectified current is averaged by the external capacitor C7, and the average rectified current controls the gain of the variable gain cell ΔG. The gain cell is connected as an expandor in the feedback loop of the op-amp; a 3dB increase in the gain of the ΔG cell, producing a 6dB increase in feedback current to the summing node at



the op-amp input. If the input rises 6dB, the output can rise only 3dB.

The speed with which the gain changes to follow the input signal is determined by the rectifier filter capacitor C7. A small value will follow rapidly but will not fully filter low frequency signals on the control input. Any ripple on the gain control signal will modulate the signal passing through the ΔG cell, producing third harmonic distortion, so there is a trade-off between fast attack/decay times and distortion. C7 should not be reduced below about 0µ47.

The ΔG cell has a built-in compensation scheme for temperature variations and for cancelling odd harmonic distortion. A THD trim terminal is provided, but not used here, for cancelling even harmonic distortion caused by internal offset voltages. The operational amplifier is also internally compensated.

The non-inverting input is tied to an internal reference voltage and the summing node at the inverting input is tied internally to the ΔG cell output as well, the invert input is brought out of the package directly and via an internal resistor. This allows the gain of the stage to be controlled by internal components only or, as we have done, by an external network (R7, R8, C2). The output stage is capable of ± 20 mA output current.

For maximum dynamic range, the control (rectifier) input current should be as large as possible but should not exceed 300 µA (3 V using only the internal resistor). Maximum ΔG cell input current is 140 µA (2.8 V with internal components only).

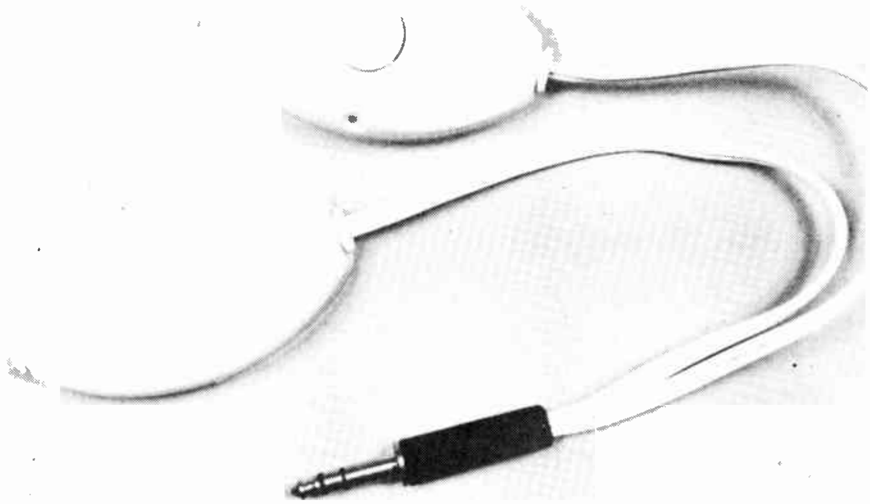
Q1 is a high gain amplifier which is always driven into hard clipping, as described in the text. R11, RV1, C12 and C13 form a tone control network which varies the fuzz-tone by rolling-off the top end. The clipping amplifier feeds the second half of IC2 which is connected as an envelope follower.

In the usual expander configuration the control and signal inputs are tied together, so that a 3 dB rise or fall at the input produces a 3 dB variation in the gain of ΔG, giving a 6 dB rise or fall at the output.

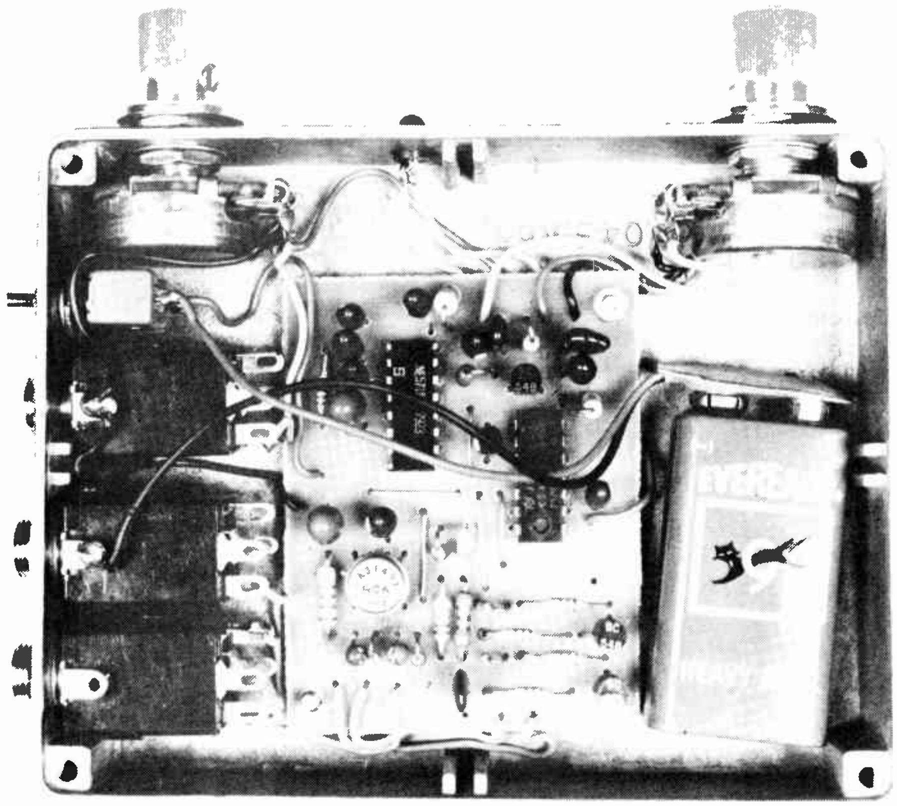
When connected as an envelope follower the control input is the signal whose amplitude envelope is being impressed on the straight-through signal, and a 3 dB variation of the control input will produce a 6 dB rise or fall at the output.

The attack/decay times of the follower are set by C16; it is best not reduced below about 0µ1.

The switching system uses a CA 4016 quad analog switch with Q2 and Q3 as drivers. With both control lines floating SWs A and C are closed, B and D open. When the fuzz control line is grounded Q3 cuts-off, opening C and closing D; similarly when the sustain line is grounded, A opens and B closes.



The switches we used are single-pole, double-throw types which may be found in some hardware stores or electrical wholesalers.



We housed the fuzz unit in a diecast aluminium box, type 043B. It's not as much of a squeeze as it looks. A piece of sponge rubber will secure the battery.

level drive to the clipping stage, making the fuzz sound independent of the instrument input level.

For a more precise description of the NE 571 Compander, refer to the 'How it works' section.

The fuzz stage, Q1, is a high gain amplifier stage. Because of the high, constant drive from the compressor it is always driven into hard clipping, resulting in an output which is substantially a squarewave. The output of the fuzz stage is fed through a tone control which varies the quality of the sound by rolling-off the high frequencies – one of the reasons for the treble boost at the input stage was to ensure that there would be some high frequencies to roll-off at this point!

The by now well-and-truly-fuzzed signal is fed to the signal input of IC2/2, the second half of the NE 571 Compander. This time the device is set-up as an envelope follower with a signal input and a control input; the output of IC2/2 is whatever frequencies are applied to the signal input but with the amplitude envelope of the signal fed to the control input (for details see 'How it works'). It is this envelope follower, plus some simple switching, which makes The Fuzz Unit so versatile – of which more shortly!

A deliberate modification to the envelope follower ensures that IC2/2 shuts-off completely when the signal on the control input falls below a certain level. This is a simple 'noise gate' function which prevents the amplification of low-level signals and noise, eliminating the hisses and buzzes of unwanted sounds and the squeals and howls of unexpected feedback! This function operates only when Fuzz function is selected.

As we mentioned earlier, The Fuzz Unit is capable of producing either sustain, fuzz with sustain, or fuzz without sustain. These variations are achieved by selecting the appropriate output and the appropriate drive to the control input of the envelope follower.

The switching system is entirely electronic, so the guitar signal never leaves the box even if the footswitches themselves are a dozen yards away. The signal is not required to travel long lengths of cable, and so is not attenuated or subject to interference. Also, single-pole non-audio type switches may be used, allowing a larger choice of switch types (audio quality footswitches are hard to find at the moment!).

Two switch lines are used to control

four electronic switches operating as two sets of change-over switches. One line controls SW A and SW B, (sustain on/off), the other controls SW C and SW D (fuzz on/off).

If neither fuzz nor sustain is selected, SW A and SW C are closed while SW B and SW C are open; the output of the unit is derived from the input pre-amplifier (so it will be a little louder and a little brighter than the guitar itself) via A and C.

If sustain is selected SWs A and B change over and the output is from IC2/1.

Selecting fuzz closes SW D and opens SW C. Whether it is fuzz with sustain or fuzz without sustain now depends on the position of the sustain select switch. If sustain is selected the drive to the control input of the envelope follower is the compressed signal from IC2/1; compression followed by expansion restores the amplitude envelope of the signal, so the output will have the dynamic characteristics of the original guitar sound, but will sustain for longer than usual. If sustain is not selected, the envelope follower control input is from the pre-amp, therefore the output of IC2/2 is the original signal expanded. Because of the value chosen for C7 and C16, the Fuzz Unit will produce a rather long 'delayed attack' effect when in this mode. If a shorter attack is wanted, C7 and C16 should be reduced; this will give a faster attack in 'fuzz without sustain', and enhanced attack in 'fuzz with sustain'.

Construction

The major problem in constructing this project is the non-availability of certain components. We were unable to find a reliable supply of audio-quality footswitches, and for this reason opted for external switching using a pair of Clipsal No. 360 Series 250 V/10 A footswitches. These are definitely not your usual stage gear, but they are very rugged and work very well indeed. Also, they are cheap!

For a touch more class use a commercial dual footswitch such as the Companion or the Roland FS 2 (around $15). With a bit of juggling you may be able to mount the project in one of these boxes. We used an 043B diecast aluminium box which is about the smallest possible container. If you are lucky enough to find a pair of audio footswitches and wish to mount them in the top you will need a deeper box than the 043B.

The usual method of switching the battery in effects boxes is to use a 6.5 mm socket with a separate pair of switching contacts — power is applied whenever a guitar is plugged in. We were unable to locate any of these sockets, so we have used an on/off switch.

Once the box has been drilled, the pc board should be assembled according to the circuit and layout diagram. Be sure that polarised components are correctly installed. The ICs should be put in last, as they are electrically fragile.

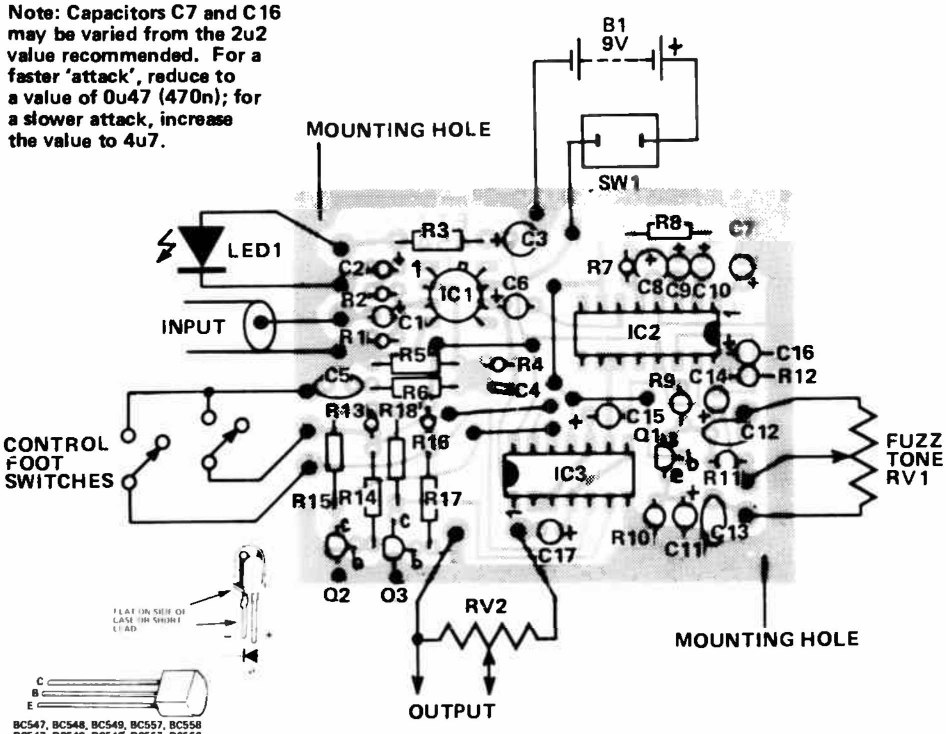
All solder joints should be clean and neat, with no stray connections across tracks on the pc board. Finally, interconnect the various major components as shown in the wiring diagram, using the shortest possible lengths of wire; use care when soldering the LED, as they are very heat sensitive and easily cooked.

Use insulated wire, and make sure that nothing is shorting to the box; the battery is best restrained by using a piece of double-sided tape.

After carefully checking that all connections are as they should be, apply power and you've got 'The Fuzz'.

Best results are obtained with the guitar output as high as it will go without causing distortion on loud notes when The Fuzz is switched to sustain only. ●

Note: Capacitors C7 and C16 may be varied from the 2u2 value recommended. For a faster 'attack', reduce to a value of 0u47 (470n); for a slower attack, increase the value to 4u7.



The pc board pattern is on page 159.

PARTS LIST - ETI 454

Resistors ...... all ½W, 5%

R1, R2	180k
R3	1k5
R4	82k
R5	22k
R6	8k2
R7, R8	10k
R9	4k7
R10	3k9
R11	22k
R12	1M
R13	12k
R14, R15	47k
R16	12k
R17, R18	47k
RV1	50k lin.pot
RV2	10k log. pot

Capacitors

C1, C2	15u tantalum
C3	22u tantalum
C4	100p disc ceramic
C5	10n greencap
C6, C7	2u2 tantalum
C8	22u tantalum
C9, C10	2u2 tantalum
C11	10u tantalum
C12	4n7 greencap
C13	22n greencap
C14—C17	2u2 tantalum

Semiconductors

Q1—Q3	BC548
LED1	TIL 220R or similar
IC1	CA 3140
IC2	NE 571
IC3	CD4016

Miscellaneous

Metal box, 043B or similar; pc board - ETI 454; 9V battery, type 216; DPST miniature switch; two phone-jack sockets, mono; 1 phone jack socket, stereo; two knobs; pc board spacers; nuts and bolts.

A simple intercom

The perenially popular intercom — this circuit illustrates how to wring the maximum performance from the minimum number of components.

AN INTERCOM is an eminently *practical* device. Communication between rooms in a house is immensely aided by an intercom. The same goes for house and garage – or any other outbuilding.

The drawback with many intercoms is that that can be *too* effective. They shout at you. Whilst one can turn down the volume by one means or another, it's rather like using a sledge hammer to crack an acorn – as the saying goes. This intercom is simple, inexpensive and is ideally suited to quiet situations where volume is not all-important.

A small loudspeaker serves as both microphone and speaker in this intercom. Housing the project we have left up to you. It is quite possible to fit the components in a palm-sized box, such as one of the small 'zippy' boxes available inexpensively from a number of suppliers. The intercom may be powered from a 3 Vdc plugpack if you wish.

How it works

At first glance this circuit looks very simple, but its operation is quite ingenious as it performs different functions for transmit and receive.

To allow us to understand how it works, let's look at the receive mode first. When the pushbutton is not pressed the loudspeaker is connected across the line, in series with the battery. None of the remaining components are used in the receiver as they are isolated from the battery by the pushbutton. The battery voltage is connected across the line in series with the loudspeaker and is fed to the transmitter. Any change in current drawn by the transmitter will cause a movement of the cone of the loudspeaker. If a speech signal is fed down the line it will be heard in the remote speaker.

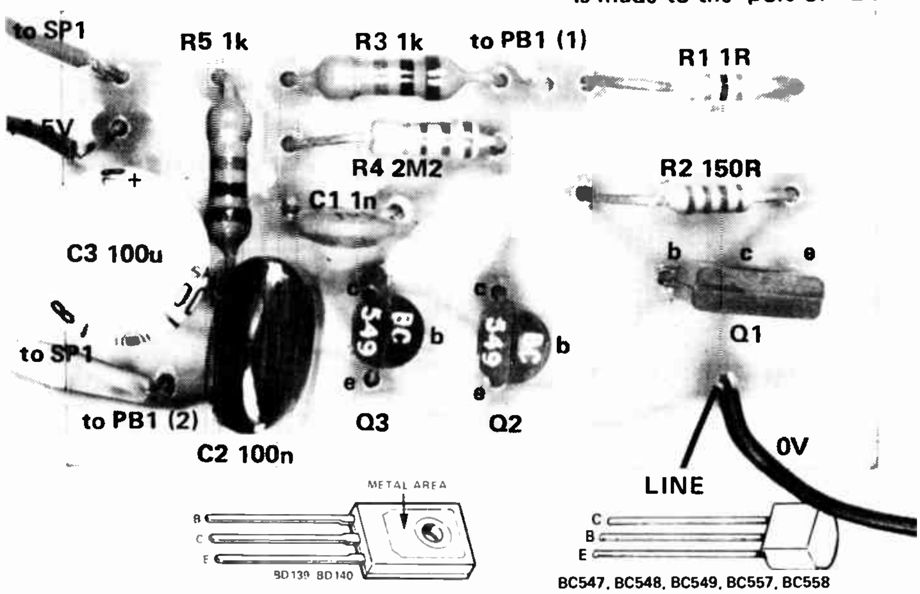
If you speak into the cone of a loudspeaker, the cone will vibrate in sympathy with the changing air pressure from the sound. The vibration of the cone moves the voice coil of the speaker which cuts the lines of force in the magnetic field of the speaker magnet. When a wire is moved through a magnetic field it generates a current in the wire in sympathy with the movement. The loudspeaker can thus be used as a microphone, the speech signal output being taken from the voice coil as it converts the sound energy impinging on the cone to electrical energy in the voice coil.

In the transmit mode, the battery is isolated from the circuit by the depressed pushbutton and the supply voltage appears across the line from the receive station. The signal from the loudspeaker passes through a capacitor, C2, which blocks the dc from the battery but allows the speech signal to pass to the base of Q3. The transistors Q2 and Q3 form a high gain pair which amplifies the speech signal and drives the output stage, Q1. The output transistor varies the amount of current drawn from the line in sympathy with the speech. Because this current moves the cone in the receiver loudspeaker, the speech can be heard at the receiver.

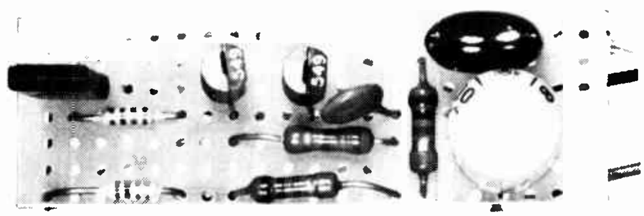
As the frequency spectrum of speech is mainly within the range 200 Hz to 3 kHz, the frequency response of the transmitter has been limited to about 3 kHz by placing a small capacitor across the base-collector junction of Q3. This causes a reduction in gain of that stage at high frequencies by introducing negative feedback which increases with frequency. Resistors R2, R3 and R4 set the bias on the stages and the one ohm resistor, R1, provides some emitter bias on the output stage as well as limiting the maximum output current.

The transmitters have been designed to work with supply voltages as low as 2½ volts. However, a 4½ volt supply allows for quite a high voltage drop in the line so that the intercom may work over quite a long line. We tried it over the length of the office (about 30 m) but some readers will, no doubt, have much greater distances in mind. For really long line lengths, the battery voltage could be increased to say, six volts.

The second line connection is made to the pole of PB1



Overlay for the pc board. Take care with the orientation of the capacitor C3 and the transistors.



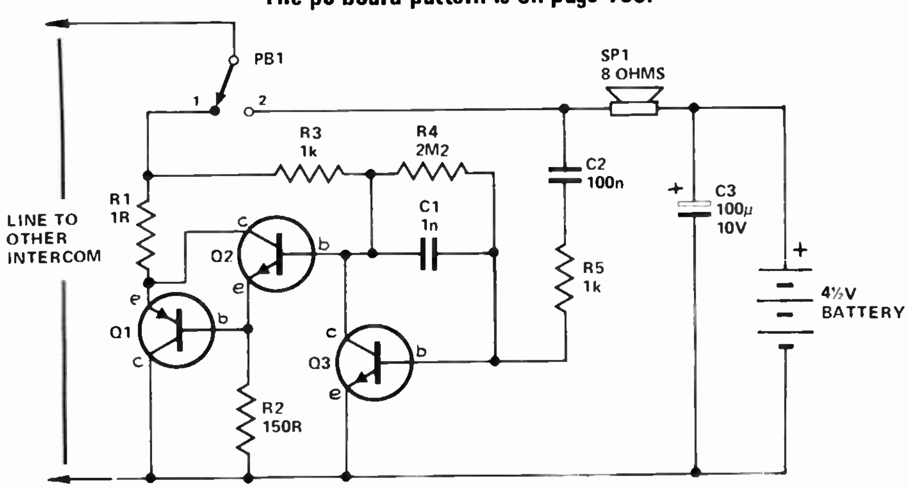
We assembled one unit on a piece of matrix board, laid out as shown.

Construction

We constructed one of our units on matrix board and the other on a pc board. Both methods work equally well, though constructing the matrix board version is a little more tedious and requires some care so that incorrect connections are not made. The orientation of the transistors is the only point to watch.

To power the intercom units, a standard 4½V battery may be used at each end. For longer battery life, three D-cells would be better, wired in series. If power is available, a 3 V plug-pack battery eliminator at each end should provide about four to five volts with the unit in operation.

The pc board pattern is on page 158.



PARTS LIST - ETI 262

Resistors all ½ W, 5%
- R1 . . . . 1R
- R2 . . . . 150R
- R3 . . . . 1k
- R4 . . . . 2M2
- R5 . . . . 1k

Capacitors
- C1. . . . . 1n
- C2. . . . . 100n
- C3. . . . . 100μ 10V electro

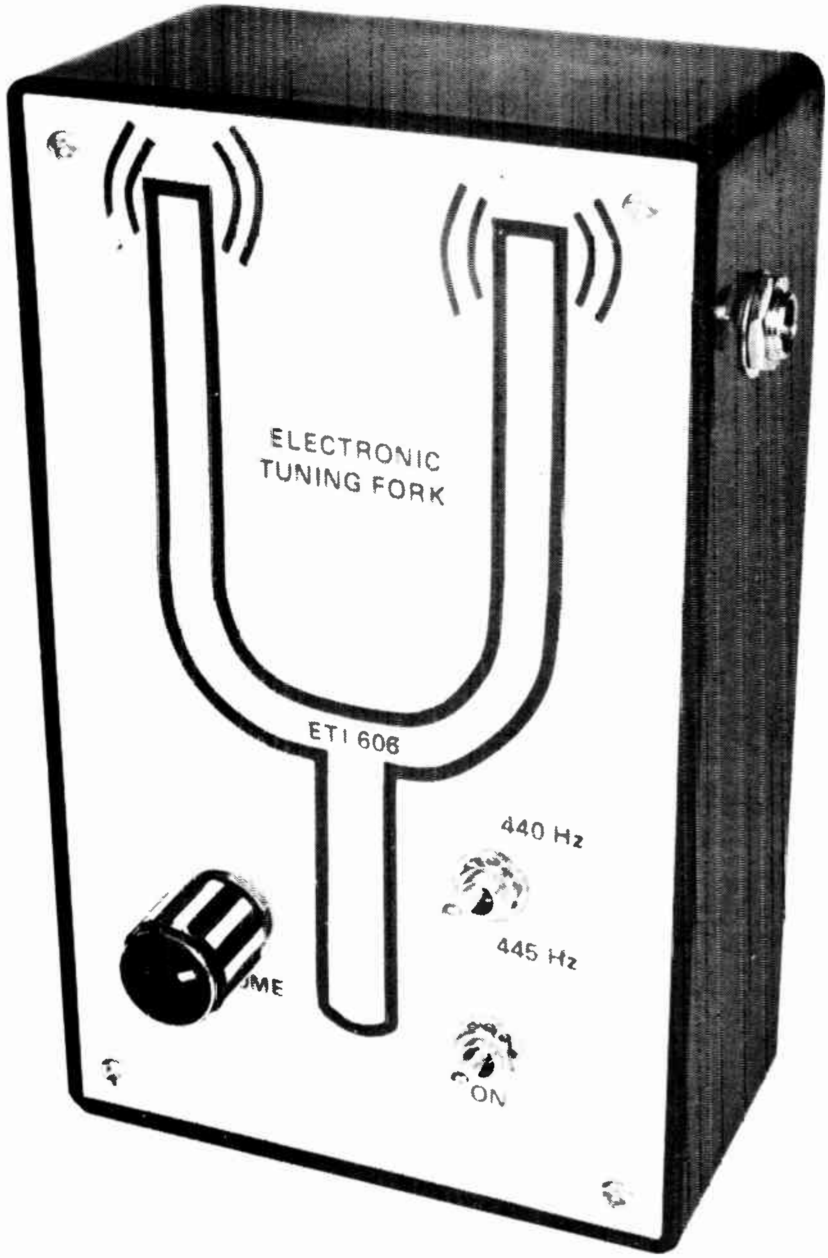
Semiconductors
- Q1 . . . . BD140
- Q2, Q3 . . . . . BC549, BC109, DS549.

Miscellaneous
- PB1 . . . . SPDT push button
- SP1 . . . . eight ohm speaker
- B1. . . . . 4½ V battery or three 1½ V cells in series (with holders if required), ETI 262 pc board.

An electronic 'tuning fork'

Design **Phil Cohen**

Article **Staff**



BRIEF HISTORY OF THE TUNING FORK

According to "The Oxford Companion to Music", the tuning fork (or pitch fork as it was called, and we shall soon see why) was invented in 1711 by a British gentleman called John Shore who was Sergeant Trumpeter to the court and lutenist in the Chapel Royal. Though famous for his trumpet playing (Handel and Purcell composed works for him), it was in his capacity as lutenist that he came to invent the tuning fork. Handel's tuning fork was made by Shore, and it still exists.

John Shore was clearly something of a 'character' for he introduced the new 'pitch fork' with a pun:

"I have not about me a pitch pipe, but I have what will do as well to tune by, a pitch fork", which he would trot out at concerts where he played the lute.

It was a mid-19th century scientist, Rudolph Koenig, of Paris, who refined the pitch fork to that general form which is commonly used today.

MUSICAL INSTRUMENTS are generally a clever and harmonious blend of physics and aesthetics (both aural and visual). But, underlying all this wonderful harmony and human cleverness is the law of 'the cussedness of nature'. This law, simply explained, says that through all the consistency and harmony we find in nature runs a streak of cussedness always causing *something* to be out of place. It is this very streak of cussedness that has thwarted attempts to date to develop a 'unified field' theory that would link gravity, electricity and magnetism.

It doesn't seem, at this stage, that gravity, electricity and magnetism have much to do with musical instruments and tuning forks, but we'll get around to it!

For one musical instrument to be played with another requires both to be tuned to the same fundamental pitch (or frequency). If not, the sound will be unpleasant – generally described as discordant.

Over the centuries there were various ideas as to what basic 'standard' pitch would be adopted. After some considerable squabbling a 'standard concert pitch' was settled upon in 1929. This gave the note 'A' a pitch of 440 Hz. That standard remains to this day. Of course, it means that modern orchestras playing the music of Hadyn, Mozart and Bach, for example, will not be playing in the pitch in which the music was originally composed.

Another, perhaps more graphic, example occurs in recordings made by modern pop groups of old 'blues' masters. In the days when many of these 'race' records were being cut in America – direct to disc, too! – many musicians, particularly guitarists, played in widely varying pitches. A comparison between The Beatles' recording of "Matchbox Blues" and those made some 30 or more years earlier by Leadbelly and Blind Lemon Jefferson reveals a remarkably wide variation. Leadbelly tuned his 12-string guitar 'low', Blind Lemon Jefferson tuned his six-string guitar 'high' and The Beatles played in 'British Standard Concert Pitch'.

There are few musical instruments which will retain their tuning for any appreciable length of time. All of the portable stringed instruments (guitars, banjos, mandolins, violins, cellos ad infinitum) are particularly prone to drifting strings. Wind instruments also suffer – you have to take them apart to carry them and they must be tuned when re-assembled for playing.

See what we mean about the cussedness of nature ?

This problem gave rise to the need for some device which would serve as an accurate standard to which instruments could be tuned. Even the piano and oboe – which are generally used as tuning references in an orchestra – must be tuned from time to time.

In 'olden times' pitch-pipes were employed as pitch standards. These were simple wooden "whistles" of the open pipe or vibrating reed variety. These little 'fixed pitch' devices, whilst simple and portable, suffered from pitch inaccuracies brought about by changes in air temperature and humidity. However, they're still in use as they're fine where no great pitch accuracy or adherence to a standard is required. The 'tuning fork' as such was invented by John Shore in Britain in 1711 (see note on history).

The traditional tuning fork consists of two cantilevered bars attached to a common base – it resembles that common eating utensil, hence the name. When the tines are struck (or one tine) they will vibrate, producing a sound of a definite pitch, or frequency, determined by the length of the tines. The pitch is largely unaffected by temperature, except by gross variations, and accuracy can be maintained within about 0.1%.

They are portable and relatively inexpensive but suffer from low sound level output and do not give a sustained note – it 'dies away'. What's more, as many modern groups use electrically amplified instruments and sound reinforcement, a failing of tuning forks is lack of a pick-up.

Again, the cussedness of nature raises its head. Remember too, the popularity of the electric guitar. They have magnetic pickups and require plugging into an amplifier. Now you see what electricity and magnetism have to do with musical instruments ! Gravity ? Oh, most instruments will go out of tune when dropped from a height !

HOW IT WORKS – ETI 606

The signal is generated at a high frequency (about 3.6 MHz) by a crystal oscillator and then divided down to the output frequency by a counting circuit. IC1c is the oscillator – gates biased into their linear region by R1 and R2. Capacitor C1 forms a phase-shift network with the bias components, providing a shift of 180 degrees at the crystal frequency. As the crystal is in series with the feedback path, the circuit will oscillate at the crystal frequency.

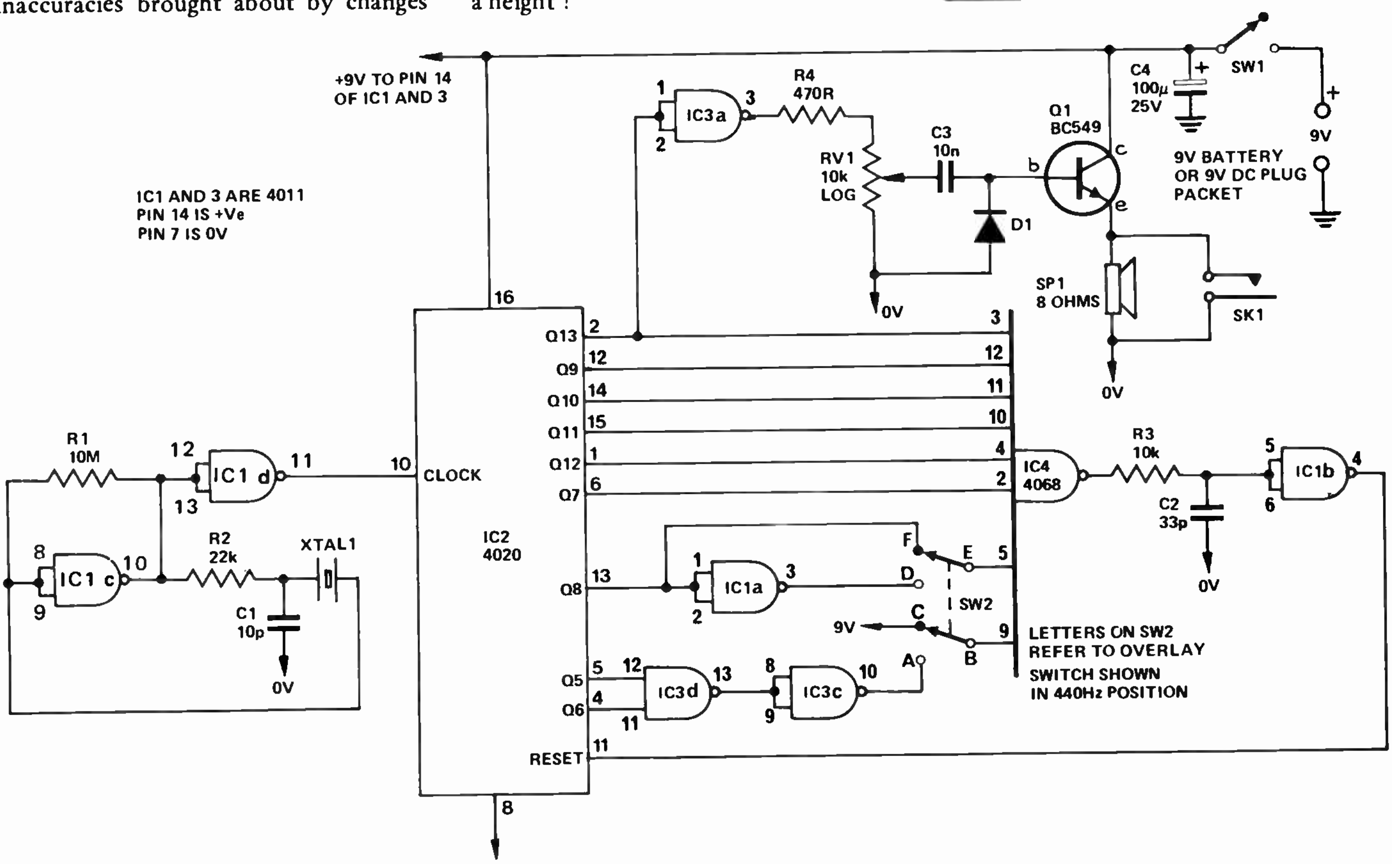
IC1d forms a buffer between the oscillator and the clock input of IC2, a 14-stage counter.

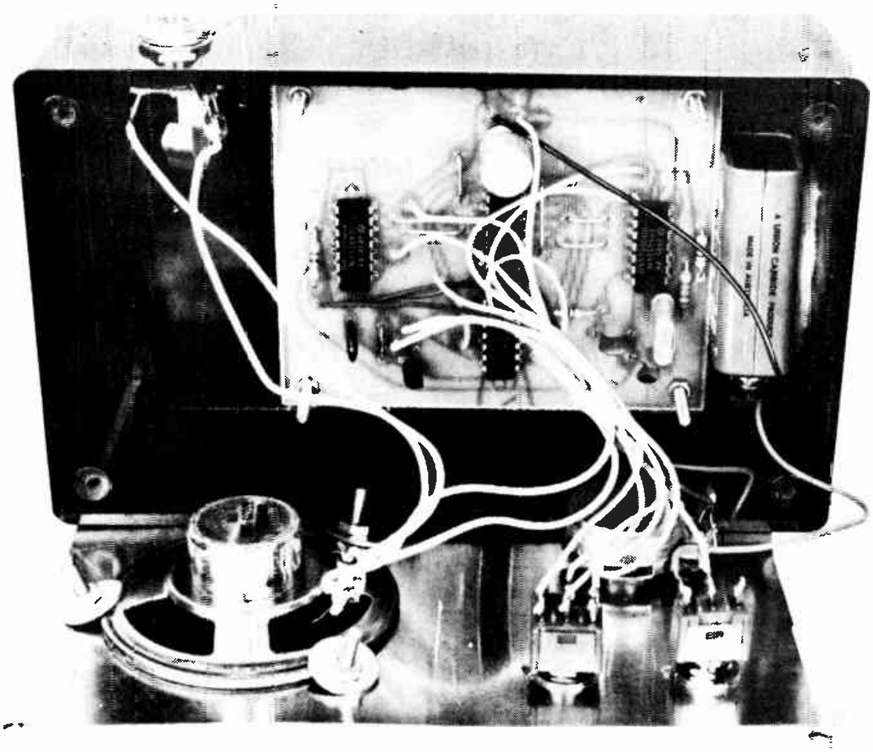
As the required division is not a power of two, decoding of the counter (IC2) outputs is necessary. This is provided in three gates – IC1a, IC3c and IC3d. These modify the outputs of IC2 to obtain the required division by resetting IC2 after the appropriate count.

Switch SW2 changes the decoding for either a division by 8128 for a 440 Hz output or 8048 for a 445 Hz output.

When all the inputs of IC4, an eight input NOR gate, go high its output goes low and drives IC1b via a network to remove noise pulses (R3, C2). IC1d then provides a reset signal to the divider, ready for the next count.

The Q13 output from the divider provides a signal at the required frequency and, after buffering provided by IC3a is fed to the volume control. The pulses are then fed to an emitter follower (Q1) and thence to the speaker.





As the project was to be battery operated, it was clear that CMOS ICs would be necessary in the circuit and this imposed a limit on the frequency of the crystal of about 5 MHz.

There are two very common crystals available from many outlets: one on 4.433619 MHz which is the PAL colour TV system chrominance sub-carrier frequency, and 3.579545 MHz which is the NTSC system chrominance sub carrier frequency. (We couldn't find out why the latter is common here – but, there it is!) We chose the lower frequency of the two for several reasons. Firstly, 4.4 MHz is pushing the limit of CMOS if repeatable results were to be obtained by constructors. Secondly, it was the cheaper of the two!

Obtaining 440 Hz from such a high frequency requires dividing by a very large number. To get 440 Hz requires dividing by about 8130 while 445 Hz requires dividing by about 8050.

Accordingly, a 4020 CMOS divider was settled upon. This will provide a division ratio as high as 2^{14}. By suitably decoding the various outputs from the divider and resetting it when the appropriate count is reached, the output will be at (or close to) the frequency we want.

Thus, the outputs of the 4020 are decoded at a count of 8128 – conveniently close to 8130 – producing an output of 440.396 Hz. That's only 0.09% high. This is within the tolerance range of a standard tuning fork. To obtain an output close to 445 Hz, the 4020 outputs are decoded at a count of 8048, producing an output of 444.775 Hz which is only 0.05% low.

A fairly simple audio output stage has been provided, driving a small speaker, and a jack socket output for connection into an amplifier.

Current consumption is around 10 mA, so a No. 216 9V battery should last a very long time with the sort of intermittent use this project is likely to experience.

Demand for an 'electronic' tuning fork arose in recent years, seemingly as a result of the rapid increase in 'all-electric' bands. A number of commercial models have appeared but it seems that the perennial 'do-it-yourselfers' would rather build their own. Some readers have enquired about the possibility of doing an electronic tuning fork as a project – and here you have it.

The design

The problem appears fairly straightforward – synthesize 440 Hz with an accuracy and stability of 0.1% or better. First thought was to use the 50 Hz mains frequency as a reference (as it is very stable in frequency) and phase-lock an oscillator to it. This was tried using a 3900 quad op-amp as oscillator and PLL and some CMOS divider chips – five ICs in all. It worked, but the device had a number of practical drawbacks.

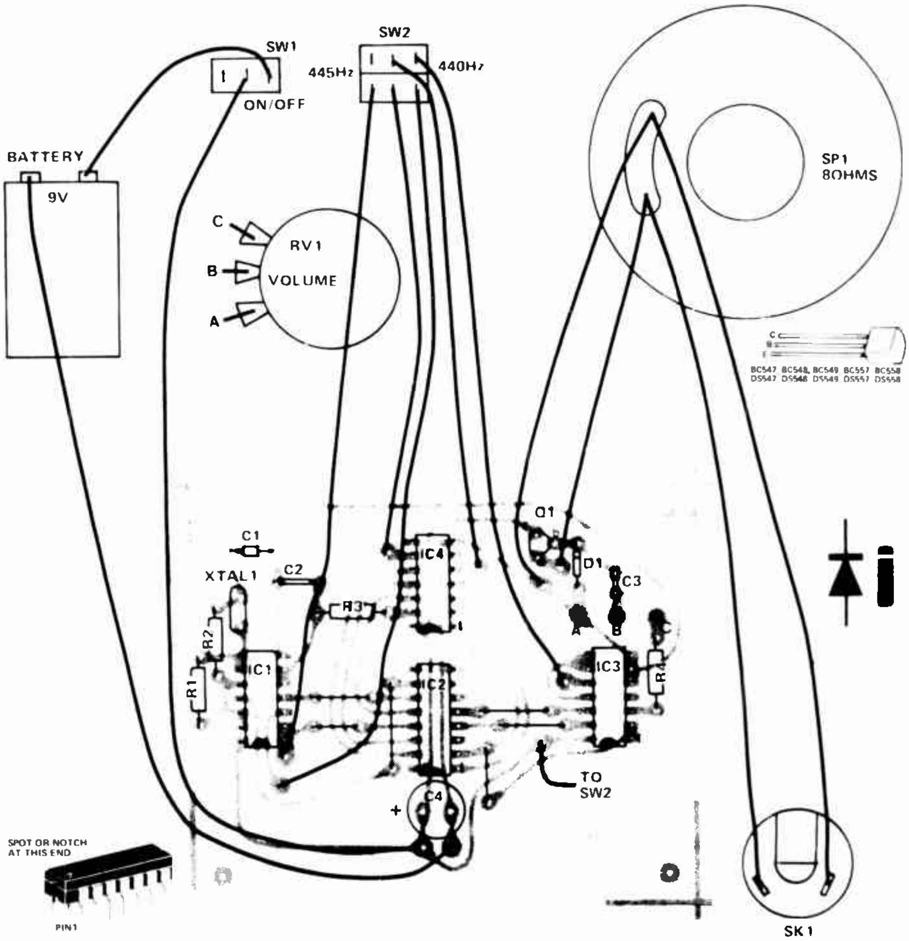
First up, 50 Hz mains had to be available. A musician friend pointed out that, here, we had made an unwarranted assumption. In the words of a well-known prophet: "It ain't necessarily so!". On top of that, the editor pointed out that many musicians who play stringed instruments prefer to tune about 3 Hz to 5 Hz high (or 'sharp') as it makes their instruments sound much 'brighter'. We had also heard that there were some orchestras tuning up using 'A' set at 445 Hz. This started a furious argument. As everything started to get confused at this stage and text-book consultations threw less light on the subject than was felt desirable, we decided to contact the Sydney Conservatorium of Music in an effort to resolve the dispute.

We spoke to Mr Trevor Faulcher who said that some orchestras in Sweden were using 445 Hz as a standard pitch for 'A' and confirmed that stringed instrument players preferred to tune a little sharp in pitch.

The problem now was, should the electronic tuning fork project include both 440 Hz and 445 Hz outputs or just 440 Hz alone? As the project was to be portable and battery operated the techniques that might be used to generate the required output were examined. The best bet was to use a commonly available quartz crystal and divide it down to give a 440 Hz output. A slightly different division should yield a 445 Hz output. A quick check indicated such a scheme would require fewer ICs than the PLL version first devised and that both frequencies could be provided.

Construction

We strongly recommend you use the pc board specified for this project. For a start, it simplifies construction, and secondly it reduces the possibility of wiring errors. With digital circuitry, bugs created by wiring errors can prove most frustrating to track down – particularly if you haven't had much experience with digital equipment. The project is not a difficult one; if you have had a small amount of experience constructing projects and finding your way around circuits and layout diag-



Component overlay. The pc board pattern is reproduced on page 158.

rams, then it should not prove too challenging.

It is best to commence construction by assembling the components on the printed circuit board. Leave the ICs till last – we shall see why shortly. Solder the crystal, the BC547 transistor, diode, resistors and capacitors in first. Watch the orientation of the diode, D1. Then do all the links using, say 22 gauge, tinned copper wire. There are six in all. Take care here, and refer to the overlay.

The two switches, the volume control potentiometer, the jack socket and the loudspeaker may now be connected – before being assembled to the front panel. Don't forget the battery connector. Use generous lengths of hookup wire – about 120 mm to 150 mm long. This makes for easy assembly of these components to the front panel.

Now the ICs may be inserted in the board and soldered. As they are all CMOS types, they should be handled with care. They will be supplied inserted in a conductive plastic foam or foil-wrapped styrene block. Remove them carefully. Take care to pick them up with your thumb and forefinger grasping the ends of the package, not touching the pins. Making sure you have them correctly oriented, insert them into the pc board. To check the orientation, look for a small indentation in the case immediately adjacent a pin at one end. This is pin 1. There may also be a large indentation in this end of the case. Note that all the ICs have the same orientation.

To solder the pins of the ICs, use an iron having an earthed tip and barrel. If you're unsure about this, use a clip lead to connect the iron's barrel to the negative supply rail on the pc board.

These measures will ensure you don't 'blow' the ICs with either static charges or leakage currents from the iron.

We assembled our prototype into a small 'zippy' box, measuring 160 mm by 96 mm by 50 mm. The aluminium front panel was drilled to take the controls positioned as shown on our template. You don't have to be too exact, there's plenty of leeway. Speaker mounting may seem a little mysterious. Several large holes were drilled where the cone faces the panel. The speaker may be glued in place or screws placed around the edge (only three are necessary) with large washers under the nuts overlapping the edge of the speaker, thus holding it in place. The panel on our prototype was covered with a Scotchcal overlay, as shown in the photograph. The sound from the speaker can be heard quite clearly through this and there is no need to cut holes in the Scotchcal. This helps protect the speaker, too.

Take care where you mount the jack socket. See that it clears the speaker magnet – with the jack plug inserted ! – when the panel is assembled and that it doesn't foul the pc board.

The pc board is held in place with four bolts and some 12 mm standoffs fixed to the base of the box. Mount it down one end so that the battery may be jammed between the end of the box and the pc board, using a small piece of foam rubber.

If you wished, this project could be powered by a small plugpack 'battery eliminator' – (try Ferguson Transformers Pty Ltd or A & R Soanar Pty Ltd).

The last thing to do is check that you have the switches wired correctly. Make sure that when you switch from 440 Hz to 445 Hz the output goes a little sharp in pitch. If the volume control works in 'reverse', simply transpose the two wires going to the outside connecting lugs on the potentiometer. ●

PARTS LIST - ETI 606

Resistors all ¼W, 5%

R1	10M
R2	22k
R3	10k
R4	470R

Capacitors

C1	10p ceramic
C2	33p ceramic
C3	10n greencap
C4	100µ 25V electro

Semiconductors

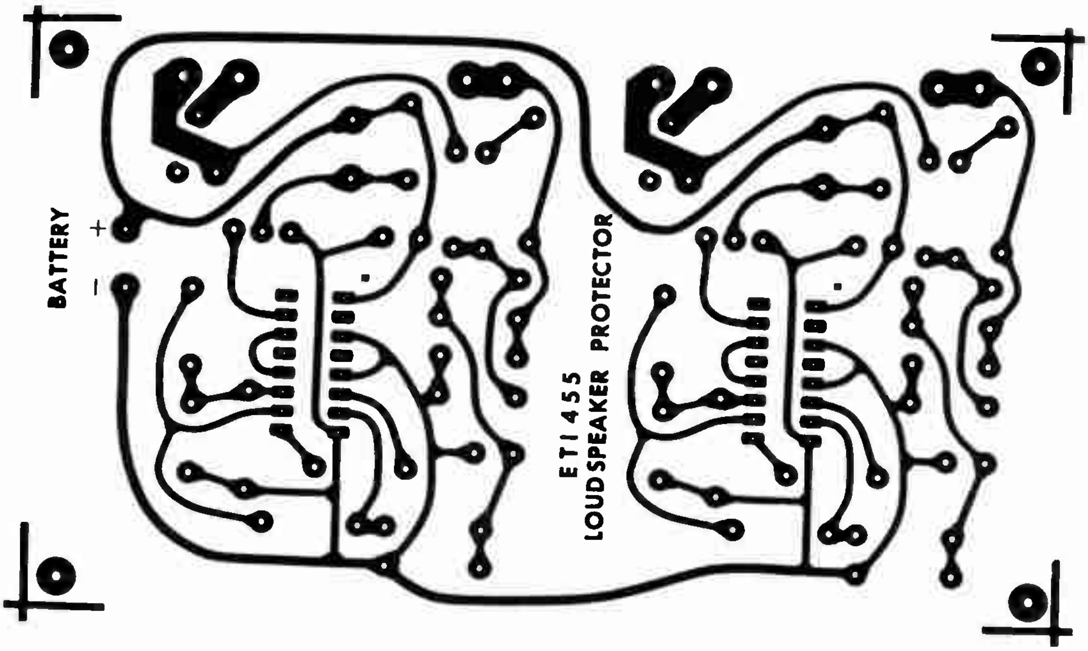
IC1, IC3	4011B or C
IC2	4020
IC4	4068
Q1	BC548, BC108 or similar
D1	IN914 or similar

Miscellaneous

RV1	10k log potentiometer
XTAL 1	3.579545 MHz Xtal (see text)
SP1	8 ohm speaker
SW1	SPST miniature toggle switch
SW2	DPDT miniature toggle switch
SK1	mono jack socket

9 V, No.216 battery or Plug Pack (Ferguson type PPA9 - DC or similar), ETI 606 pc board, Zippy box to suit (155 mm x 105 mm x 50 mm), knob, plug for jack socket (if needed).

(Continued from page 57).



Project 721

Aircraft Band Converter

AN INTEREST IN what can be heard on the shortwave frequency bands between 3 MHz and 30 MHz often kindles an interest in what can be heard 'beyond' 30 MHz, apart from TV and FM broadcasting stations.

For many communications hobbyists a variety of fascinating services can be found on the very high frequency (VHF) bands above 30 MHz. One of the more interesting bands lies between 118 MHz and 126 MHz – the aircraft band.

Domestic aircraft communications, both private and commercial, generally involve a pilot talking from his plane to a traffic controller at an airfield as well as talking to other pilots. Signals from aircraft can be heard over quite long distances as they are flying quite high and thus the horizon, from the aircraft, can be up to several hundred miles away.

There are 360 channels allocated in the aircraft band, each assigned a specific use or for use in a particular area. Amplitude modulated (AM) transmission is used which simplifies the requirements for a receiver to listen on this band.

Apart from a hobbyist interest, we have had occasional enquiries from readers who wish to have a receiving system to monitor a particular channel or channels for various reasons.

This converter should suit either purpose very well.

The Converter

Why a converter – why not a complete receiver? Firstly, a shortwave listener will already have a receiver. A converter to 'change down' the aircraft band frequencies to a suitable band between 3 MHZ and 30 MHz is a simple, and inexpensive, solution. For those wishing to monitor some portion of the aircraft band the output of the converter could be connected to an ordinary multi-band transistor portable to provide quite adequate results. Alternatively, a fixed frequency IF (intermediate frequency) strip with detector and audio stages could be constructed.

For simplicity and cheapness we have modified an existing and well-proven design – the ETI707A 144 MHz solid state converter. This was designed for radio amateurs and others interested in reception of signals on the 144 - 148 MHz band. It was originally described in the February 1976 issue of ETI and since then many hundreds have been successfully built – by beginners and experienced constructors alike. It is a very successful design, so why re-invent the wheel?

The converter is crystal locked – that is, a quartz crystal oscillator is mixed with the signals from the antenna, the signals then appearing at a lower frequency at the converter output. The frequency of the crystal used will determine the frequency band of the converter output.

For a number of reasons, we chose the output (or IF) frequency to be around 10 MHz. Inexpensive crystals are available for the aircraft band to give an IF output from the converter of 10.7 MHz – a standard IF frequency. The same crystals can be employed if you wish to use a tunable shortwave receiver following the converter. There is a minor inconvenience though – the tunable receiver's dial has no simple relationship to the input frequency. The advantage is that inexpensive crystals cost around half that of a crystal made to order to provide a direct frequency relationship.

The choice is up to you. Choosing and ordering crystals is covered later in the article.

As the converter has quite a deal of gain, resulting in very good sensitivity, an RF Gain control has been provided. Very strong signals on a channel near to the one being monitored may cause interference. Judicious use of the RF gain control will reduce or remove the interference while enabling you to still hear the desired signal. Then again, a very strong signal on the channel you are monitoring may overload your receiver, resulting in very distorted reception. Reducing the RF gain will remove the problem.

PARTS LIST – ETI 721

Resistors all ¼W, 5% *

R1	150R
R2, 3	100k
R4	150R
R5	1M
R6	56k
R7	560R
R8	680R
R9	10k
R10	4k7
R11	470R
R12	270R

Potentiometer

RV1	100k A pot

Capacitors

C_C	22p ceramic
C1	6p8 ceramic
C2 - C5	1n ceramic
C6 - C8	6p8 ceramic
C9	1n ceramic
C10	100p poly or ceramic
C11	10n poly or ceramic
C12	100p poly or ceramic
C13	68p poly or ceramic
C14	47p poly or ceramic
C15	6p8 ceramic
C16	1n ceramic
C17	6p8 ceramic
C18	10n poly or ceramic

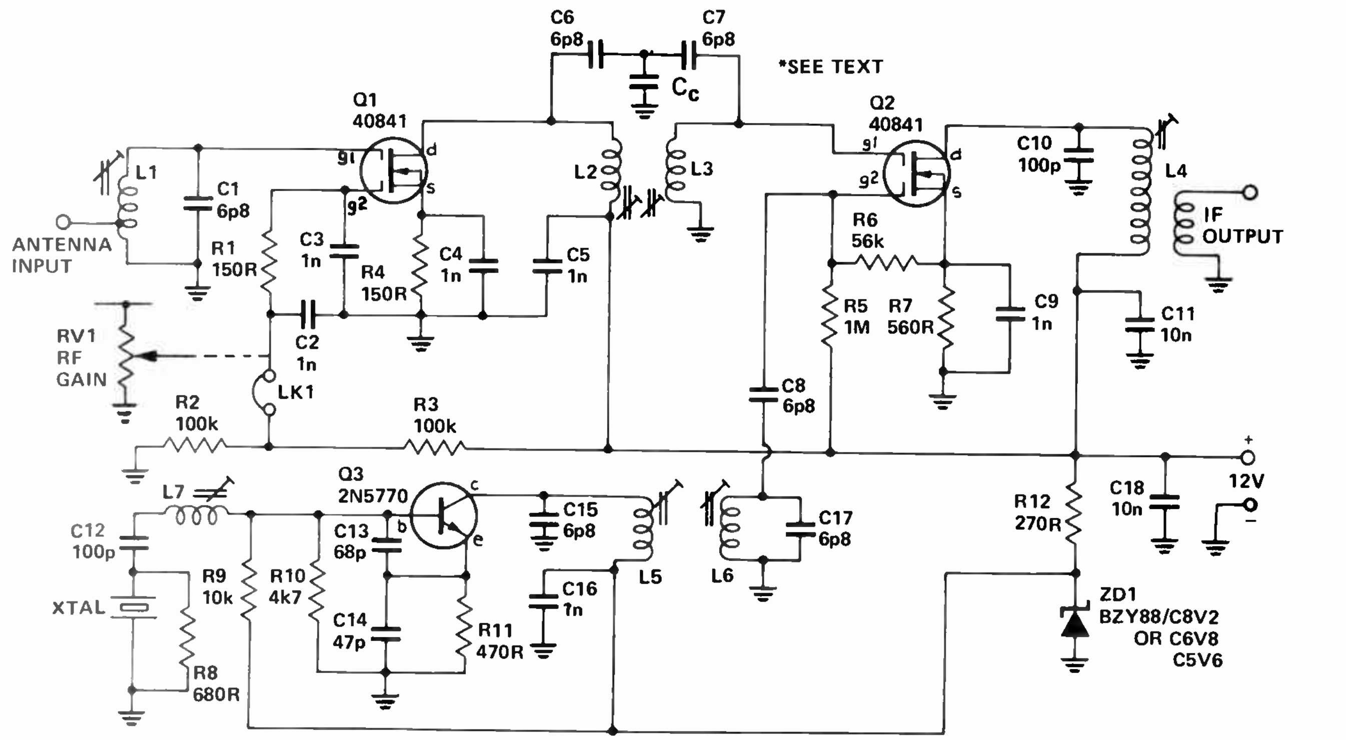
Semiconductors

Q1, 2	MFE131, 40673, 40841
Q3	2N3563, 2N3564, 2N5770
ZD1	BZY88/C8V2 or /C6V8 or /C5V6 or /C5V1

Miscellaneous

7 x 722/1 Neosid coil formers
3 x 7100 Neosid screening cans
2 x 7300 Neosid screening cans
7 x Neosid ferrite slugs, 4 x 5 x 10/F29
coil wire
pc board . . ETI 707A
crystal . . . see text
zippy box (see text), 2 coax sockets,
2 x 20 mm, 6 BA spacers, nuts, bolts, etc.

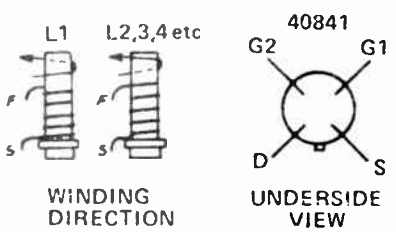
*Resistor values may be plus or minus one standard value either side of those quoted without ill effect. Capacitor values should not be altered.



Coil Data

Wind L2, L3, L4, L5, L6 and L7 *clockwise* up the former. L1 is wound *anti-clockwise* up the former. The start of each coil is the 'cold' or 'earthy' end. All slugs are F29 type ferrite.

L1	5 turns, 22 B & S tinned copper wire spaced over 10 mm, tap at 2 turns from cold end.
L2, L3	6½ turns, 22 B & S enamelled wire, spaced over 8 mm.
L4	25 turns closewound with enamelled wire, any gauge between 25 and 30 B & S, 5 turn link at top of former.
L5, L6	5½ turns, 22 B & S enamelled wire, closewound.
L7	*10 turns, 22 B & S enamelled wire, closewound, for crystals in the range 30 MHz to 50 MHz. *6 turns for crystals in the range 50 to 70 MHz.



Construction

The printed circuit board has been specially designed for this application and no other construction technique should be employed unless you are very experienced in circuit construction at these frequencies.

It is best to commence construction by mounting the coil formers. They may be glued on the board over the pilot holes or the board drilled to the appropriate diameter for the base of the formers and then gluing the formers in place. Use the shield cans to locate and/or hold the formers on the pc board when gluing them directly to the board. It is wise to insert the slugs in the formers *after* gluing to avoid accidentally gluing them to the formers. The best type of glue to use is one of the 'instant' bond glues such as "Superglue", "Bondza", "Super 500" etc. Many glues available will not bond to pc substrate materials – particularly fibreglass pc material.

The next step is to wind the coils. They may be wound *in situ* if you wish, alternatively they may be wound on a suitable diameter former (such as a 5 mm or 3/16" drill shank) and then slipped over the formers on the board.

Take careful note of winding direction and the start and finish connections. Refer to the component overlay when soldering the coil leads in place. Do not mount the shield cans until all the minor components have been soldered in place.

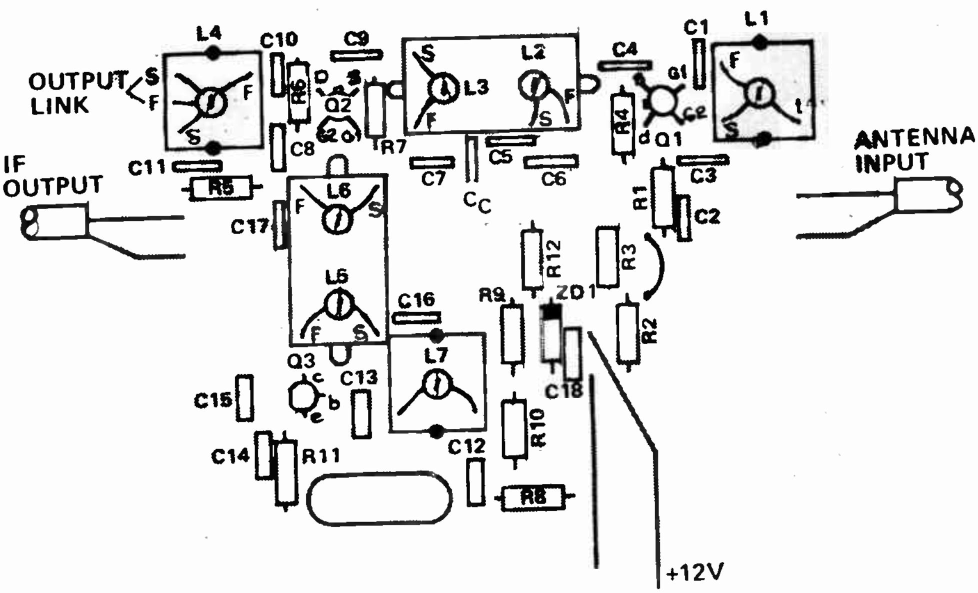
When mounting the minor components take particular care with orientation of the transistors, FETs and the zener diode. All components should be mounted right down on the pc board to minimise lead length. Stakes or pins should be used for the connections to the antenna input, IF output and dc connections.

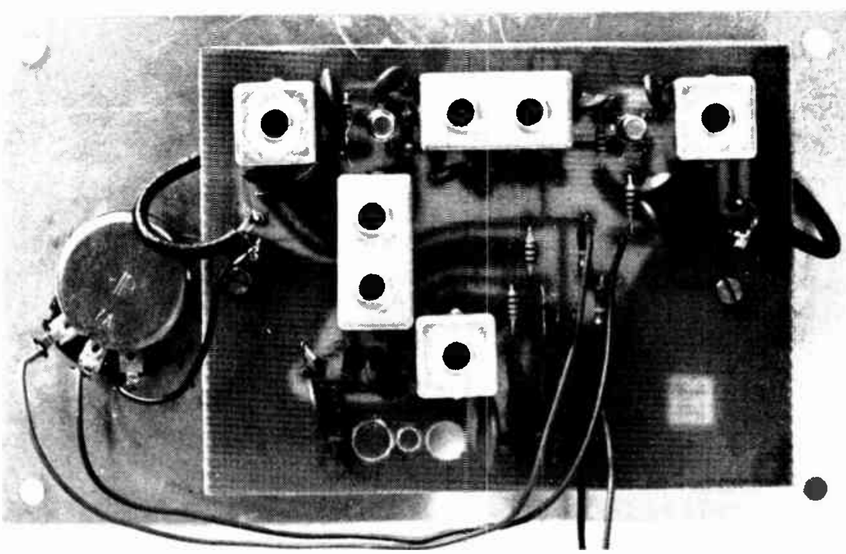
There is provision on the pc board to mount a crystal socket for a 'style-D' crystal. These have a 12 mm pin spacing and stand about 20 mm high. Alternatively, if the smaller size crystals are used, having a pin spacing of 5 mm or pigtail connections, then they may be soldered in place under the board. Take care when doing this. Do it quickly and use the minimum amount of heat to avoid damaging the crystal.

If desired, the crystal may be mounted separate from the pc board. Keep lead length between the crystal and the board connections as short as practicable in this case.

The shield cans for the coil assemblies should be mounted last. It may be a wise idea to check that the converter is working before soldering the shield pins to the pc board.

The completed converter may be mounted in a suitable box. The one we used was a small 'zippy' box measuring 159 x 96 x 50 mm overall. They are available from a number of component suppliers. The pc board was mounted on the aluminium panel using two spacers. Antenna and IF output sockets, along with the RF gain pot, were also mounted on the panel and dc power





leads taken through a hole in the side of the box. Small lengths of coax cable were used to connect the input and output sockets to the pc board connections.

Alignment

The particular method of alignment will depend on how you will be using the converter. To commence the alignment you will need to have on hand the appropriate aligning tool. You will need a plastic screwdriver-tip alignment tool to suit the Neosid ferrite cores. They are readily available from many suppliers. Most general purpose alignment tool kits available will have a suitable tool. These kits cost around $2 - $3, contain four tools with various tips and are generally called 'TV alignment' kits.

You will need a dc power supply delivering between 12 and 15 volts; the converter will draw between 30 and 50 milliamps. A receiver with a S-meter is a decided advantage when aligning the converter. You will need a signal generator, with AM modulation, covering the range 118-126 MHz.

If you are using a tunable receiver for the IF, then the following procedure should be followed:

Connect the converter to the receiver. Use a short length of coax cable. If the converter is working you will notice an increase in the noise level on a sensitive receiver when power is applied. You can check that the crystal oscillator is working by removing the crystal temporarily – a decrease in the noise from the receiver will be noticed.

1. Set the receiver frequency to the middle of the tuning range of the converter's output. The converter RF gain should be at maximum all through the alignment procedure.

HOW IT WORKS – ETI 721

The circuit is quite straightforward, comprising an RF stage (Q1), a mixer (Q2) and an overtone crystal oscillator-multiplier (Q3). Dual-gate MOSFETs are used in the RF and mixer stages as they have good gain, low noise figure and good freedom from crossmodulation and overload problems.

Signals from the antenna are first amplified by Q1 and passed to gate-1 of the mixer Q2. The oscillator, Q3, is set to a precise frequency by the crystal. The injection frequency to gate-2 of the mixer is derived from the collector of Q3, being two or three times the crystal frequency. The signal frequency and the injection frequency are mixed in Q2, their *difference* is selected by the tuned circuit in the drain – this is the desired output frequency.

A low-Q tuned circuit, L1-C1, is used between the antenna input and gate-1 of Q1. The antenna input impedance is *mismatched* to the impedance of the gate to optimise noise figure. The drain of Q1 is coupled to gate-1 of the mixer, Q2, via a double-tuned, bandpass coupling circuit consisting of L2, C6, Cc, C7 and L3. A combination of inductive coupling and common-capacity coupling is used to achieve a wide bandwidth.

Gate-2 of Q1 requires a bias of +6V for full stage gain. A link between gate-2 decoupling (R1,C2,C3) and the junction of R2-R3 allows for the connection of a gain control potentiometer.

The mixer has about 1.5 volts of bias applied to gate-2. The conversion frequency is injected at this gate and a small amount of forward bias improves the mixer conversion gain. The output, or IF, is coupled via L4 which is resonant at 10 MHz with C10. This is a low-Q tuned circuit for the broad bandwidth necessary if the tunable IF receiver is used.

The crystal oscillator stage, Q3, is designed to cope with either third or fifth overtone crystals and may double or triple the crystal frequency in the collector. Tuned circuit L5-C15 selects the appropriate harmonic. Energy is coupled from L5 to L6 which is resonated to the required frequency with C17. These two tuned circuits filter the injection frequency. This prevents any spurious mixing occuring in Q2.

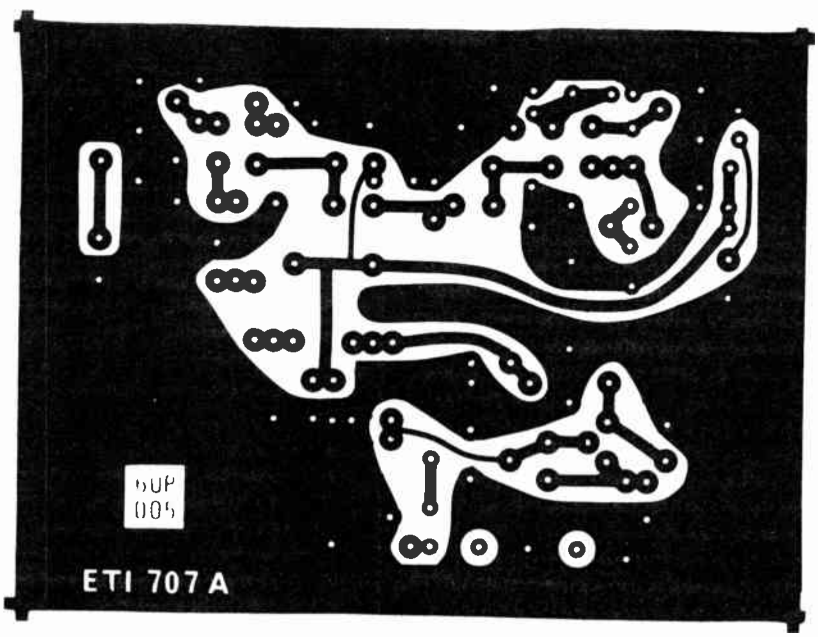
Coil L7 is used to 'trim' the crystal frequency.

A regulated supply to Q3, provided by the zener diode, ZD1, prevents power supply variations from affecting the crystal frequency.

2. Tune the slug in L4 to obtain a peak in the receiver noise level.
3. Set all the other coil slugs flush with the tops of the coil formers.
4. Using the signal generator, with a fairly high output level, peak L4 again for best signal strength.
5. Set the generator to a frequency near 119 MHz and tune the receiver until you pick up the signal. Now adjust the slugs in L2 and L6 for best signal strength. Decrease the output of the signal generator so that these adjustments are made on a fairly weak signal.
6. Set the generator to a frequency near 125 MHz, or the highest frequency in which you are interested, and tune the receiver until you pick up the signal. Adjust the slugs in L1 and L5 for best signal strength. Keep the generator output at a low level for best results.

SOME CHANNEL ALLOCATIONS

Frequency	Channel Usage
118.1	Bankstown and other towers
118.7	Canberra Parafield towers
118.9	Melbourne departure
119.1	Club frequency
119.4	Sydney approach
120.5	Adelaide/Brisbane/ Melbourne/Sydney towers
120.9	Automatic information service
122.1	Area frequency
123.0	Sydney departure
124.2	Adelaide approach
124.4	Sydney approach
124.7	Brisbane/Melbourne approach
125.3	Sydney departure
125.8	Area frequency



7. Now set the generator to a frequency half way between these two frequencies. Tune the receiver to pick up the signal and adjust the slug in L3 for best signal. Check the adjustment of L4.
8. Return to 119 MHz and peak the slug in L2 again.
9. Repeat the procedure, 'touching up' each slug.

If the converter is to be used on one channel, or a couple of channels less than 1 MHz apart, then all the coils need only be adjusted for best signal strength on one channel.

Overall sensitivity of the converter-receiver system is very good, signals as low as 0.2 uV being clearly audible. The gain control range is about 20 dB.

Choosing A Crystal

The frequency injected at gate 2 of the mixer FET, Q2, may be above or below the signal frequency by an amount equal to the IF frequency. For a tunable receiver used as an IF. the injection frequency should be lower than the *lowest* signal frequency by 10 MHz. Thus, as you tune the receiver upwards in frequency from 10 MHz, you will tune signals above the lowest aircraft band frequency (118 MHz). In this way there will be a simple relationship between the signal frequency and the receiver's dial. If 10 MHz equals 118 MHz, 10.5 MHz will equal 118.5 MHz, and so on. For this situation the injection frequency will be 118 – 10 = 108 MHz. As the crystal oscillator output (collector of Q3) is twice the crystal frequency, the crystal frequency should be half of 108 MHz = 54 MHz.

If you use a tunable receiver then a fifth overtone crystal at 54.000 MHz should be ordered. Tolerance and adjustment range also have to be specified. A value of 20 parts per million (ppm) for tolerance and adjustment range is satisfactory. Firms such as Bright Star Crystals or Hy-Q should be able to supply a crystal to order.

Alternatively, a crystal at one-third the injection frequency may be used. Taking the 108 MHz injection frequency, as just illustrated a 36 MHz crystal may be used.

To determine the crystal frequency required for any case, use the following formula:

$$\text{Crystal} = \frac{\text{lowest signal frequency} - \text{IF}}{2 \text{ or } 3}$$

Inexpensive crystals intended for use in 'scanning' receivers are available from Dick Smith's. These provide an injection frequency *above* a particular aircraft channel frequency for the standard IF frequency of 10.7 MHz. For example, for the 125.8 MHz channel, the injection frequency is 136.5 MHz. These crystals have the channel frequency marked on them, not the crystal frequency.

Setting the crystal frequency

If you require accurate frequency readout then the crystal frequency will need 'trimming'. Coil L7 is provided for this purpose. For best results a digital frequency meter capable of measuring to 150 MHz is necessary.

Lightly couple the DFM to L5 or L6 via a small value capacitor and see if you get a sensible reading. You may need to connect it directly across gate-2 of the mixer, Q2.

Adjust L7 until you obtain the correct injection frequency according to the crystal chosen.

Multi-channel operation

If you intend using a fixed frequency IF (on 10.7 MHz) then a group of crystals may be used to select the desired channels of interest. A single-pole, multi-position switch may be used to select appropriate crystals.

Delete L7 on the pc board and replace it with a link. The components L7, C12 and R8 are also deleted. Each crystal needs to have this circuit attached. The channel switch is then connected with the pole to the junction of R9 and R10 and the trimming coil for each crystal connects to the appropriate switch contact.

The following article describes a simple groundplane type antenna designed for our aircraft band converter.

SIMPLE ANTENNA FOR OUR AIRCRAFT BAND CONVERTER

Our Project 721 has proved quite popular – for many more reasons than we anticipated when the project was conceived. Here is a simple groundplane type antenna that is easy to construct and uses commonly available parts.

THE BEST ANTENNA for monitoring purposes on VHF is one which receives signals equally well from every direction. Such an antenna is actually impossible to build, however, the nearest approach is an 'omnidirectional' antenna. That is, an antenna that responds to signals equally from all directions towards the horizon.

Most transmissions encountered in the 120 MHz band are vertically polarized; the simplest antenna one can construct to receive vertically polarized transmissions from almost any direction is the 'groundplane'.

In this antenna, a vertical, quarter-wavelength long whip (the 'active' part of the antenna) is situated at the centre of two crossed, halfwavelength long metal elements – the groundplane. The centre conductor of a coaxial cable feedline connects to the bottom of the vertical element while the outer conductor (braid) of the coax connects to the junction of the two groundplane elements.

In practice, this antenna will receive signals ranging from very low angles (towards the horizon) to quite high angles, with nearly equal sensitivity.

Construction Comments

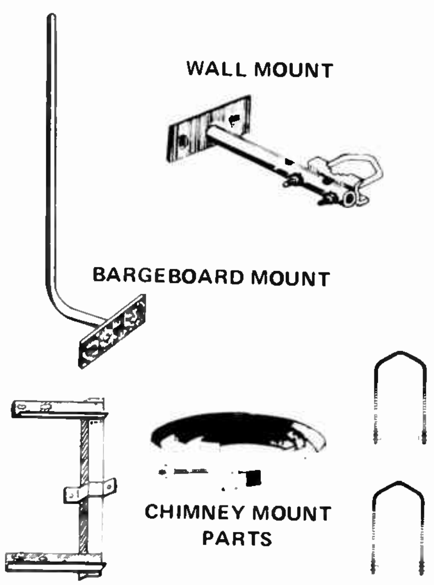
So that this antenna would be easy to build by a majority of interested constructors we have chosen parts which are readily obtainable.

The vertical element (A) is a standard low-band VHF whip sold for mobile applications. It consists of a length of tapered fibreglass covered in copper braid all protected by heatshrink tubing. A plated brass ferrule on the bottom has a tapped hole to mate with a standard mobile antenna mount. The whip as it comes is longer than required for the frequency of interest and is cut to the length indicated (61 cm). This is easily accomplished with a pair of heavy sidecutters.

These whips are obtainable from a number of sources and we have listed them at the end of the article.

The mobile antenna mount is also a 'standard' item, readily available from a variety of sources. There are two choices here – you can either use a 27 MHz CB antenna mount or a special 'VHF/UHF' mobile antenna mount. They are quite similar in construction, however, the VHF/UHF type incorporates a different style of termination for the coaxial cable feedline which provides a better 'match' to the antenna.

Note though, that the VHF/UHF bases available provide a weatherproof termination for the coax feedline. This is a decided advantage.



Commonly available TV antenna mounting components are inexpensive and provide a range of mounting options for the antenna described here.

The groundplane elements are made from standard 9.5 mm (3/8") aluminium tube. This is available quite cheaply in two-metre lengths from hardware stores (such as Pauls in Sydney) or aluminium suppliers. These elements are bolted to a bracket bent up from a small sheet of aluminium, as shown in the assembly diagram.

The aluminium bracket should be drilled before bending. Exact details are not given as mechanical details will vary, depending on the size and spacing of the U-bolt, the mast and the particular antenna base used. The assembly diagram provides a guide. One groundplane element mounts inside the bend, take this into account when marking the bolt holes for drilling. Element bolt holes may be about 30 mm apart.

If you wish, the bracket may simply be screwed to a wooden mast, rather than bolted to a tubing mast as shown in the illustration. There is plenty of scope for different mounting methods, but the basic assembly as shown should be followed.

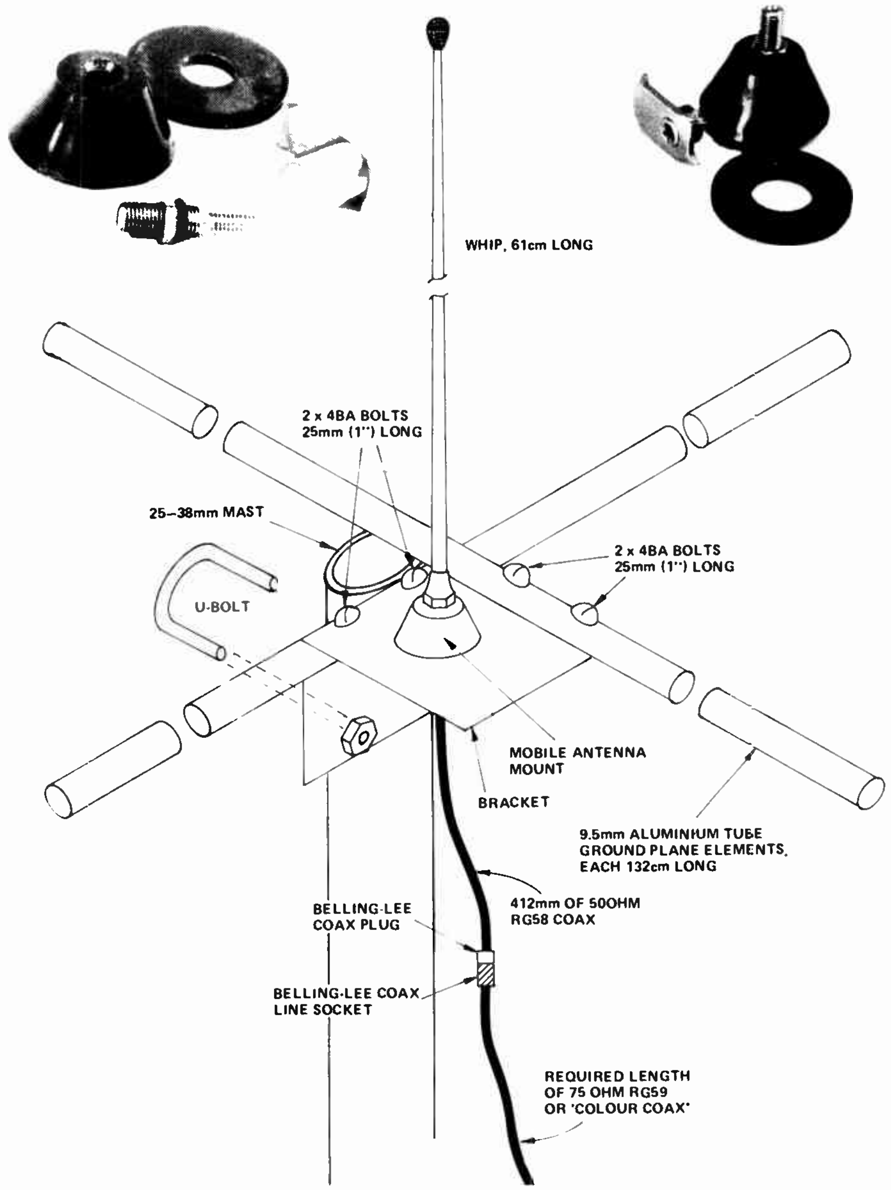
Cut the groundplane elements to length as shown in the illustration. Mark and drill them according to how you have drilled the bracket.

Do not cut the whip to length at this stage.

Assembly

All drilling should be done first. Do an individual trial assembly of the antenna mount and the elements just to see that everything fits without coming afoul of the other parts.

Bend up the bracket and assemble the antenna base, connecting the coax at the same time. Attach the two groundplane elements. Note that one is



Assembly diagram for the antenna. Inset above left shows the solderless Jackson 2-226 antenna mount, inset above right shows Scalar's OB base.

mounted beneath the bracket, in the bend. The other is mounted on top. The bolts go right through bracket and element.

Finally, screw the whip to the mounting base, measure 61 cm up from the bracket and cut the whip at that point.

Mounting Tips

The antenna may be mounted using TV antenna mounting components. These are relatively inexpensive and widely available. Standard wallmounts, bargeboard or chimney mounts and mast sections are ideal.

Mount the antenna as high as practicable and away from other objects for best results.

Coaxial Feedline

Standard 75 ohm coaxial cable is used for the feedline. This is commonly used for colour TV installations.

The impedance of a groundplane antenna of this sort of construction is generally around 35 to 40 ohms. To obtain best performance from the antenna it is necessary to 'match' the feedline impedance to the antenna impedance. Fortunately, there's a very simple way to do this.

A length of coax, one quarterwave-length long, having an impedance equal to the geometric mean of the two different impedances (that is: the square root of the product of the two impedances) will 'transform' between the two impedances. This technique is called the "Q-match transformer" method.

Conveniently for us, the square root of 35 ohms by 75 ohms is very close to 52 ohms. Thus, we can use a piece of

PARTS LIST ETI-722

Whip	Fibreglass quarterwave mobile whip. Obtainable from Mobile One or Scalar (Cat. No: M11).
Base	Mobile antenna base. Obtainable from Mobile One (HF base A), Scalar (type MB or OB) or IFTA (Jackson, model 2-226). The latter is a solderless type.
Bracket	16 or 18 gauge aluminium 75 x 150 mm min size.
Elements	9.5 mm (3/8") dia aluminium tube.
Coax	RG58 (52 ohms) cut to 415mm; RG59 (75 ohms) or similar, length to suit installation.
Connectors	Belling-Lee type, coax plug (e.g.: Dick Smith Cat. No: P-2020) and coax line socket (e.g. DS (e.g. DS Cat No: P-2030).
Miscellaneous	4 BA bolts and nuts, U-bolt to suit mast diameter

RG58 52 ohm coax, cut to an 'electrical' quarter wavelength (to account for the velocity factor of the cable — a wavelength is shorter in coax due to the effect of the cable's dielectric). This is inserted between the antenna and the main feedline as illustrated in the assembly diagram.

The bandwidth of this system, and the whole antenna, is quite adequate for the application.

A standard Belling-Lee coax line plug is attached to the end of the RG58 matching section and a Belling-Lee coax line socket is attached to the end of the 75 ohm feedline. This join should be securely taped with insulation tape, or even covered with heatshrink tubing, to protect the connectors from the effects of the weather. ●

Addresses

IFTA 1 Greville St, Randwick 2031 (PO Box 21, Bondi Beach 2026), phone: (02) 665-8211.

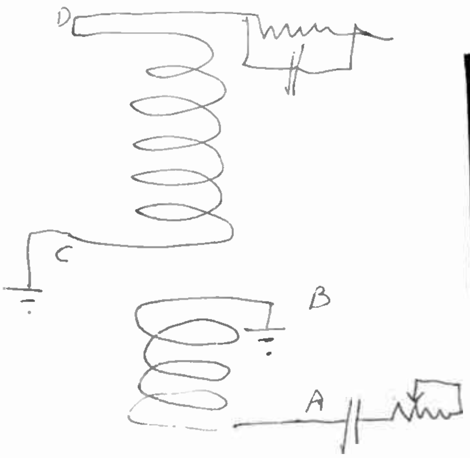
Mobile One 17 Sloane St, Marrickville 2204, phone: (02) 516-4500.

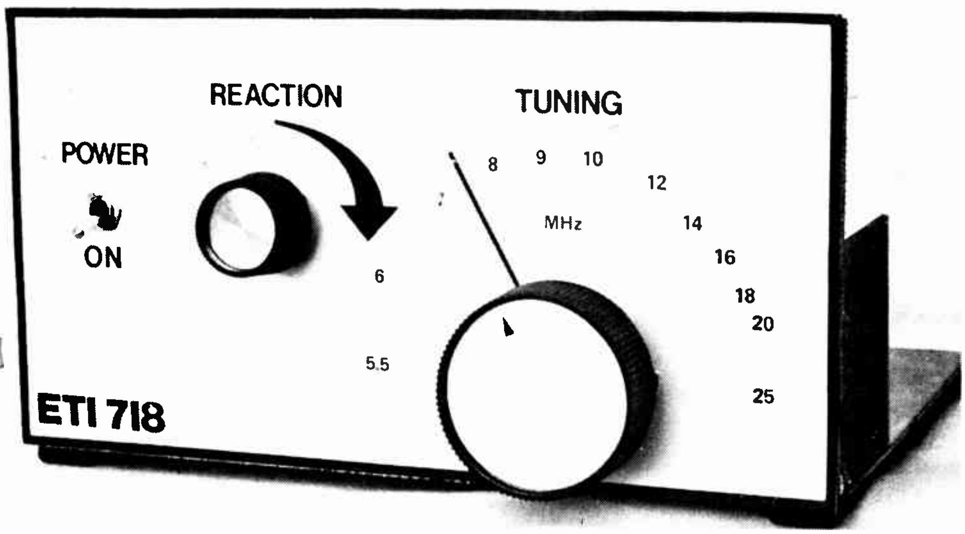
Scalar 20 Shelley Ave, Kilsyth 3137, phone: (03) 725-9677.
20 The Strand, Penshurst 2222, phone: (02) 570-1392.
969 Ann St, Fortitude Valley 4006, phone: (07) 52-2594.

These firms should be able to assist with whips and bases to suit the antenna and addresses of nearest suppliers.

SHORT WAVE RECEIVER

Maybe you can't afford to buy the super-radio you'd like, don't worry . . . . .we've got the answer.





APART FROM THE very early sets, which were based upon coherers and other devices you never hear of today, the first radios were very straightforward designs totally unlike today's sophisticated superhets. The early Tuned Radio Frequency (TRF) sets were simply a tuning circuit with some gain and a detector circuit, but later designs used positive feedback, in the form of reaction, to increase the performance. It is still possible to get a lot of fun from sets of this type.

By using modern solid state components a very simple reaction set can be built which offers surprisingly good performance at low cost. The Field Effect Transistor has almost identical performance to the earlier valve and is the basis of this design.

The circuit of fig. 1 uses an MPF 131 dual gate MOSFET as a regenerative detector, followed by a BC548 audio amplifier stage which is capable of driving a crystal ear piece, high impedance head phones, or being fed to the input of an amplifier. The frequency coverage is approximately 5.5 to 25 MHz, or 54 to 12 meters.

This coverage includes many interesting features such as the international broadcast bands at 49, 31, 25, 19, 16, and 13 metres, as well as amateur bands at 40, 20, and 15 metres.

Operation

Satisfactory operation depends on the proper use of regeneration, which unless operated correctly will result in poor performance and interference to neighbouring sets.

Initially, set C1 about half closed and increase the regeneration until a point can be found where signals are heard when tuning. Increasing the regeneration will increase the volume, until a point is reached where a whistle is heard when tuning across a station. The most sensitive point is where this whistle just fails to arise.

Regeneration has to be adjusted in conjunction with the tuning, because the setting of RV1 will change as the set is tuned across the band. The tapping position of the coil also influences regeneration, and may have to be lowered to obtain correct operation on some frequencies. The tapping point found to give the best results will also depend on the length of antenna used. As a starting point, try the middle tap and then move the tapping point up or down the coil to give the strongest signals, while still able to achieve regeneration.

Reception of CW signals is possible by using the regeneration control so the set is just oscillating, while the tuning gang is set so that a beat note is heard. This can also be done for SSB signals but the tuning will be very critical.

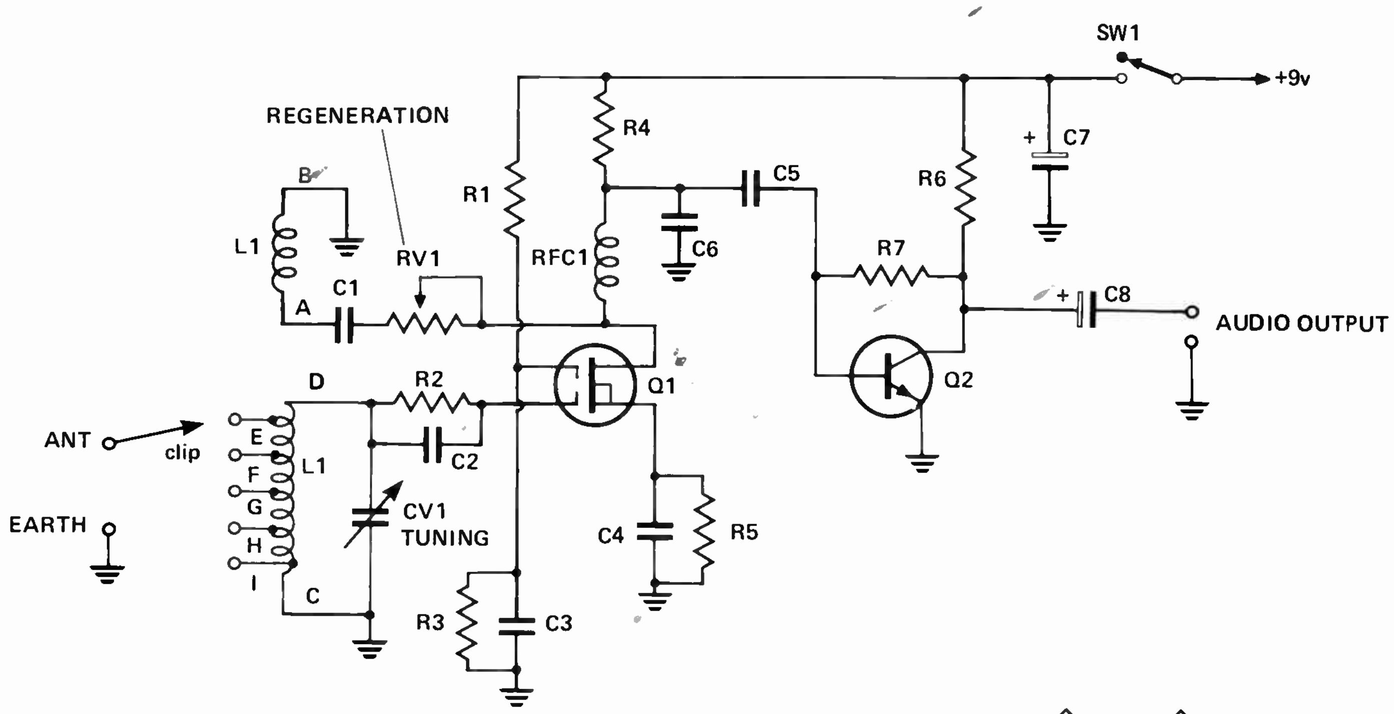


Fig. 1. Circuit diagram of the receiver.

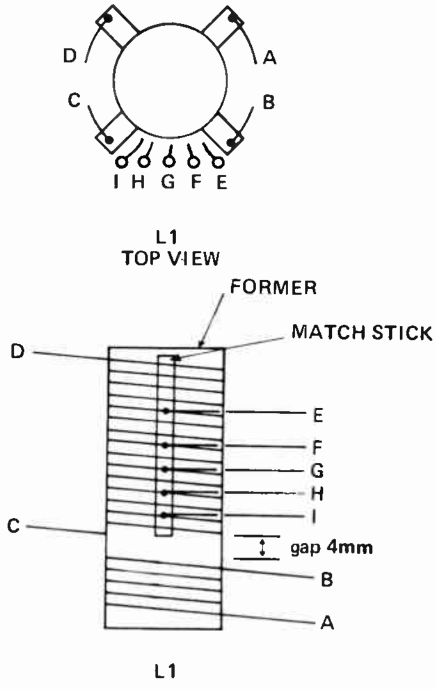


Table 1 – Coil Winding Details

Reaction coil: 4 turns of 24 B & S enamelled wire, closewound at the base of the former in a clockwise direction.

Tuning coil: 15 turns of 24 B & S enamelled wire, closewound, starting 4 mm above the top of the reaction winding in a clockwise direction. Taps at 2,4,6,8 and 11 turns fror the bottom of the winding. Turr which are tapped are raised ove matchstick.

HOW IT WORKS – ETI 718

Signals from the antenna are coupled into the tuned circuit (L1, CV1) via the clip lead and the coil taps. The tapping point is varied to give the best match from the antenna to the circuit, yielding the best performance.

The tuned circuit acts as a filter, only letting the desired frequency through to the FET (Q1), since the tuned circuit resonates at a frequency set by the position of the variable capacitor, (CV1). As the value of the capacitor is varied, so the resonant frequency of the tuned circuit, and the frequency of reception, is varied.

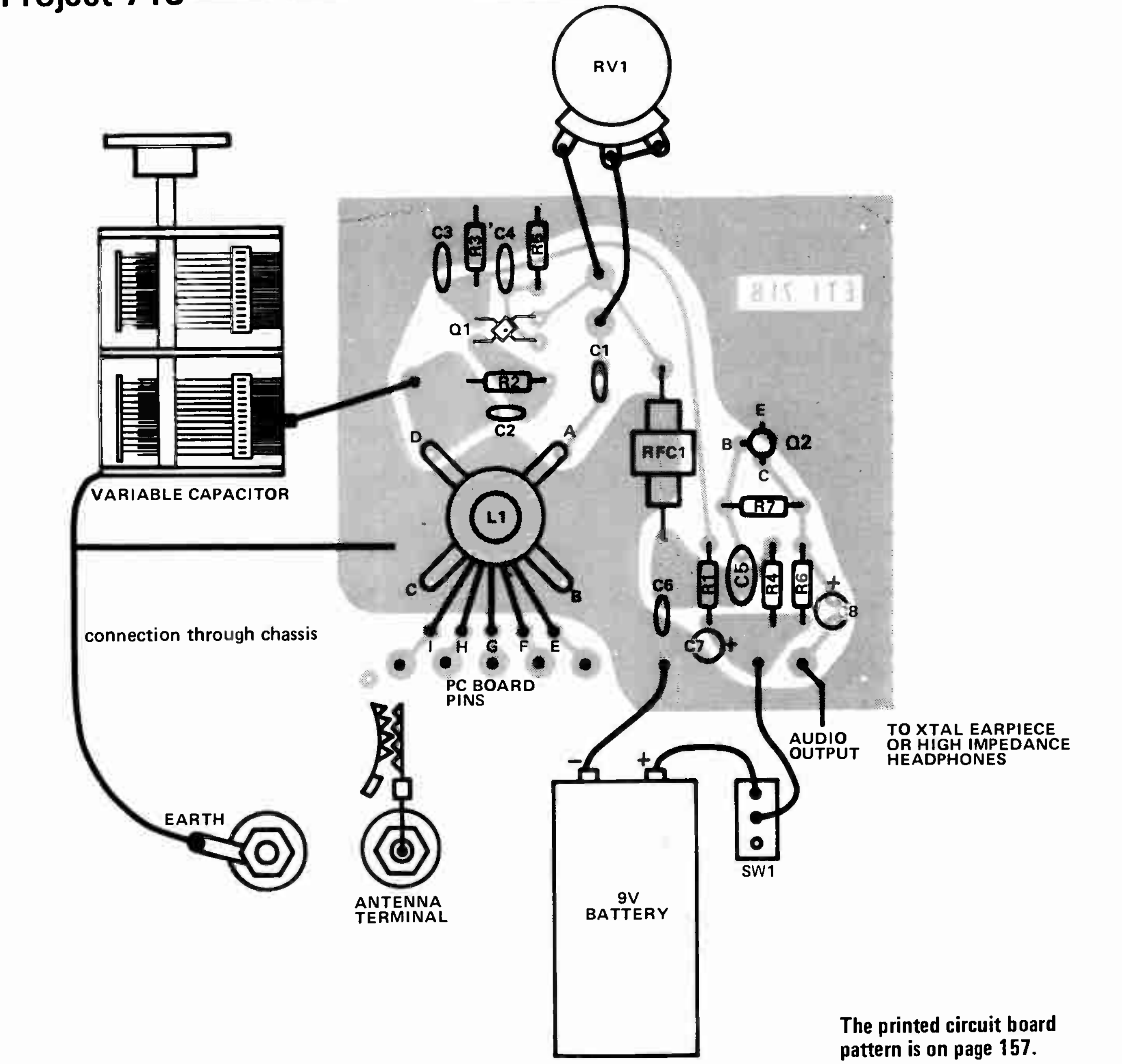
The radio frequency signal at the desired frequency is then fed to the FET (Q1), where it is amplified and appears at the drain. Because the radio frequency choke (RFC1) presents a high impedance (or near open circuit) to radio frequencies the signal passes through C1 and RV1 to the regeneration coil wound on L1. Some of this signal, the amount determined by the setting of RV1, is coupled back to the tuned circuit.

For regeneration to occur, the signal fed back to the input must be the same polarity or 'phase' as the incoming signal.

A phase reversal occurs in the FET, so a second phase reversal is necessary. This is achieved by connecting the feedback to the reaction coil upside down (i.e. to the bottom of the winding, and the earth to the top). In this condition of positive feedback the circuit can be made to oscillate.

The feedback signal now passes through the tuned circuit again to the FET, although this time it is 'detected' before it is amplified once more. Detection recovers the audio information from the signal before audio amplification. The radio frequency choke looks like a short circuit to the low frequency audio signal which passes through it. It cannot however pass through resistor R4, but is coupled to the audio amplifier (Q2) via C5, where it is amplified before being fed to the output. Any unwanted RF signal which happens to get through the RF choke is shorted to earth by a small value capacitor (C6).

Maximum circuit gain, and therefore maximum audio output, occurs when the regeneration control is advanced so that the circuit is just not oscillating. This point also yields the best 'selectivity', or the ability to distinguish between close stations.



The printed circuit board pattern is on page 157.

Fig. 2. Component overlay, as seen from the component side of the board. Note carefully the connections to the coil.

PARTS LIST – ETI 718

Resistors all ¼ W, 5%
- R1 . . . . 4k7
- R2 . . . . 1M2
- R3 . . . . 10k
- R4 . . . . 2k2
- R5 . . . . 1k
- R6 . . . . 10k
- R7 . . . . 4M7

Potentiometer
- RV1 . . . . 2k lin pot

Capacitors
- C1. . . . . 10n ceramic
- C2. . . . . 270p ceramic
- C3,4 . . . . 100n ceramic
- C5. . . . . 100n greencap
- C6. . . . . 1n ceramic or greencap
- C7. . . . . 10µ tantalum 16 VW
- C8. . . . . 4µ7electro 16 VW

Variable Capacitor
- CV1. . . . . 415p tuning capacitor or similar (see text)

Semiconductors
- Q1 . . . . MPF131 dual gate MOSFET
- Q2 . . . . BC548 or similar

Miscellaneous
- pc board . . . . . . ETI 718
- pc board pins
- coil former. . . . . 12 x 30 mm air cored Dick Smith Cat. No. L-1110
- RFC1. . . . . 2.5 mH RF choke Dick Smith Cat No. L-1824
- box to suit . . . . . (see text)
- SPST on/off switch
- planetary drive, 5 to 1 reduction
- length of 24 B&S enamelled wire
- 9 V battery and battery clip
- knobs, rubber feet, crystal earpiece or high impedance headphones, headphone socket

Construction

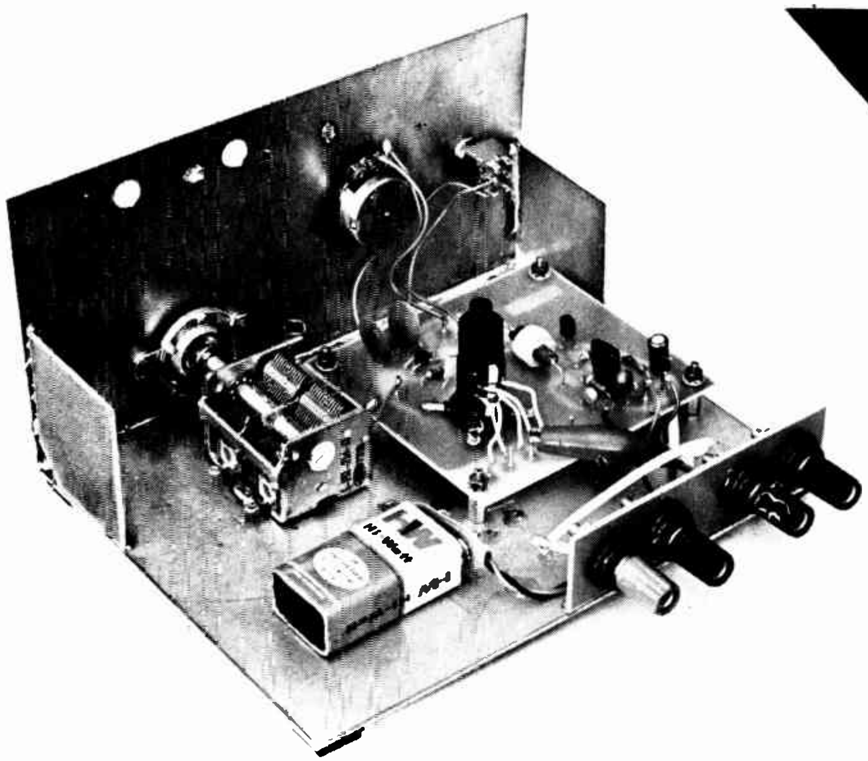
All the components except the tuning capacitor are mounted on a printed circuit board, (see fig. 2). Other types of construction such as vero board can be used but may not offer the same repeatability of results. The coil (L1) is wound separately as in Table 1 and later mounted on the PC board. If the type of former in the parts list is used, the solder lugs on the former will line up with holes in the PC board and the former can then be held down onto the board by its connections. Short lengths of wire are used between the coil taps and the PC board. Printed circuit pins are then soldered into the tapping points and the tap changed by means of the alligator clip from the antenna terminal.

In our receiver we used one section of a second hand dual tuning gang. Most gangs from an old radio will do as long as only one section is used, the lowest frequency of operation depending on the value of capacitance.

The chassis is 175 by 90 mm and 140 mm deep, and is constructed entirely from single sided PC board (copper side inward). This method is both cheap and easy, the front panel being soldered onto the base plate. Squares of PC board are soldered into the ends for rigidity of the front panel.

A planetary drive mechanism is used with the tuning capacitor and is attached to the front panel with two nuts and bolts. A plastic cursor can be cut from a sheet of thin perspex and attached to the outside of the drive mechanism with Araldite to provide a dial pointer.

The regeneration potentiometer and the ON/OFF switch are also mounted on the front panel, with the antenna, earth and output connections mounted on a small piece of PC board at the rear. All wiring should be kept as short as possible, especially to the regeneration control and the tuning capacitor.



Rear view of the completed unit. We used one section of a dual gang tuning capacitor. The terminals from left to right are: Antenna, Earth, and the two output connections.

Antenna and Earth

Although some signals can be heard with a small indoor antenna, an outdoor antenna is much better. The antenna should be as long and as high as practicable, running perhaps from the house to a tall tree or other building. Figure 3 shows a typical antenna installation which will give good results. The lead in from the antenna should be kept as short as possible, so a good position for the set would be close to a window.

An earth is not essential but is generally worthwhile, since it can help to avoid the effects of hand capacity by grounding the metal chassis. The set can be earthed to a water pipe or run to a metal spike driven into the ground.

Performance

The number of short wave signals that can be heard depends upon the time of day, early morning, late afternoon and night being the best. After a few periods of listening at various times you will know what to expect. Using an indoor antenna we were able to receive strong signals throughout the day and the number of stations heard rapidly increased towards dark.

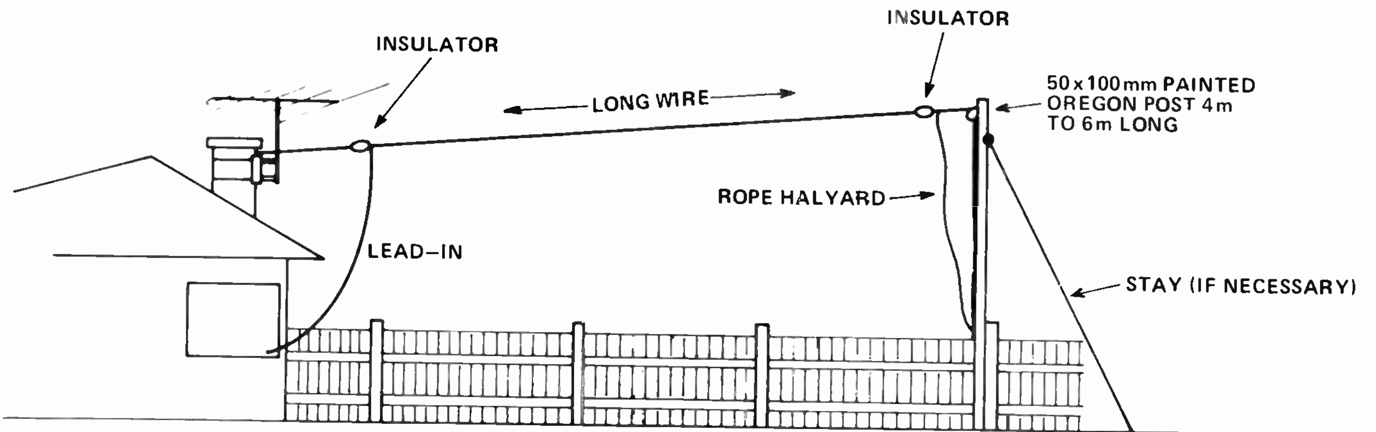
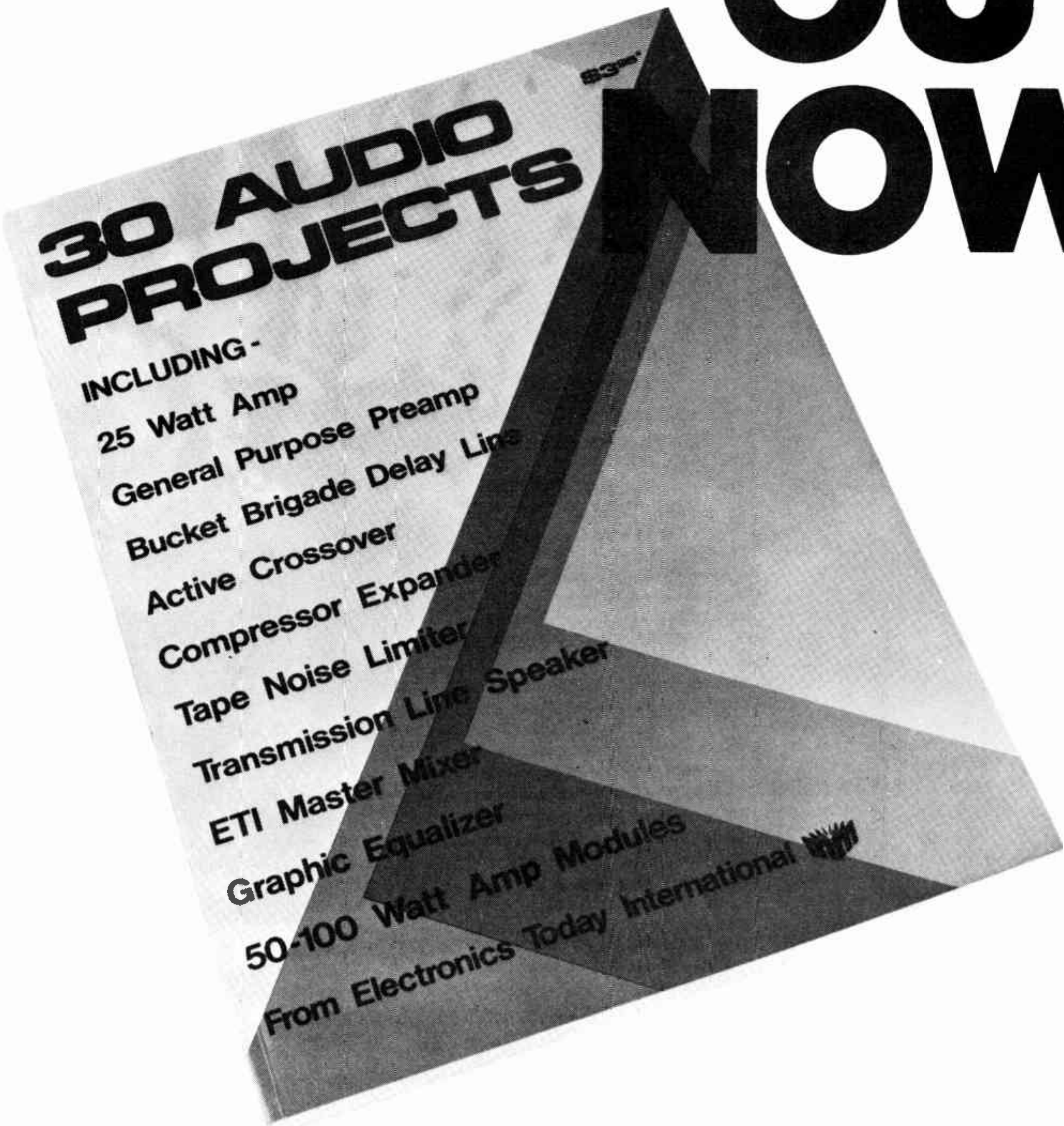


Fig. 3. A typical Long Wire antenna. The Lead—in should be as short as possible

OUT NOW



Thirty Audio Projects is the latest in our line of books designed especially with the serious constructor in mind. Ever found yourself leafing through back-issues of ETI for the circuit of a low-noise input stage? Or looking for some information on bucket brigade devices? Or do you need to know that the design you're using has been checked and re-checked for circuit errors and built by people all over the world before it is published? Thirty Audio Projects contains just that — thirty projects of the highest ETI standard, checked and re-checked and then presented in a compact and complete form.

The price is $3.95 — that's under fifteen cents per full project design — and they're all audio projects, thirty of our most sought-after designs. Projects include: Simple 25 watt amp; Bucket brigade delay line; Active crossover; Compresser/expander; Tape noise limiter; ETI speaker system; Professional-feature mixer; Howl-round suppressor; the ever-popular 50/100 watt amp modules; Graphic equaliser; Spectrum analyser; audio millivoltmeter.

A universal process timer

Phil Wait

This simple timer has myriad applications in electronic and photographic work. It features a LED display that "counts down", indicating elapsed time, that is readily visible in daylight or in a darkroom.

VARIOUS PROCESSES in fabricating electronic projects require timing a chemical reaction or process – developing photoresist in making printed circuit boards being a prime example.

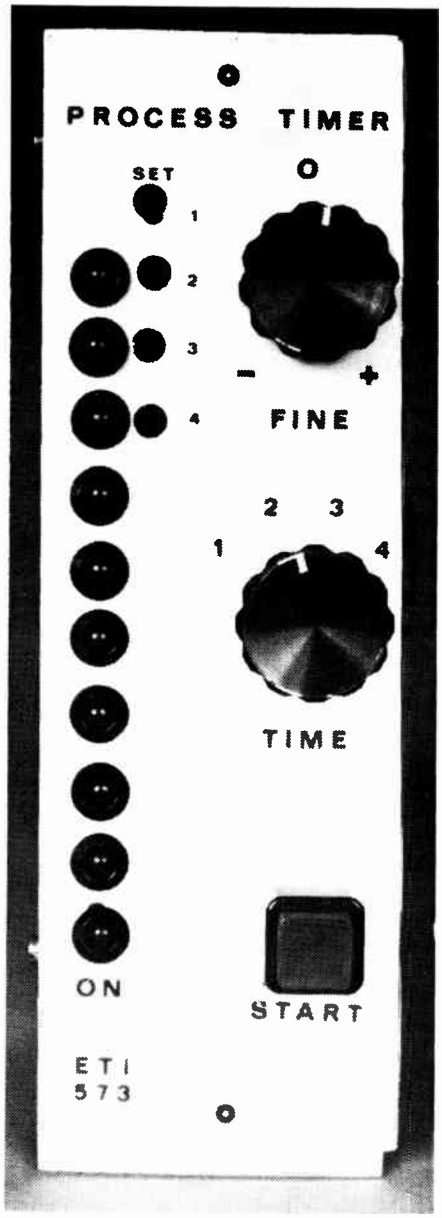
Following the completion of our darkroom here at ETI which we use for making negatives and printed circuit boards, it was decided a simple timer was needed to control the light source used for exposure. Because different times are used for exposing film, printed circuit photoresist and Scotchcal, the timer had to have switchable ranges which could be pre-set between a fraction of a second and ten minutes. Some form of elapsed time indication was considered necessary for the longer exposures as was some form of fine adjustment for either slightly under- or over-exposing the film. Finally, the unit had to switch 240 volts at several amps to control a bank of UV-fluoro tubes used for exposing photoresist.

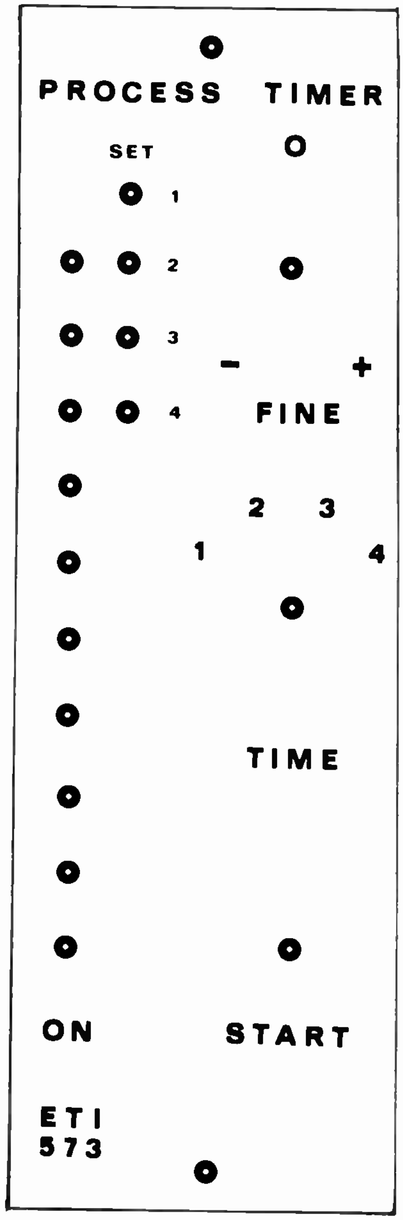
Someone then suggested it would make a good project – after all, there's very little we do here that many of our readers don't do themselves at home.

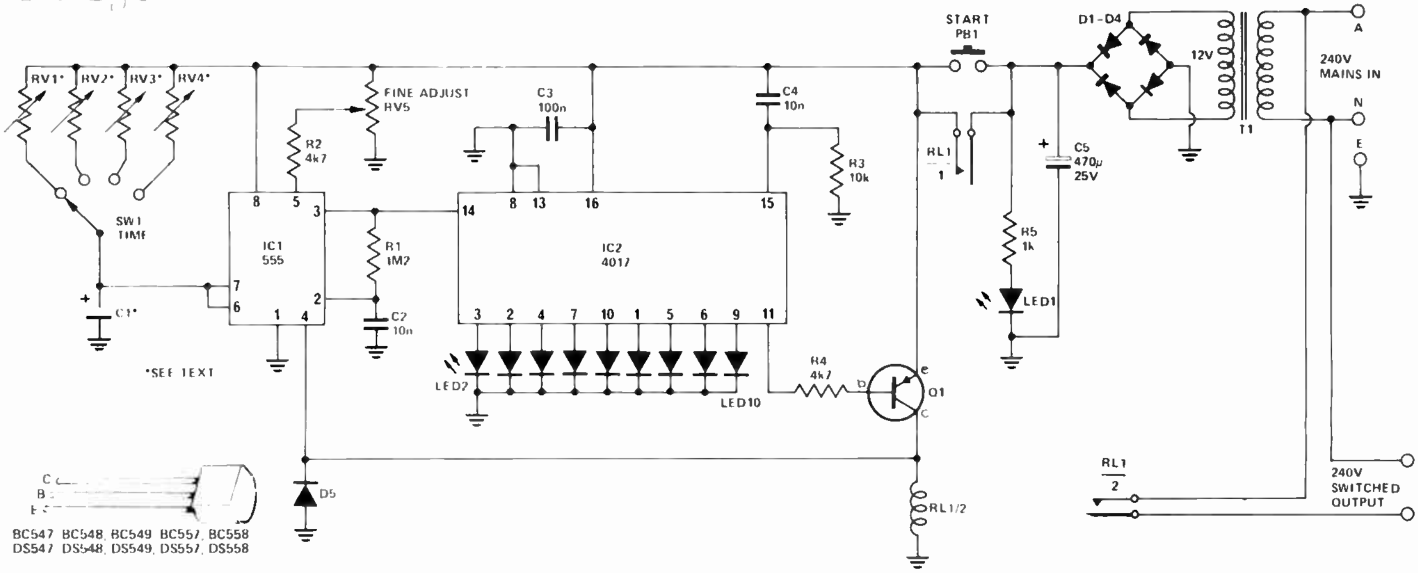
In fact, this timer is not just limited to the applications we use it for, but can be used to control anything from an egg timer to an injection moulding machine. Judging from some of the calls we get from readers, this timer should find its way into all sorts of applications.

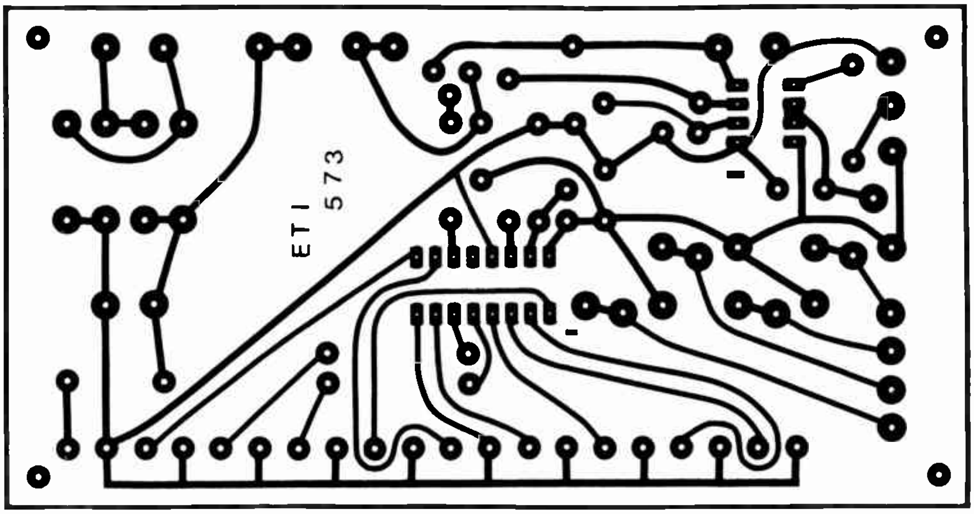
The technique

The easiest way of producing a time delay is by using a 555 timer IC, but a glance at the data sheet shows that it should not be used for periods in excess of 100 seconds. By using the 555 as an oscillator and feeding its output into a 4017 counter/decoder IC the maximum









Maximum time delay	1 sec	10 sec	100 sec	1000 sec
value of C1	1 µF	1 µF	10 µF	100 µF
value of RV (1 - 4)	200 k	2 M	2 M	2 M

Table of values for C1 and RV1 - RV4 required for differing time delays

timing period can be increased ten fold. The unused decoded outputs can then be connected to a column of LEDs which will give an indication of elapsed time.

Each pulse from a 555 clocks the 4017, moving a high level along its ten decoder outputs, lighting each of the LEDs in turn. When the high level reaches the last output it is used to operate the relay and thus the time delay has been multiplied by ten.

A permanently-lit LED has been included at the bottom of the row to show when the unit is on. This also gives a better indication of elapsed time in a darkroom, as the LEDs can be seen to step towards a reference light.

Four time ranges have been provided with a trim pot on each one for easy adjustment. The table gives the values for each trim pot and C1, for a variety of times. The minimum time is limited by the time taken for the relay to operate, maximum time by the limitation of the 555. In practice, times from 100 mS to twenty minutes can be achieved. For very short times the time elapsed indication will not be much use and the LEDs can be left off the board.

Fine adjustment of the timing is achieved by adjusting the threshold voltage on pin 5 of the 555. When the voltage on pin 5 reaches a set value, the output (pin 3) of the 555 goes 'low' (i.e: the 555 triggers). This voltage is normally set at two-thirds the value of the supply rail, fixing the time during the charging cycle of C1 when the 555 triggers.

If the threshold voltage is increased, the time taken for C1 to charge to the required value increases, and the frequency of oscillation decreases. Thus, the total timing period is increased.

What device you want to control

HOW IT WORKS – ETI573

The timer consists of a 555 timer IC used as an oscillator driving a 4017 counter/decoder IC, the decoded outputs being used to drive a row of LEDs and switch a relay.

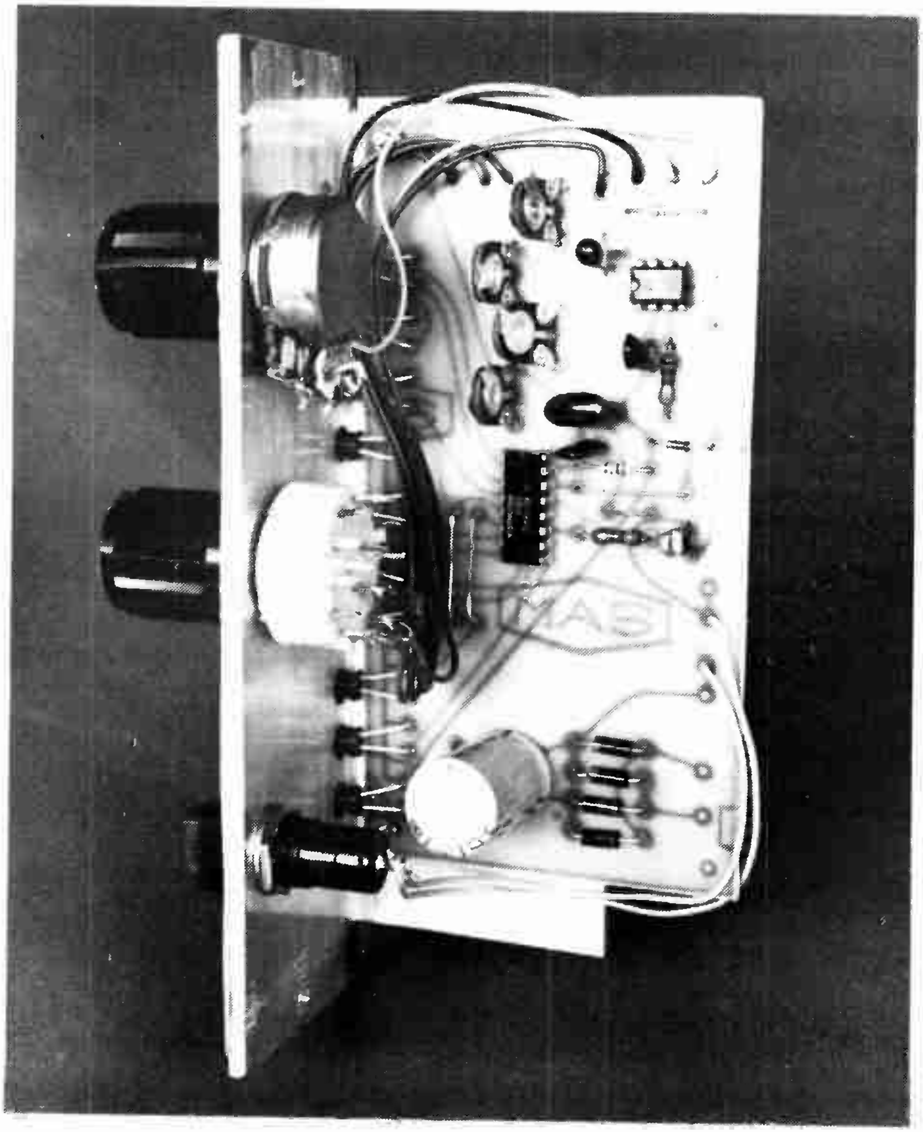
The timing period is set by the frequency of oscillation of ICI. This is dependent on the time constant of RV1-RV4 and C1. As either of these components are increased in value the time constant will increase and the frequency of oscillation decrease. Fine frequency adjustment is provided by RV5 which adjusts the threshold voltage on pin 5 of the 555. This voltage is normally set at two thirds of the supply voltage, but here it is adjusted varying the required voltage across C1 to the 555.

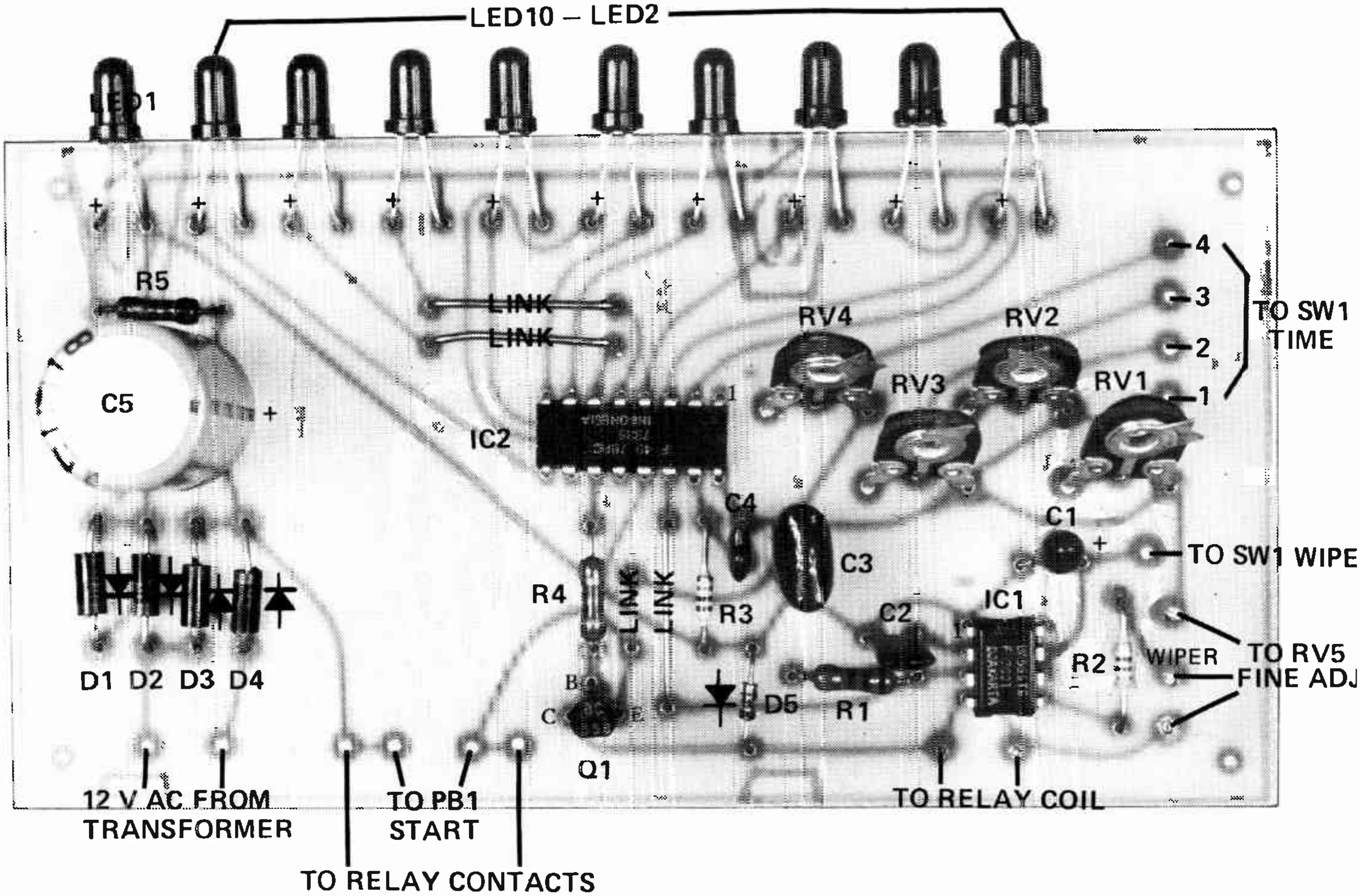
Output from the 555 is fed to the clock input of the 4017. After each pulse a different decoded output of the 4017 goes high, lighting each LED in turn. After the tenth clock pulse the output on pin 11 of the 4017 goes high. We shall come to what that does shortly.

When power is first applied, the relay contacts RL1/1 are open and the bottom LED (LED 1) is lit. When the 'start' button is pressed the 4017 is reset to zero by a positive pulse applied to pin 15. This pulse is provided from R3 and C4. Pin 11 goes low, turning on the PNP transistor Q1, and the relay operates. The now closed relay contacts (RL1/1) short out the start button and sustain the power after the start button has been released. The transistor also drives the reset line of the 555 (pin 4) which commences to oscillate. This ensures accurate timing of the first cycle.

On the tenth pulse from the 55 pin 11 of the 4017 goes high, turning off Q1, stopping the oscillator, and the relay is de-energised. The contacts RL1/1 open removing the supply to the timer returning it to its original condition, ready for the next sequence.

During the timing period, the second set of contacts RL1/2 close and can be used to switch up to 5A using the relay specified.





with the timer will determine the type of relay you use. This unit is capable of driving quite large relays, however, we used a commonly available Omron type having contacts rated at 10 amps.

Construction

First, you will have to determine from the table the correct values of RV1-RV4 and C1 to provide the times you want for your application.

Next, mount all the components taking care to correctly orientate the semiconductors. The LEDs are best mounted by inserting them into their holes and bending them over flush with the edge of the pc board. The photo shows the way I mounted the LEDs.

The completed unit can be mounted in a variety of ways to suit individual applications. Either in a box, together with its relay and a mains female output socket for the switched output, or on a panel with a remote transformer and relay as I did.

To mount the unit against a front panel, drill a row of ten holes for the LEDs and four holes to line up with the trim pots for screwdriver adjustment of the timing. The start button, timing switch and fine adjustment pot can be mounted anywhere convenient. The pc board should be mounted against the panel so the LEDs protrude through the holes.

PARTS LIST - ETI 573

Resistors — all ½W, 5%

R1	1M2
R2	4k7
R3	10k
R4	4k7
R5	1k

Potentiometers

RV1–RV4	See text
RV5	10k lin pot

Capacitors

C1	See text
C2	10n greencap
C3	100n greencap
C4	10n greencap
C5	470µ 25V electro

Semiconductors

D1–D4	IN4004 or sim Power Diode
D5	IN914 or sim
Q1	BC558, BC178, DS558
IC1	555
IC2	4017
LED1–LED10	TIL220R or sim LED

Miscellaneous

SW1	One pole, four pos. oak switch
PB1	Momentary Push Button
T1	12V, one amp transformer (Ferguson type PS12/15 VA or sim.)
RL1	12V relay with two changeover contacts, Omron type LY2 or sim

ETI 573 pc board, knobs, suitable box or bracket.

Setting up

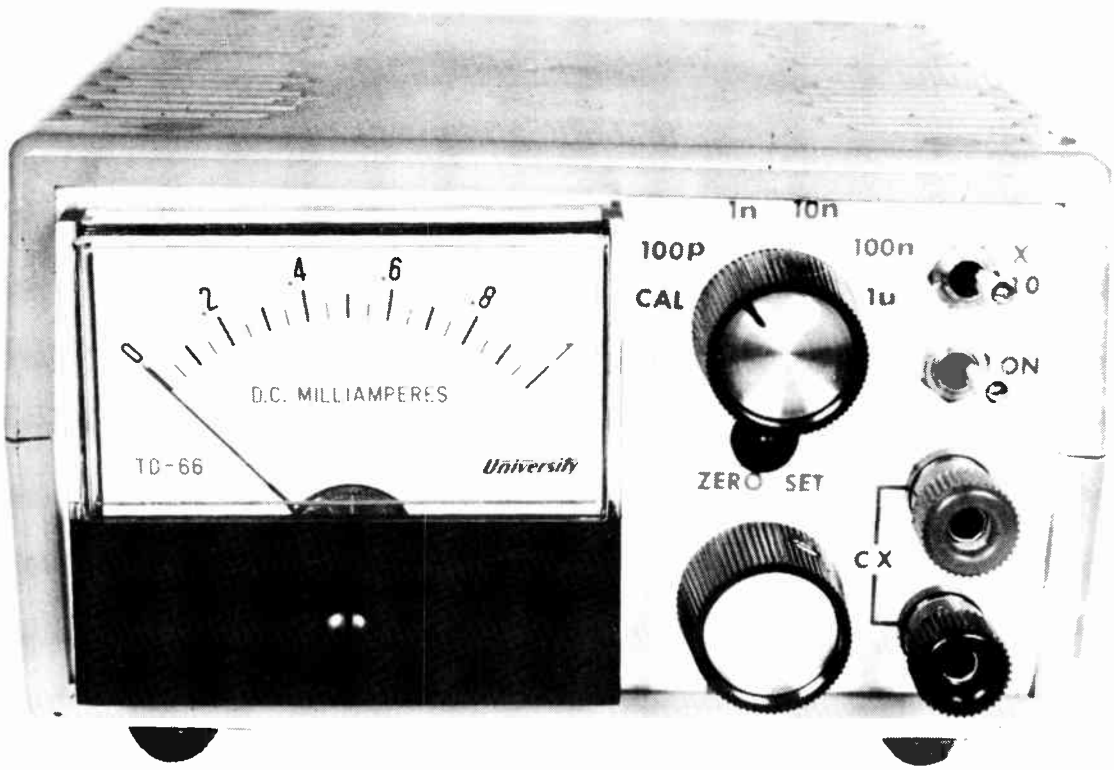
Having assembled the unit, all that remains is to calibrate the ranges. This is easily done with the aid of the second hand of a watch. For shorter times, say under five seconds, an oscilloscope is best.

Simply monitor the positive supply after the relay contacts RL1/1 and measure the time the contacts operate. For other purposes it may be best to set the ranges by trial and error, such as when the unit is being used for a pc board or Scotchcal development timer. In either case, the fine adjustment control should be set in its mid position when calibrating. ●

Capacitance meter features linear scale and low cost

This is the third instrument in our series of simple, inexpensive, look-alike test gear projects.

Roger Harrison



WE FIRST published a capacitance meter project over two years ago. The Linear Scale Capacitance Meter, Project 136, (ETI, March 1978) enjoyed a certain amount of popularity at the time it was published, but ran into a few snags. Unfortunately the edgewise mounting meter became difficult to procure as did, later, the case. Also, the meter required calibration by hand. Correspondence from a number of readers also suggested extending the range of the instrument to enable capacitors up to 10 uF to be measured.

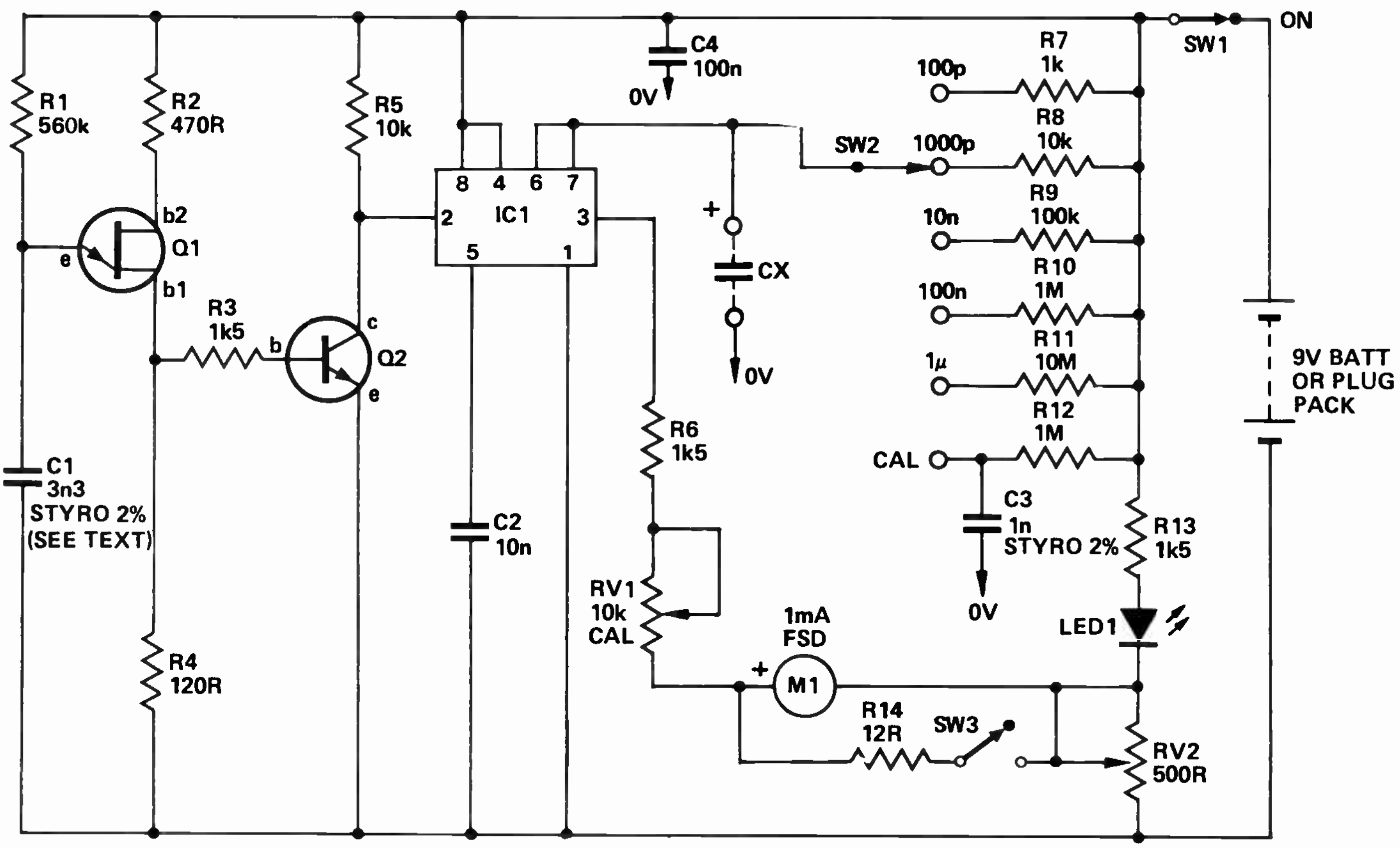
So, when we were considering our current range of simple, inexpensive test gear projects, the old linear scale capacitance meter was an obvious candidate for revamping to include in the series. Phil Wait took it in hand and here it is – the all-new, singing-dancing, lemon-fresh Linear Scale Capacitance Meter!

This unit has been constructed using the same type case, meter and range switch as the two previous projects in the series: the frequency meter, ETI-150, and linear scale ohmmeter, ETI-151. It can be powered from internal batteries or a small plugpack.

Since constructing the original project, the writer has been consistently amazed at how often it has been used. When considering the purchase or construction of test instruments, most people take resistance measurement for granted – but, in so many applications, capacitance measurement comes a good second. ▶

SPECIFICATIONS – ETI 152

Capacitance ranges (full scale)	100p, 1n, 10n, 100, 1u – to 10u on x10
Accuracy	5%, estimate to 2% on meter scale
Calibration	from internal capacitor, 2%
Supply voltage	9 Vdc from battery or plugpack



HOW IT WORKS – ETI 152

A unijunction transistor, Q1, is connected as a relaxation oscillator with a frequency determined by R1-C1. The frequency of oscillation in this instance is about 1 kHz.

Pulses of about 1 us duration are produced across R4 each time the UJT "fires". The resistance between b2 and b1 of the UJT reduces to a low value each time the emitter conducts. Much of the charge stored in C1 is "dumped" across R4 for the short duration that the e-b1 junction of Q1 conducts.

The narrow pulses across R4 drive the base of Q2 via R3, which serves as a base-current limiting resistor. The pulses cause Q2 to conduct for the same duration, that is, about 1 us, and negative-going pulses from the collector of Q2 drive the "TRIGGER" input of the 555 timer, IC1. This is connected to operate as a monostable in this circuit.

When IC1 receives a trigger pulse at pin 2, the flip-flop is set, releasing the short circuit across Cx and driving the output, pin 3, high. The voltage across the capacitor then increases exponentially for a period that depends on the value of the unknown capacitance Cx. The period is determined according to the formula:

$$t = 1.1\,R_r C_x$$

– where 'Rr' is the range resistor, and 'Cx' the capacitor being measured.

At the end of the period, the comparator inside the 555 resets the flip-flop which in turn discharges the unknown capacitor, Cx, and drives the output to its low state.

This cycle is repeated each time a negative-going trigger pulse appears at pin 2 of IC1.

Thus, as the range resistor value (Rr) is fixed, the ON/OFF ratio of the output voltage will be determined by the value of Cx. The ON/OFF ratio is independent of the relaxation oscillator frequency and trigger pulse duration.

The current measured through the 'load' resistor on the output (R6) of IC1 will thus be directly proportional to the value of the unknown capacitor Cx.

The meter, M1, measures the current through R6, the meter inertia 'averaging' the current.

As the voltage at the output pin does not quite swing between the +ve supply rail and the 0V rail in its 'high' and 'low' states respectively, the dc offset is compensated for by returning the 'load' current through an offset voltage developed across RV2 via R13 from the supply rail.

Zero-setting is accomplished by making RV2 variable. A calibration control is provided by making a portion of the 'load' resistance variable – RV1 here.

The 'X10' switch simply reduces the sensitivity of the meter, allowing measurement of a high output pulse-on to pulse-off ratio.

Ranges

The unit will measure capacitance from 5 pF up to 1 uF in five ranges with a x10 facility to extend the top range to 10 uF. Full-scale values for each range are: 100 pF; 1 nF (1000 pF or 0.001 uF); 10 nF (0.01 uF); 100 nF (0.1 uF) and 1 uF – extended to 10 uF with the x10 switch.

The x10 switch actually works on all ranges and is handy when checking capacitors that over-range when a particular range is selected, so that the appropriate range can be readily found.

Different ranges can be provided by selecting different values for the range resistors R7 to R11. For example 47 pF to 0.47 uF (in five ranges), 4.7 uF with the x10 in, could be obtained by changing R7 to 470R, R8 to 4k7 etc. However, the meter scale would need to be recalibrated. As it stands, the scale reads capacitance directly.

The meter scale provides divisions of 5% and the actual capacitance value can be estimated to about 2% or so, once the unit is calibrated. Overall accuracy will depend on the meter and the calibration capacitor accuracy.

PARTS LIST - ETI 152

Resistors — all ½W, 5% (except R7–R12)

R1	560k
R2	470R
R3	1k5
R4	120R
R5	10k
R6	1k5
R7	1k 2%
R8	10k 2%
R9	100k 2%
R10	1M 2%
R11	10M 2%
R12	1M 2%
R13	1k5
R14	12R

Potentiometers

RV1	10k min vert mounting trim pot
RV2	500R lin pot

Capacitors

C1	3n3 2% tolerance - see text
C2	10n greencap
C3	1n 2% tolerance - see text
C4	100n greencap

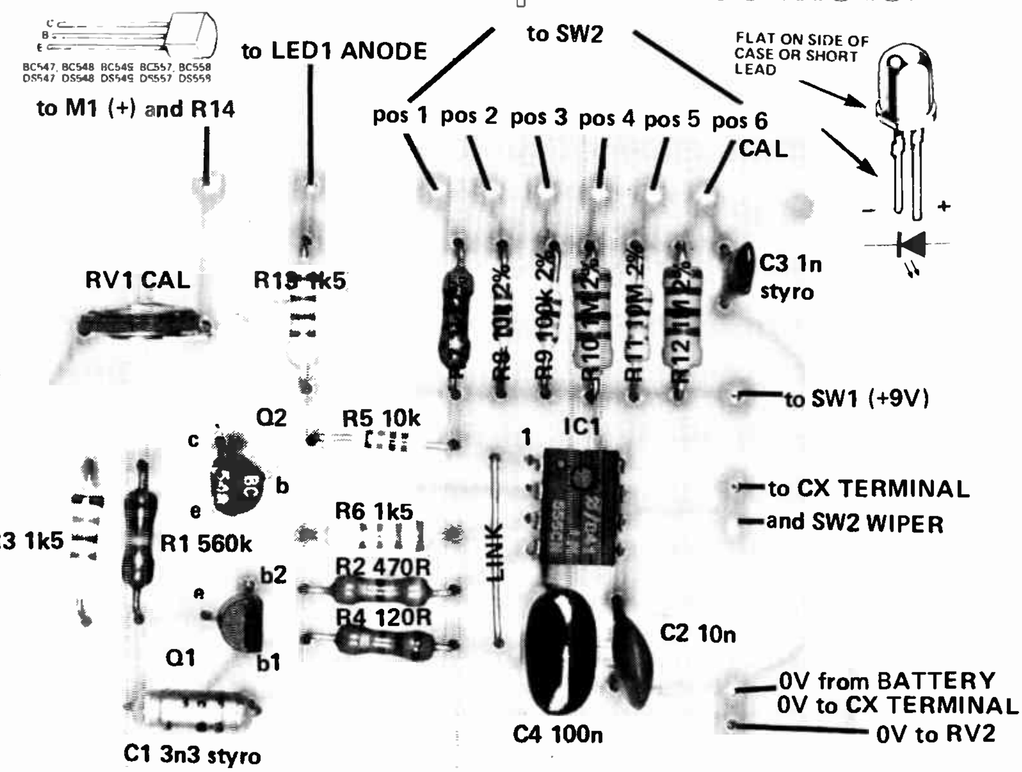
Semiconductors

LED1	TIL220R or similar LED
Q1	2N2646, 2N2647 uni-junction
Q2	BC548, BC108
IC1	555 timer

Miscellaneous

M1	1mA FSD meter 60 mm square, University TD66 or similar
SW1	SPST miniature toggle switch
SW2	one pole six pos wafer switch
SW3	SPST miniature toggle switch
SK1, SK2	screw terminals

ETI 152 pc board, 9V battery (type 216) and battery clips, plastic case 130 mm x 130 mm x 75 mm, knobs.

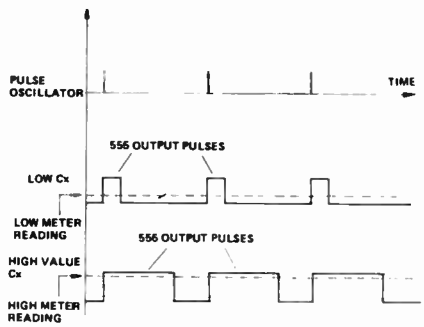


Design

A pulse oscillator, Q1, running at a pulse repetition frequency of about 1 kHz, triggers a 555 timer IC which is connected as a monostable multi-vibrator. The 555 in this configuration will produce a pulse at its output, pin 3, having a period determined by the values of the range resistor selected and the unknown capacitance. The lower the value of the unknown capacitance, the shorter the duration of the output pulse from the 555. Conversely, the higher the value of the unknown capacitance, the longer the duration of the output pulse.

The output pulse is passed through a moving-coil meter which will integrate the pulse waveform. The reading on the meter will thus be directly proportional to the ratio of the time the output pulse is on to the time it is off, resulting in a linear relationship of capacitance to meter reading. A low value of capacitance connected to the 'CX' terminals will produce a short duration pulse and thus a low meter reading; a high value of capacitance will produce a long duration pulse and a high meter reading, as illustrated on the accompanying diagram.

The output pulse of the 555 swings between values of about 2/3 of the supply voltage ('high') and 1/3 of the supply voltage ('low'). Thus, the meter needs to be returned to a voltage of about 1/3 of the supply, otherwise current would flow through it continuously. Conveniently, this voltage is set by a pot on the front panel which serves as a 'zero set' control. The meter is calibrated by varying the resistance in series with the meter, rather than having preset range resistors. This results in better accuracy and requires only one preset control. The CAL. position on the range switch is for occasional checking. Any significant variation in the calibration will generally indicate a low battery.



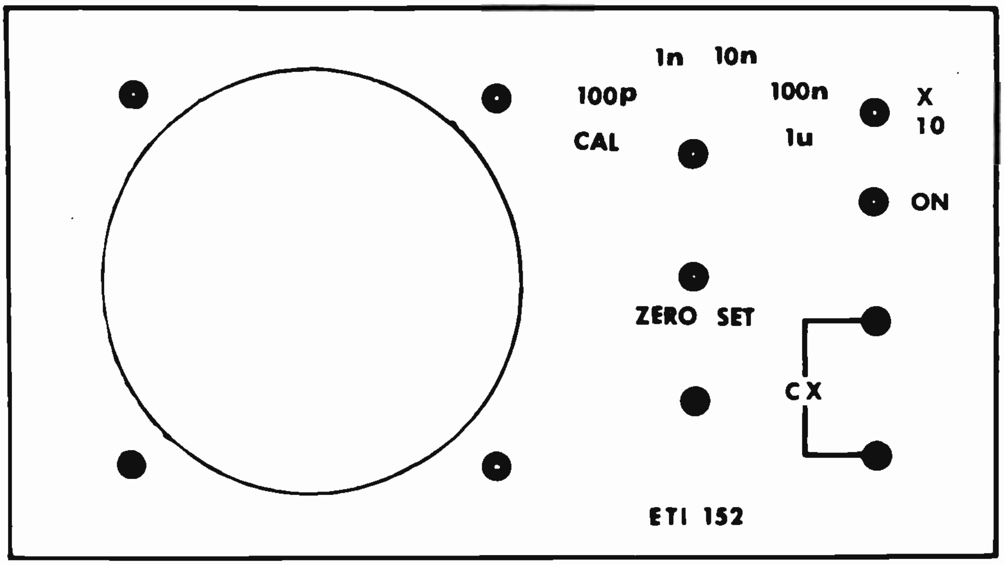
The unknown capacitance, Cx, determines the width of the output pulses from the 555 monostable. The meter integrates these pulses to produce a reading which is directly proportional to the unknown capacitor's value.

Construction

We mounted our meter in a matching case to our Linear Scale Ohm meter and Frequency Meter. The front panel layout is a little cramped but all switches and terminals are easy to use with plenty of finger room.

Start your construction with the pc board making sure that the integrated circuit is the right way around. Take care also with the transistor and UJT orientation. Capacitors C1 and C3 determine the overall accuracy of the instrument and should be close tolerance types. Some suppliers carry a range of close tolerance silver mica or styroseal capacitors. Alternatively, if you have a friend or employer with a capacitance bridge you can select one close to the required value (1n) from standard tolerance types. See Shop-around on page 160 for suppliers that stock suitable capacitors. The range resistors R7 to R12 should also be close tolerance (2%) types.

All other components, including



the x10 range resistor, are mounted on the front panel. Mount the smaller switches and terminals first, followed by the potentiometers and last of all the meter. The resistor R14 is wired from the positive meter terminal to one of the contacts on the range switch, SW3.

The printed circuit must be mounted so the lead length from the Cx terminals is as short as possible to avoid stray capacitance. Mount the pc board to the bottom of the case just behind the terminals and use tinned copper wire to make the connections making sure that the wires are well spaced from each other and well away from the rest of the circuit. Wire each connection from the board to the components on the front panel carefully to avoid errors.

When the construction is complete check all the wiring but don't assemble the lid to the box yet. Switch to the 1n range and turn the instrument on. Adjust the ZERO SET pot and see that the meter pointer varies about the zero scale marking. If it doesn't, check the pc board and panel wiring. If all is well, set the control so the meter pointer is on the scale zero mark. Then, switch to the CAL position and the meter pointer should move up the scale. Adjust the CAL trimpot on the pc board, RV1, so that the meter reads '1'. Switch to any range and you're ready to go!

You will find that stray capacitance affects the meter zero reading on the 100p scale. Simply adjust the ZERO SET control so that the meter reads zero before taking a measurement on this range.You'll find that once the instrument is zeroed on the 1n range, the higher ranges will not require further adjustment of the zero set.

In use, occasionally check the calibration. If grossly in error, your battery is about to go flat. A No.216 battery should give quite a long life as the unit draws less than 20 mA. For longer life a No.2362 battery is recommended. If you operate the unit from a plug-pack, one rated at 6 Vdc output should deliver more than 8V at this low load, which is perfectly adequate.

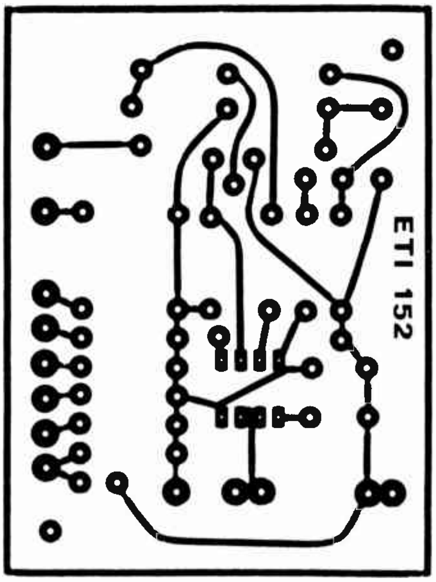
Remember that any devices used to grip the leads of capacitors being measured will add stray capacitance and you will need to compensate for this by readjusting the zero set control. However, this will only have to be done on the 100p and 1n ranges as the added capacitance will be negligible on the higher ranges.

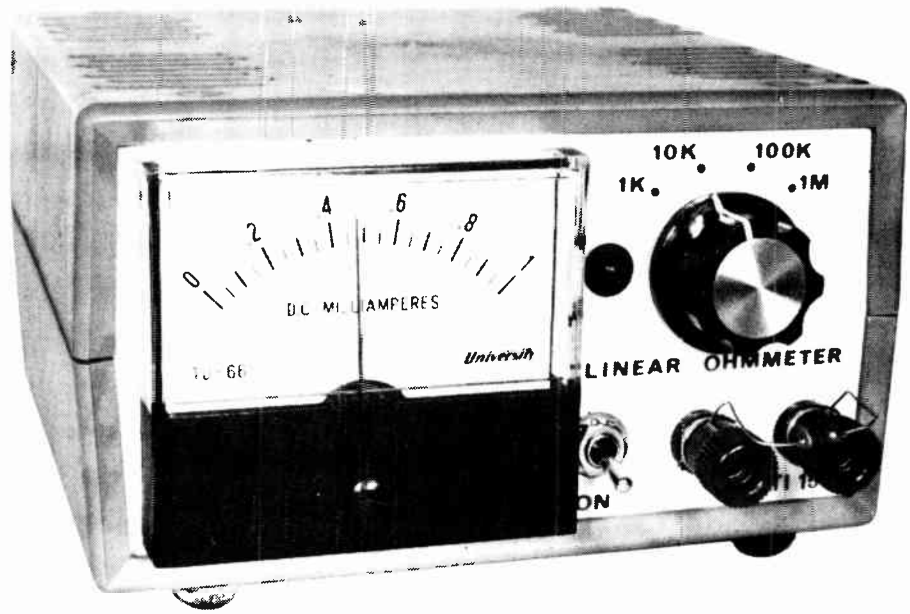
The 'x10' switch is primarily intended to extend the 1u range to 10u, although it is useful on the other ranges – when a capacitor being measured over-ranges you can assess whether it is just above the range selected or many ranges up in value.

Well, there you go! I hope you find this instrument as useful as I have. ●

Above is a full-size reproduction of the front panel artwork. You may cut it from the book if you wish and use it directly. Alternatively, Scotchcal reproductions will be available from Radio Despatch Service in Sydney.

Same-size reproduction of the pc board artwork. See Shoparound on page 160 for details on pc board suppliers.





Electronic ohmmeter features linear scale and high accuracy

Many workshop, laboratory and hobby applications require accurate measurement of resistor values or accurate matching of resistors of the same nominal value. This simple instrument fills the bill for the sort of measurement required.

THIS INSTRUMENT is a simple and inexpensive semi-precision ohmmeter that can be used to give accurate readings of resistance from a few tens of ohms to one megohm. The unit has four decade ranges covering 1k to 1M full scale and has a full scale accuracy of 2% if low tolerance range resistors are used.

Conventional moving coil ohmmeters have non-linear scales which typically cover two to four decade ranges of resistance value on a single scale. With such a range of resistance it is impossible to obtain an accurate reading, especially at the higher values. To measure resistance values with reasonable accuracy, the usual method is to use a Wheatstone Bridge, often very expensive and time consuming.

By contrast, this ohmmeter gives resistance readings on a linearly calibrated scale and covers only a single decade of resistance on each switched range. The instrument thus gives inherently more accurate readings of resistance than multimeter type ohmmeters.

The technique

The circuit consists of a voltage reference feeding an operational amplifier. The gain of the op-amp is set by the ratio of the range resistors, R3 to R6, to the feedback resistor, Rx. A moving-coil meter is connected to the output of the op-amp and the reading will be the reference voltage multiplied by the gain of the op-amp. Therefore, the reading is proportional to the gain of the op-amp which in turn is proportional to the value of Rx, the unknown resistor.

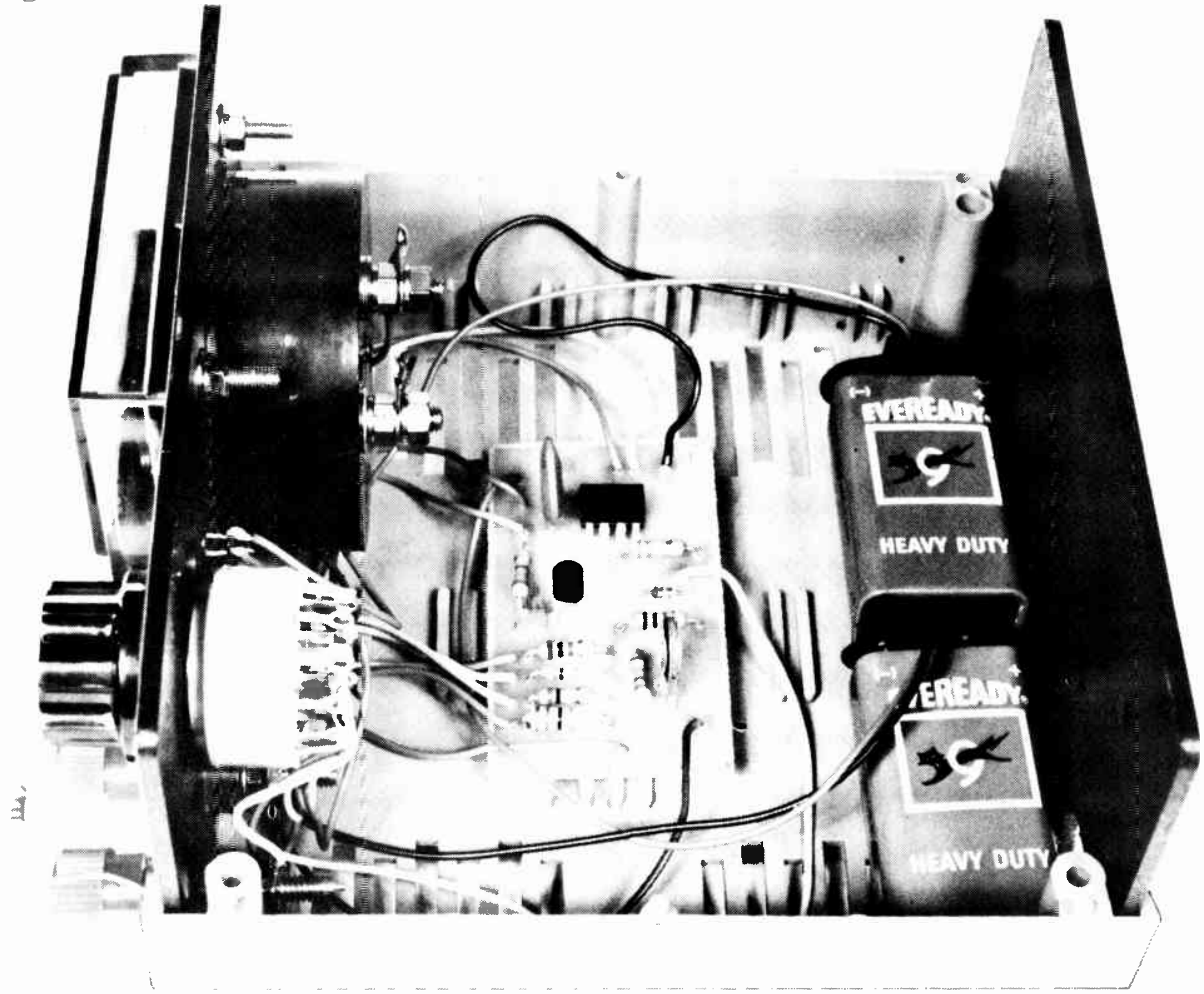
The op-amp we selected is a 301, used for its low input current. This ensures that the highest resistance range is not shunted by the input resistance of the op-amp causing inaccuracy at higher values. In fact a 10M range could be added but would not be accurate over about a few megs. The lowest resistance range is determined by the current capacity of the op-amp, reference supply, and the batteries.

Calibration of the instrument is achieved by adjusting the trimpot for correct reading with a known resistance.

Construction

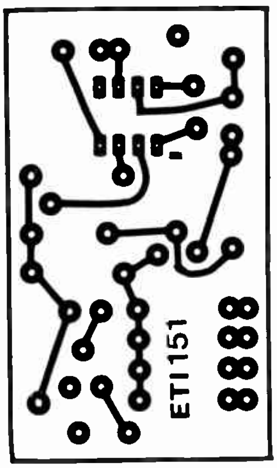
The ohmmeter can either be constructed as a completely contained unit, with its own moving-coil meter, as we have done, or it can be built as an add-on to an existing multimeter having a 1mA dc current range. As the meter is the most expensive part the latter method is by far the cheapest way of doing it.

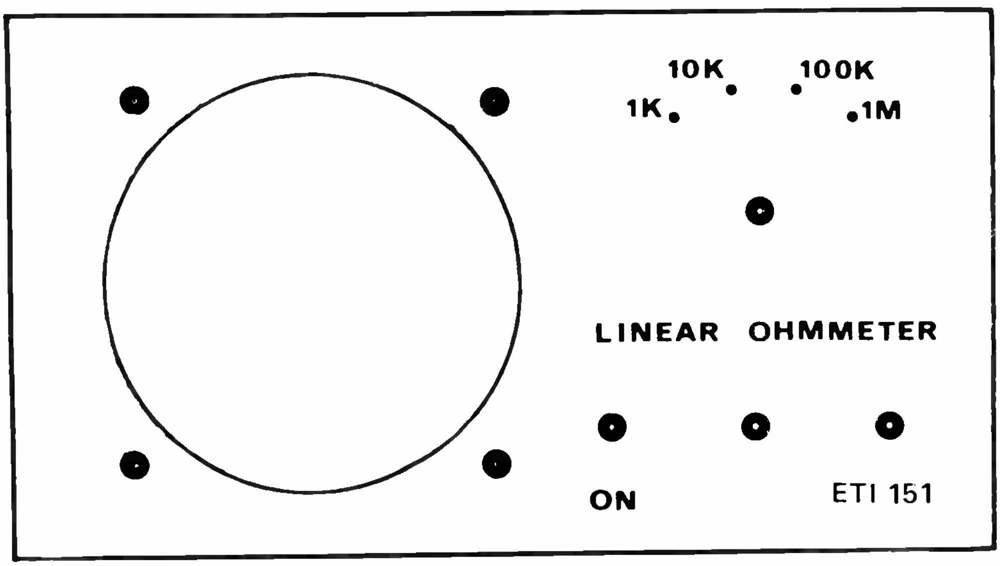
The construction is straightforward with all the minor components mounted on a pc board. Take care with the polarity of the zener diode. The 301 op-amp cannot be substituted by a



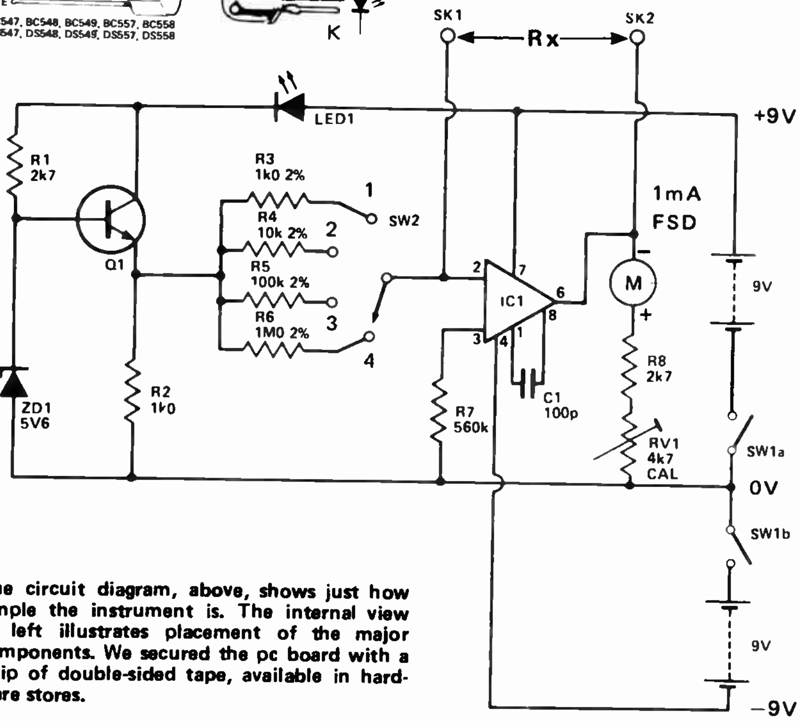
741 as it has been selected for its low input current. The overall accuracy of the instrument is determined by the tolerance of the range resistors (R3 to R6) and the accuracy of the meter. If 1% or 2% resistors are used the accuracy of the instrument will be about two percent. See Shoparound for a list of suppliers with close tolerance resistors.

When the pc board assembly is complete, fit the board into the box and complete the wiring to the major components. We used a common plastic case, identical to the one used for the Linear Scale Frequency Meter (page 61). If you are making an add-on version of the meter, fit a couple of screw terminals in place of the meter for





RIGHT: Front panel artwork. Scotchcal overlays will be available from Radio Despatch Service in Sydney.



The circuit diagram, above, shows just how simple the instrument is. The internal view at left illustrates placement of the major components. We secured the pc board with a strip of double-sided tape, available in hardware stores.

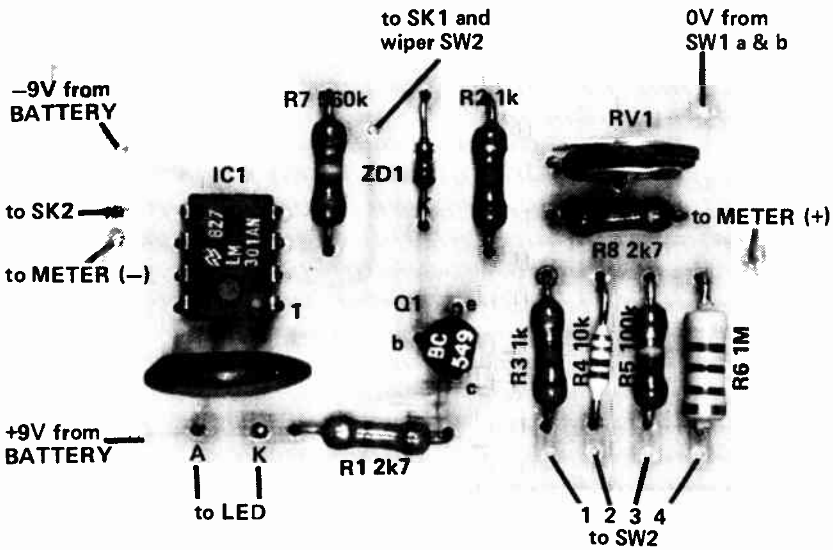
connection to your multimeter.

We used a 'Lorlin' range switch made by C&K. These switches start out life as a two-pole six-position switch and are easily changed to four position by moving round a small metal ring beneath the securing nut. Only one pole is used. In this way, C&K have come up with a single switch which can be changed to suit your own needs.

If your supplier stocks this switch he will show you how to adjust it. Any other single-pole four-position switch will do just as well.

Calibration

When construction is complete, switch the unit on and check that the LED lights up. If it doesn't, check the wiring and the polarity of the LED. When all is well connect an accurately known resistor (having a value within the range of the instrument) across the terminals and adjust the trimpot for the correct reading. The unit is then ready for use and should not require further calibration. You could purchase a 1k, 1% resistor specifically for this purpose. ●



HOW IT WORKS – ETI 151

The linear scale ohmmeter circuit is divided into two parts: a reference voltage generator and a readout unit that indicates the value of the resistor under test. The reference voltage generator section of the circuit comprises zener diode ZD1, transistor Q1, and resistors R1 and R2. The action of these components is such that a stable reference of about 5V is developed across R2. This reference voltage is fed to the op-amp resistance-indicating circuit via range resistors R3 to R6.

The op-amp is wired as an inverting dc amplifier, with the 1 mA meter and R8-RV1 forming a voltmeter across its output, and with the op-amp gain determined by the relative values of ranging resistors R3 to R6 and by the negative feedback resistor Rx. RV1 is adjusted so that the meter reads full scale when Rx has the same value as the selected range resistor. Under this condition the op-amp circuit has a voltage gain of precisely unity. Since the values of the reference voltage and the ranging resistors are fixed, the reading of the meter is directly proportional to the value of Rx, and the circuit thus functions as a linear-scale ohmmeter and has a full scale value equal to the value of the selected range resistor.

PARTS LIST - ETI 151

Resistors all ½W
(* See text)

R1	2k7 5%
R2	1k 5%
R3	1k*
R4	10k*
R5	100k*
R6	1M*
R7	560k 5%
RV1	5k minimum vertical trim pot

Capacitors

C1	100p ceramic

Semiconductors

LED1	TIL220 red LED or similar
ZD1	5V1 400mW zener diode
Q1	BC109, BC549, or similar
IC1	301 op amp

Miscellaneous

SW1	DPDT minimum toggle switch
SW2	one pole four position wafer switch
M1	1mA FSD meter 60 mm square, University TD66 or similar
SK1, SK2	screw terminals

ETI 151 pc board, two 9V batteries (type 216) and battery clips, plastic case 130 mm x 130 mm x 75 mm, knob.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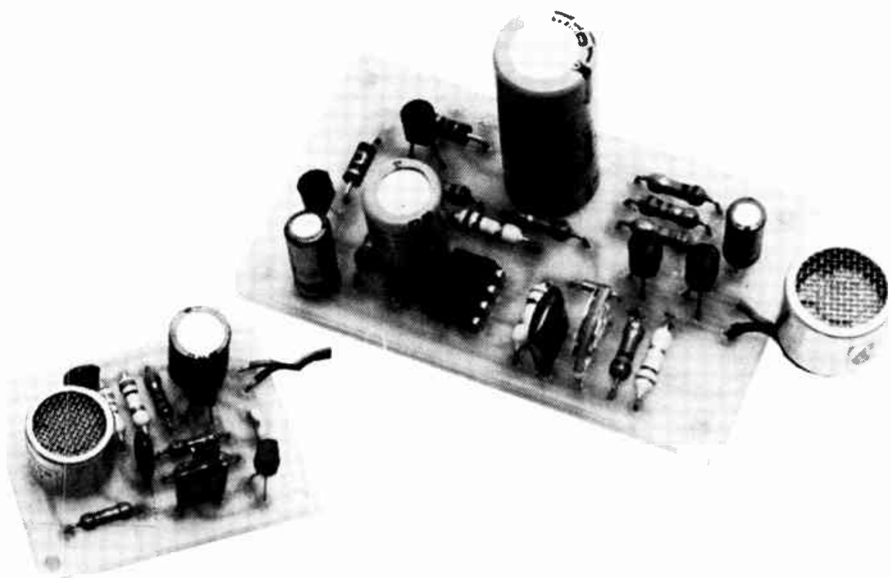
FIELD STRENGTH/POWER METER
PRESETTABLE COUNTER
MICROWAVE OVEN LEAK DETECTOR
LINEAR-SCALE CAPACITANCE METER

ULTRASONIC SWITCH

Two-board design forms basis for a wide range of applications from door-bells to data transmission!



THE USE OF an invisible beam to transmit information or to act as an alarm system has always been fascinating. We have described light operated systems of the infra-red (invisible), normal light and laser beam types. We have also published a radar alarm system. This unit uses a high frequency acoustical beam, well above the range of human hearing, which can be used simply as a door monitor, i.e. to give an alarm if the beam is broken, or can be modulated at up to several hundred Hz. This will allow information to be transmitted.

Construction

The construction of the units is not critical — any method may be used although the PC boards are recommended. We didn't mount the relay on the PCB as it can vary in size and if the unit is later used with a modulated beam, the relay will not be needed.

The only adjustment on the unit is the sensitivity control and this should be set to give reliable operation. The transmitter needs a supply voltage of 8 V to 20 V at about 5 mA. This could come from the regulated supply on the receiver board.

If it is required to extend the effect of a quick break in the beam or a quick burst from the transmitter, the resistor R9 can be replaced by C4 and this will give a minimum operation time of about 1 second.

SPECIFICATION — ETI 585

Frequency	40 kHz
Range	5 metres
Maximum modulation frequency (not with relay output)	250 Hz
Output	relay, closed when beam is made.
Power supply	
Receiver	10 — 20 Vac or 14 — 25 Vdc
Transmitter	8 — 20 Vdc (only)

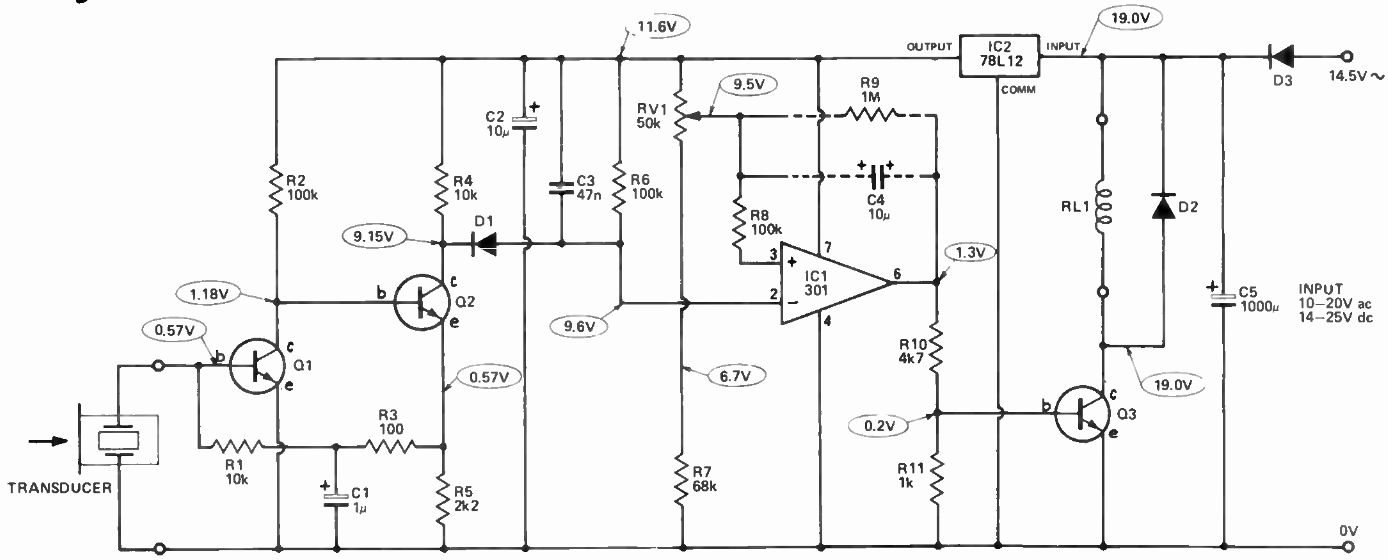
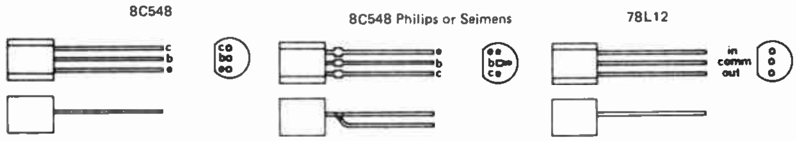


Fig. 1. Circuit diagram of the receiver.

NOTES:
VOLTAGES MEASURED WITH NO INPUT SIGNAL USING A VOLTMETER WITH 10 MEG OHM INPUT IMPEDANCE.
Q1–Q3 ARE BC548
D1 IS 1N914
D2,D3 ARE 1N4001
C4 IS USED INSTEAD OF R9 IF A MONOSTABLE ACTION IS REQUIRED.



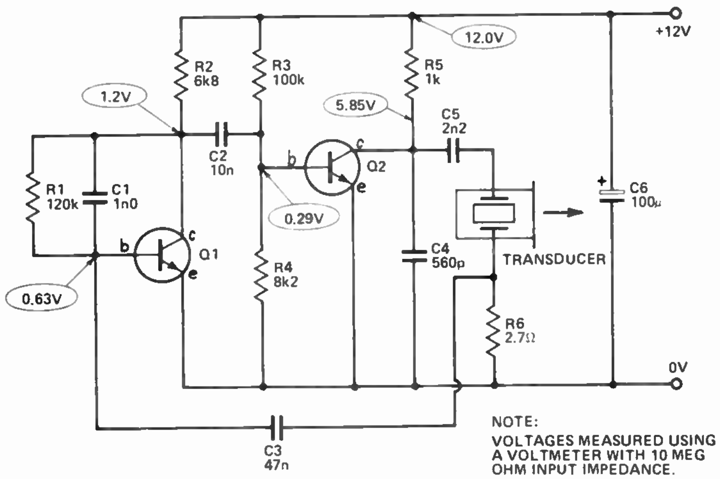


Fig. 2. Circuit diagram of the transmitter.

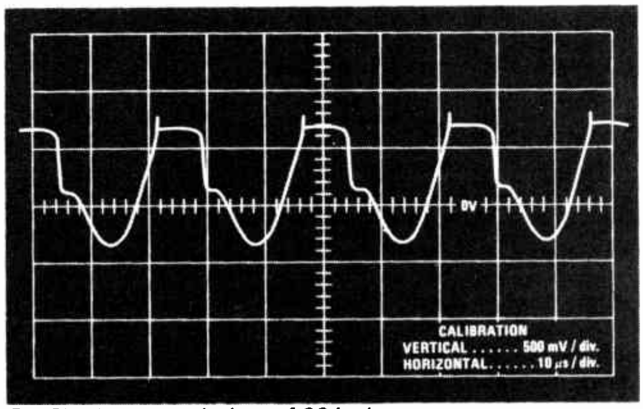


Fig. 3b. Voltage on the base of Q2 in the transmitter.

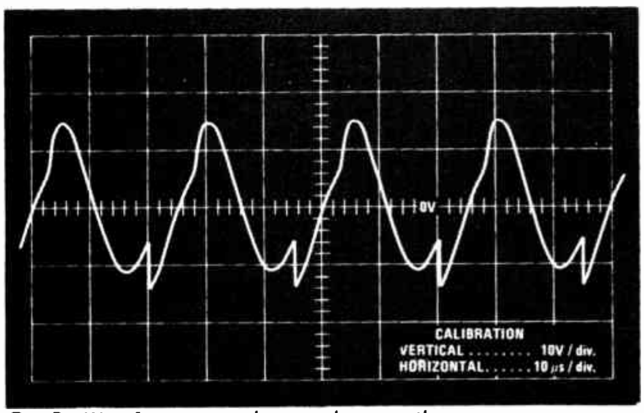


Fig. 3a. Waveform across the transducer on the the transmitter.

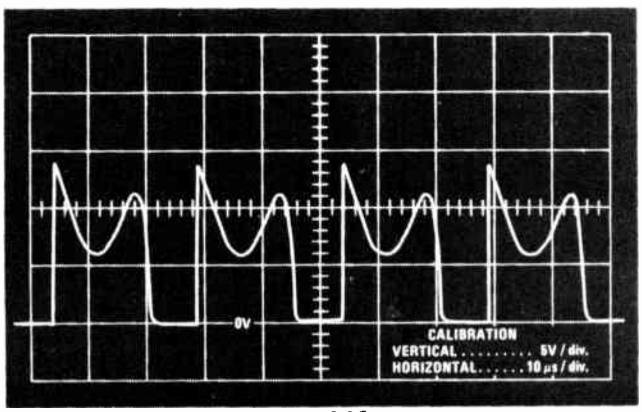


Fig. 3c. Voltage on the collector of Q2.

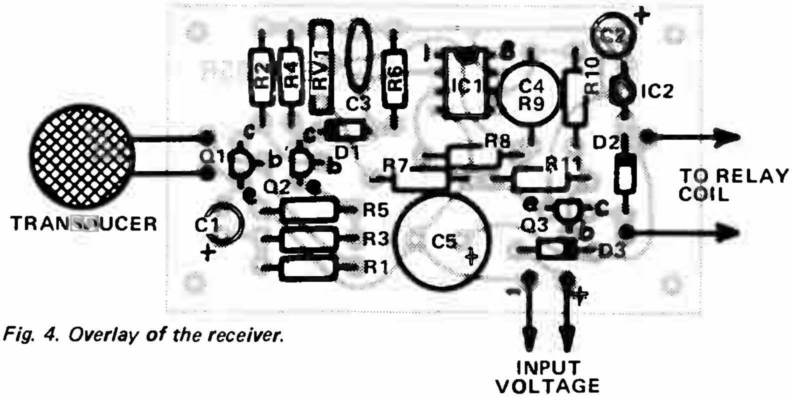


Fig. 4. Overlay of the receiver.

PARTS LIST – ETI 585 T

Resistors all ½W 5%
- R1 . . . . . . 120k
- R2 . . . . . . 6k8
- R3 . . . . . . 100k
- R4 . . . . . . 8k2
- R5 . . . . . . 1k
- R6 . . . . . . 2.7 ohms

Capacitors
- C1. . . . . . . 1n0 polyester
- C2. . . . . . . 10n "
- C3. . . . . . . 47n "
- C4. . . . . . . 560p ceramic
- C5. . . . . . . 2n2 polyester
- C6. . . . . . . 100µ 25V electro

Transistors
- Q1,2 . . . . . BC548

Miscellaneous
- PC board ETI 585 T
- 40kHz transmitter
- case to suit

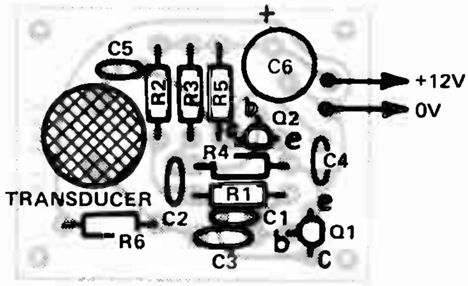


Fig. 5. Overlay of the transmitter.

PARTS LIST – ETI 585 R

Resistors all ½W 5%
- R1 . . . . . . 10k
- R2 . . . . . . 100k
- R3 . . . . . . 100 ohms
- R4 . . . . . . 10k
- R5 . . . . . . 2k2
- R6 . . . . . . 100k
- R7 . . . . . . 68k
- R8 . . . . . . 100k
- R9 . . . . . . 1M
- R10. . . . . . 4k7
- R11. . . . . . 1k

Potentiometer
- RV1 . . . . . 50k trim

Capacitors
- C1. . . . . . . 1µ0 25V electro
- C2. . . . . . . 10µ 25V "
- C3. . . . . . . 47n polyester
- C4. . . . . . . 10µ non polarised electrolytic
- C5. . . . . . . 1000µ 16V electro

Semiconductors
- Q1–Q3. . . . BC548
- IC1 . . . . . . LM301A
- IC2 . . . . . . 78L12
- D1 . . . . . . 1N914
- D2,3 . . . . . 1N4001

Miscellaneous
- PC board ETI 585 R
- 40 kHz receiver
- 12 V relay
- case to suit

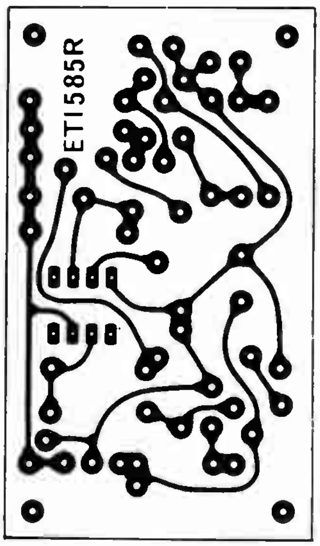


Fig. 6. Printed circuit board of receiver. Full size 70 x 40.

HOW IT WORKS – ETI 585

Transmitter

This is an oscillator the frequency of which is determined by the transducer characteristics. The impedance curve of the transducer is similar to that of a crystal with a minimum (series resonance) at 39.8 kHz followed by a maximum (parallel resonance) just above it at 41.5 kHz.

In the circuit the two transistors are used to form a non-inverting amplifier and positive feedback is supplied via the transducer, R6 and C3. At the series resonant frequency this feedback is strong enough to cause oscillation.

Capacitors C1 and C4 are used to prevent the circuit oscillating at the third harmonic or similar overtones while C5 is used to shift the series resonant point up about 500 Hz to better match the receiver.

Receiver

The output from the transducer is an a.c. voltage proportional to the signal being detected (40 kHz only). As it is only a very small level it is amplified by about 70 dB in Q1 and Q2. D.c. stabilization of this stage is set by R1 and R3 while C1 closes this feedback path to the 40 kHz a.c. signal.

The output of Q2 is rectified by D1 and the voltage on pin 2 of IC1 will go more negative as the input signal increases. If the input signal is strong the amplifier will simply clip the output, which on very strong signals will be a square wave swinging between the supply rails.

IC1 is used as a comparator and checks the voltage on pin 2, i.e. the sound level, to that on pin 3 which is the reference level. If pin 2 is at a lower voltage than pin 3, i.e. a signal is present, the output of IC1 will be high (about 10.5 volts) and this will turn on Q3 which will close the relay. The converse occurs if pin 2 is at a higher voltage than pin 3.

A small amount of positive feedback is provided by R9 to give some hysteresis to prevent relay chatter. If R9 is replaced by the capacitor C4 the IC becomes a monostable and if the signal is lost for only a short time the relay will drop out for about 1 second. If the signal is lost for more than 1 s the relay will be open for the duration of the loss of signal.

We used a voltage regulator to prevent supply voltage fluctuations triggering the unit. The relay was not included on the regulated supply, allowing a cheaper regulator to be used.

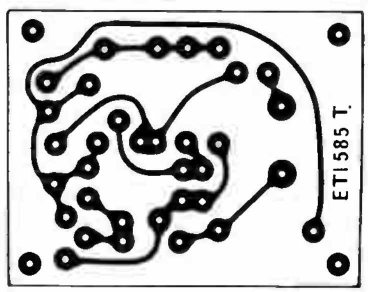


Fig. 7. Printed circuit board of transmitter. Full size 46 x 36.

Biofeedback — a bridge to bionics

Tom Benjamin

Machines to aid human motor functions, or to replace functions lost through birth defects or accidents, are now able to be linked to the brain using electronic biofeedback techniques — chief among these being the electromyogram, a sensor of the tiny bio-electrical impulses controlling muscle activity.

"Why should we offer you a pilot's job?", asked the interviewer.
"In addition to my considerable private experience, I have superior reflexes", replied Geoff.
"But surely a desk job would be more suited to your . . . uh . . . capabilities."
"My 'handicap', you mean? . . . perhaps an old trick could help me make my point. Would you mind placing your thumb and finger on either side of this card? . . . Now see if you can catch it when I drop it . . . before it slips through . . . Ready?
Without warning, Geoff then dropped the card . . . the interviewer's fingers closed on empty space.
"Now you try it," said Geoff.
The interviewer dropped the card without warning . . . it fell about 10mm before Geoff caught it.
"Following my accident," said Geoff dispassionately, "the surgeons put me back together again . . . the engineers made some improvements . . . this is one of them. There are others . . ."

THE short story above, imaginary though it is, may very well represent a real-life situation in the not too distant future.

Geoff, the bionic pilot, isn't flying yet but our minds have been prepared for his appearance years in advance thanks to 'The Six Million Dollar Man' and 'The Bionic Woman' — souped-up, sexed-up versions of last century's Frankenstein's Monster.

Today's handicapped person may sometimes feel like a "Six Dollar Man" compared with TV's Steve Austin. However, the stigma attached to prosthetic devices such as electric wheelchairs, artifical legs, and hearing aids may someday give way to the sort of intrigue and admiration we feel toward TV's growing bionic community.

From another direction, we have been increasingly prepared for the appearance of more human-like robots (see ETI July/Aug '78). The 'droids' of *Star Wars* are the only characters beside the noble Ben who show a selfless compassion — as when C3PO offers to lend his own components to his comrade R2D2. (They are also the only characters refused entry to the pub!) Today's Sci-Fi robots are much more introspective and soul-searching than ever before.

Thus, the media has looked at the bridge between man and machine from both ends. The engineer who builds a more human 'droid' and the biologist who creates machine-like capabilities for the human are each working towards a new species. A quite believable example from *2001: A Space Odyssey* was the Jupiter space craft complex, with its combination of human crew and HAL, the computer, vying for control of the mission. An alien spacetraveller might well have had difficulty in figuring out "Who's in charge here?" in a close encounter with this craft.

Current progress in bionics

In November 1978, Dr. G. Shannon, of Queensland University, published an account of a "myoelectrically controlled hand" capable of providing sensory feedback about the strength of grip applied by its electric motor — possibly the first of its kind accepted and used for any length of time by its recipient.

The mechanism used for providing a sense of "touch" was a pair of strain gauges attached to the mechanical fingers to register the slight bend which occurs when grasping. The sense of "force" was provided by an electromyograph (EMG) which amplifies the electrical activity of a muscle's nerves, converting this to a signal capable of controlling the motor. The EMG was attached to the forearm between the elbow and the patient's amputated stump. The muscles measured in this case normally control movement of the fingers — now they control an electric motor in an artificial hand.

The brain is regarded as "the last defence perimeter" of a person's identity. Fears of electrical stimulation and control of the brain have been expressed in such works as *Brave New World* and *The Terminal Man.* However, it seems likely that many severely handicapped persons will gladly trade some amount of personal identity and privacy for increased abilities with which to contact and manipulate the outside world.

Today's multiply-handicapped person — quadraplegic or brain-damaged, can look forward to a pretty sedentary life. A number of complex switching circuits can put such amenities as a typewriter, TV, and intercom at the person's disposal. Currently, these circuits interface via a blow-tube on/off switch or, more recently, via a matrix system switched by photocells activated by a beam mounted on the head. Neither of these systems can provide the multichannel, simultaneous, analogue type of control required for complex movement and manipulation. A more direct interface is required.

In addition to artificial hands, there

BIONICS: *The emulation of biological components, 'body parts', with electromechanical ones with the object of their ultimate replacement.*

Illustrating muscle relaxation training using our own electromyogram project (see page 107). This project design is based on criteria given by the author of this article and compares very well with commercially made machines. Learning to relax is Jan Collins, our general secretary and office organizer . . . . . note calm expression, unfurrowed brow and general aura of peace!

are a variety of aids being perfected to replace and assist the eyes, ears, and legs of those who are denied their use, either by birth or accident. Implantations in the visual cortex of an electronic grid which produces light sensations have brought artificial vision closer to reality than dream. Similar experiments with the auditory cortex have shown promise, although the frequency range perceived has thus far been limited.

Biofeedback

In 1901 the psychologist, J.H. Blair, sought to shed light upon "the nature of the will" by observing how subjects learned to direct muscles to serve a mental command. He taught his subjects to wiggle their ears by observing their efforts amplified via a system of pressure-filled drums onto a kymograph

MAN VERSUS MACHINE: A COMPARISON

What are some of the strengths and weaknesses that each brings to an interface between man and machine? (see ETI July '78). The space programmes and the nuclear arms race have forced a perhaps premature look at these issues. The age of cloning and bionics may well force a further look. A shopper for bionic and cloned components might keep the following shopping list:

SPECIFICATIONS AND FEATURES

MAN	MACHINE
on-line processing and data reduction of multi-sensory input	reliance upon external sensors
large CPU capacity (10^{20}bits) relative to size	limited CPU dependent upon size
delicate components require an artificial environment	capable of operation in extremely hostile environments
reliability through redundancy; multiple back-up systems	reliability through strength of components
learning capability	very limited learning capability
direct interface difficult due to the body's rejection systems	modular construction allows limitless interface
indirect opto/mechanical interface with outputs	direct amplification of outputs
complex manipulative ability	strong but clumsy manipulative ability
flexibility in short-distance locomotion over rough terrain	capable of fast, extended travel over large distances – land, sea, air, space
low energy consumption: < 100 W	high energy requirements
low energy output: < 400W	high energy output
must be protected	disposable
must be maintained alive	can be switched off indefinitely

Well, shoppers which would you choose . .

- if you wanted to move a 'fridge up two flights of stairs?
- if you wanted to turn out small components on an assembly line?
- if you were outfitting a craft bound for Alpha Centauri? . . . the Greek Isles?

(early chart recorder). A notched lever fitted to the wall of a drum transmitted small ear movements as pressure changes to a second drum to which was affixed a chart-pen. The subjects made efforts to wiggle these long-disused muscles and were rewarded by feedback from the pen tracing.

Today we know this principle as "Biofeedback" (see ETI Sept. '76). By monitoring the various activities of the body with today's sensitive electronic equipment, an average person can learn to control a variety of bodily functions as adeptly as many trained Yogis. Such activities as heartrate (see ETI – 544, Sept. '76), skin temperature (ETI – 130), skin conductance (ETI – 546), blood pressure and brainwave synchrony can be readily measured and converted into an audio/visual signal suitable for providing feedback to the trainee.

In the early '60s, Dr. John Basmajian investigated the ability of persons to control the 'motor units', which are responsible for muscle contraction, using EMG biofeedback. He used needle electrodes 25 μm in diameter, inserted beneath the skin to contact a large number of the tiny motor units. The oscilloscope tracings of the combined rhythms of the motor unit firings resemble a noise signal. To the person observing the tracing, however, the effect is like that of an orchestra. From the assembled patterns, the traces of single rhythms could be discerned. With practise, Basmajian's subjects learned to be able to recognise and control single motor unit firings – *voluntary control over the action of a single body cell in isolation*!

The significance of the discovery was not lost upon orthotists, biomechanical engineers, and doctors. The electromyograph had been in use since the '20s as an expensive laboratory tool capable of measuring the activity of the nervous system in controlling the body's movements. By the '60s, however, the devices had become cigarette pack in size and capable of interface with a variety of electronic devices. The myo-electrically (muscle-electrically) controlled prosthesis was born.

From laboratory to rehabilitation centre

The human body is notorious for its ability to reject as "foreign matter" the finest creations of the best-intending implanter. The problems encountered in the kidney have long plagued pioneers in transplant and pacemaker research.

The courtship of medicine and engineering has been equally stormy. Outsiders such as physicists, psychologists and engineers who operate within the inner sanctum of medical care often complain publicly about their 'sidekick' status, minimal financial return from the great health 'pork barrel', and lack of reciprocity in learning the other's secrets.

Even granted the smoothest of inter-professional relations, there is a lengthy process involved in fitting even the simplest of prosthetic devices to the most willing of recipients:

1. **Construction**: devices used in real life must be durable, simple to operate by someone not concentrating, "normal" in appearance, and cheap enough for the disadvantaged recipient to afford.
2. **Fitting**: an orthotic team must ensure that the device is precisely mated to the person's height, weight, shape of limb, and cosmetic needs.
3. **Training**: a team of physiotherapists and occupational therapists must put the recipient through a graduated series of tasks to allow practice in mastering the device. EMG biofeedback provides a bridge between the trainee and his new addition.

The myoelectronic prosthesis is currently only in experimental use. Many of the needs of the handicapped are better served with simpler mechanical limbs, spring-soled shoes and, of course, the ubiquitous wheelchair. But the day may not be far off when the first handicapped person opts for a myoelectric device which gives him abilities he lacked before his accident.

Current prosthetic hand 'replacements' are capable of quite a range of manipulative movement. With improved materials and electromechanical controls employing biofeedback, such prosthetics will improve markedly in appearance and performance.

The electromyogram (EMG)

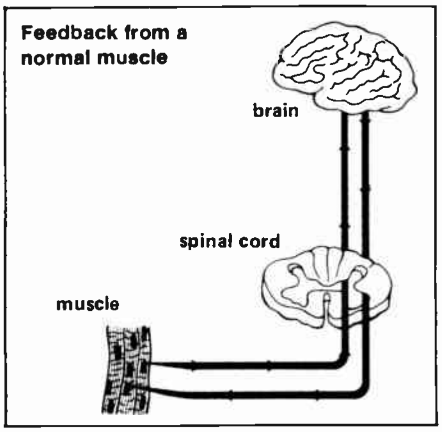
The electrical output of a muscle derives from the *motor units* which entwine the contracting fibres of the muscles. As a number of motor units fire to contract a muscle, their asynchronous firings resemble a noise signal, modulated in amplitude. Numerous studies have attempted to describe the statistical properties of the complex EMG signal. It may be regarded for practical purposes as:

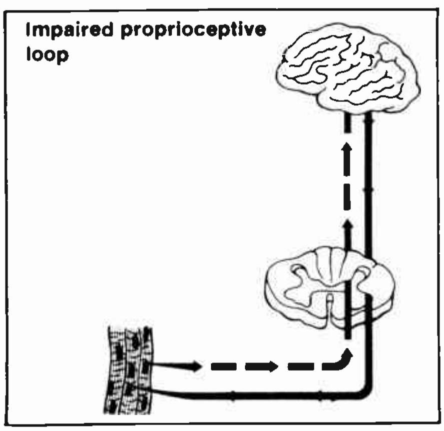
- amplitude modulation
- a weighted sum of the potentials of the motor units
- a function of the number of units, their rate of activation, and the quality of electrical contact

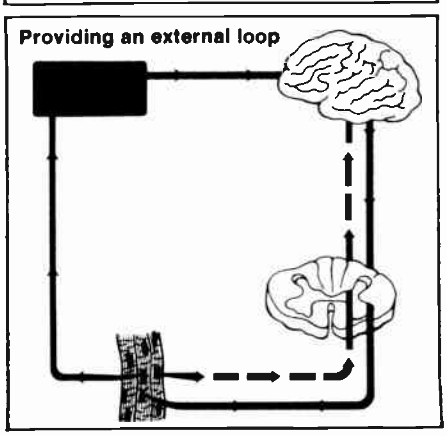
Amplification of the EMG signal presents problems to the amateur constructor. The output of a relaxed muscle is of the order of one or two microvolts peak to peak. To tap this signal from the skin is no mean feat. The skin is itself a source of electrical activity, whose surface resistance changes with mood (see ETI – 546 galvanic skin response meter, March '77), and a source of a dc potential which can dwarf the feeble EMG signal from beneath.

An amplifier which meets the strict demands of electromyography will probably have some of the following specification:

- common mode rejection of greater than 70 dB
- noise level less than 1 μV p-p
- sensitivity of at least 2 μV p-p
- linearity over the range 1 μV to 10 mV







obtained through a combination of the following features:

- ac coupling,
- a high input impedance (100 K) or 'bootstrapped' differential pre-amp.
- a threshold for amplitude which chops the midportion of the signal, giving greater contrast to small changes in input.
- filtering for mains, radio, and heart-beat frequencies.
- a narrow bandwidth, centred around 200 Hz say 100 Hz to 500 Hz.
- provision for both direct and time-integrated readings to capture both transients and average levels of activity.
- audio and visual output for feedback.

For practical use there are mechanical considerations as well. The electrodes are, of necessity, attached at some point in the system by flexible cable to allow movement by the user. But cable, however well shielded, presents its own problems of noise. One solution is to mount the electrodes, together with a compact preamplifier stage, into a single assembly worn directly on the user. The amplifier, integration, power, switching and output functions, built into a larger box, can then be connected by cable to this tiny system which rides on the body.

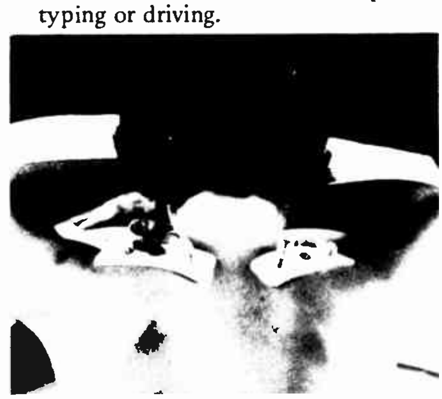
Uses of EMG

The object of training with an EMG is to begin to recognise the subtle sensations within the body which correspond to tiny variations in muscle activity level. One application is in learning to relax: the subject attempts to "switch off" his central nervous system from movement and sensation in specific areas of the body. This technique has shown promise with a variety of anxiety-based disorders and may benefit Yogis and athletes who are learning to conserve their energy. At the other end of the spectrum is the need of the physically-handicapped to use the EMG as a sort of 'strength-ometer' for re-training weakened muscles.

Typically, the user applies a conductive gel to the electrode, tapes it to the skin and adjusts the sensitivity of the device, checking the noise level. A popular and practical training procedure is as follows:

1. **Connection to forearm** – flex the fingers and note the electrical activity which corresponds to fine movements; relax the arm by picking it up at the wrist and dropping it, allowing it to flop lifelessly onto the lap; note the sensations as the arm is allowed to become more and more "numb" and "heavy".

2. **Connection to forehead** – raise and lower the eyebrows, frown, squeeze the eyes shut, bite hard: note how all of the facial muscles interconnect; close the eyes and allow the face to become "smooth", listening to the audio feedback as the muscles lose their tightness.
3. **Connection to neck** (cervical or trapezius) – shrug the shoulders, move the head from side to side: note the postures in which the muscle output becomes lowest – slightly drooped shoulders, head balanced vertically; lose that tight feeling in the neck which often accompanies typing or driving.



Having practised the above, the trainee can then strive for more complete mastery of the nervous system: causing tinier and tinier voluntary flickers of movement while remaining relaxed; relaxing quickly after muscular strain; relaxing one portion of the body while tensing another.

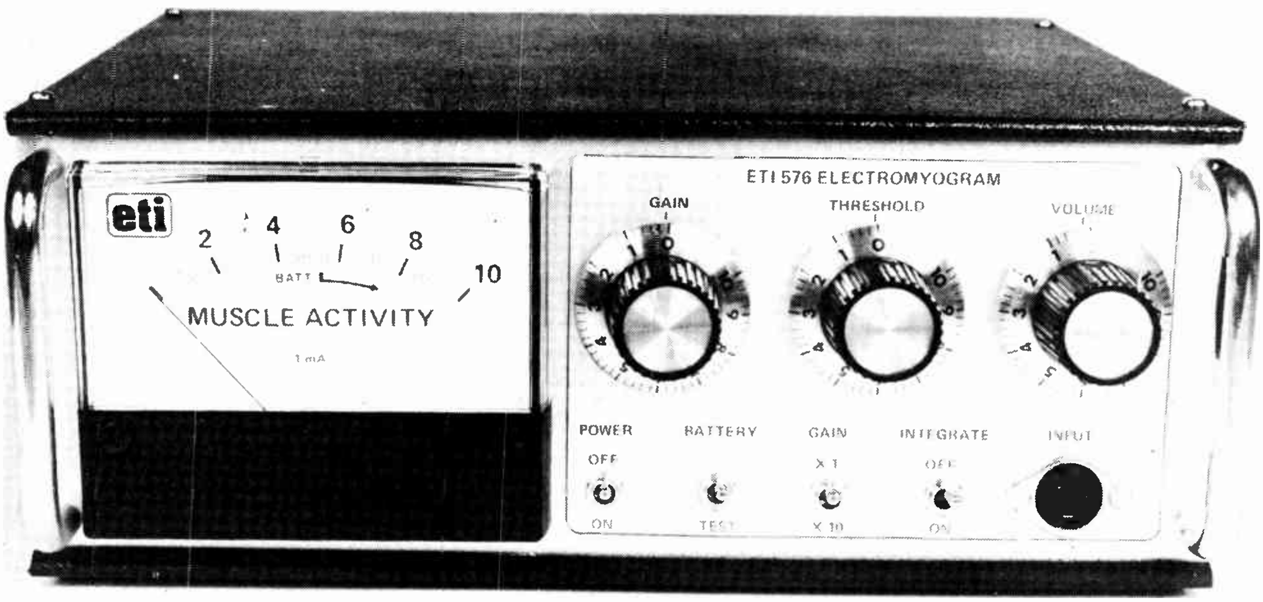
Biofeedback is an educational and athletic discipline – there are no unbreakable records, no unbeatable performances, no lack of goals and challenges. No matter how powerful and sophisticated a man's bionic body may become, the challenge of mastery will remain.

Biofeedback will continue to form a bridge between man's mind and his body. ●

Electromyogram for biofeedback use

David Tilbrook

This unit senses the tiny electrical impulses associated with muscle activity and provides an indication of this activity via a meter and a sound output. The latter is a series of pulses, the repetition rate increasing with increased muscle activity, decreasing as muscle activity declines. It may be used to 'train' particular muscles or to learn effective relaxation.



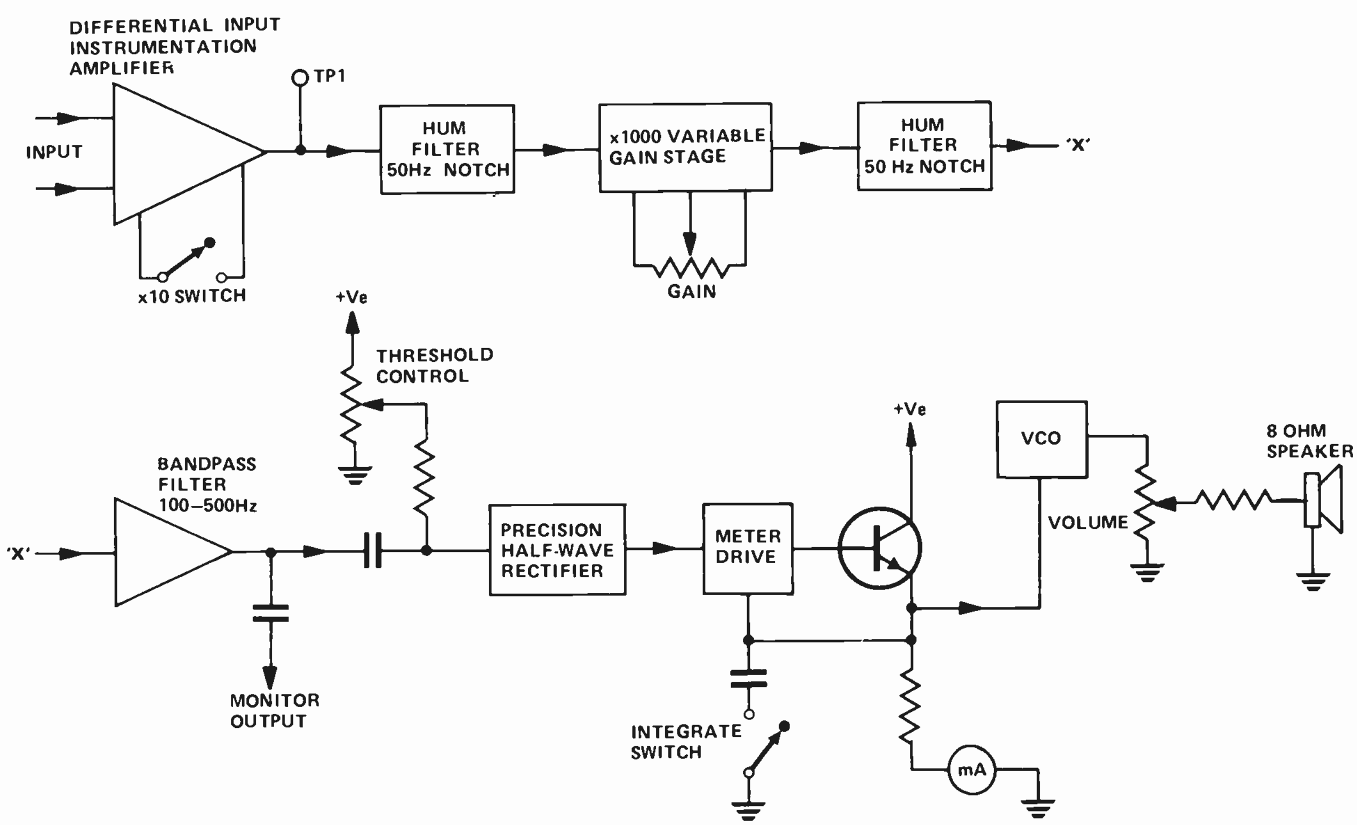
AT THE SUGGESTION of Tom Benjamin, author of the biofeedback feature immediately preceding this article, an electromyogram project was investigated to go hand in hand with the feature on the premise that it's frustrating to read about something that you can't follow up with some practical experiments!

I tackled this project with some enthusiasm as it presented a range of interesting design problems as well as having some pretty tough specifications to meet if the unit was to be at all useful. There's nothing like a challenge to stimulate a little creativity!

We have published two biofeedback projects in the past — the Heart Rate Monitor (ETI 544) in September 1976 and the Galvanic Skin Response Monitor (ETI 546) in March 1977 — but this is the most complex instrument to date. In an article on biofeedback in the September 1977 issue (pages 68 to 72), in discussing EMG devices, the writer said: "This type of instrument is not really suitable for home designing or building".

That little charmer was the first hurdle I had to face.

Before going on to the construction and setting up of the instrument, you may be interested in seeing how this design evolved and why particular circuit techniques were used.



Design problems

The design and construction of an electromyogram presents some unique problems.

The object is to detect the minute electrical signals produced by the 'firing' of muscle fibres in a particular muscle. For our purpose metal electrodes of some sort are attached to the skin over the muscle(s) of interest. For a relaxed muscle, these signals are fractions of a microvolt in amplitude. That's a small enough signal to detect on its own without having to find it amongst *volts* of 50 Hz hum that will be present in the body – induced from power and light wiring. Of course, you could do these measurements in the middle of the Gibson Desert but that's not always convenient! You only have to touch your finger to the input of an oscilloscope to get an idea of the magnitude of the hum induced onto the body.

When the body is grounded, this hum will drop to typically one volt peak-to-peak, but trying to see one microvolt in one volt of unwanted noise (50 Hz hum here) sure isn't easy.

The overall block diagram of the unit is shown in the drawing here.

Battery operation is essential as, with any device connected directly to the body, the possibility of accidental contact with mains potential from a mains-operated unit is very real – with lethal results.

The instrument is called upon to detect quite small signals in the presence of large amounts of noise. It should have variable gain control – adjustable by the user, a threshold control so that small variations of a large signal may be readily detected, a visual indication (a meter) and an audible output that follows the convention of rising pitch or pulse rate for increasing muscle activity, and vice versa. Tom Benjamin also mentions some form of bandpass filtering to sort out the predominant muscle signal which is in the 100 Hz to 500 Hz range. Selectable integration of the feedback response is also considered desirable.

First thing was to tackle the hum problem. To overcome this, a number of techniques have been employed. Firstly, I have used a differential amplifier for the input stage. This type of circuit has two input terminals. Signals on the inputs that are *out of phase* will be amplified and passed to the output, while signals that are *in phase* (called common mode signals) will be rejected. The amount of rejection is determined by the amplitude of each in-phase signal. As, in this application, the two inputs are connected to the skin, they will each receive hum signals in phase and of similar amplitude and thus be rejected to a large extent. The amount of rejection of a common mode signal is called the common mode rejection ratio (CMRR).

Most IC operational amplifiers are of the differential input type. A typical op-amp IC has a CMRR of about 90 dB – which means that any common-mode signal will be reduced by a factor of about 30,000. This is good in theory but, in practice, the use of 5% resistors in circuits results in a CMRR of around 60 dB, which is not good enough.

The differential input stage was the most difficult portion of the circuit to design as it was required to have a very high CMRR, a high input impedance and very low noise. Naturally, the home constructor should be able to reproduce the performance of our prototype, preferably without going to a lot of trouble selecting special components or through elaborate set-up procedures. I managed to achieve all these design goals – after discarding several circuits!

The need for a high input impedance is a much-debated subject. Some commercial EMG's boast input

ETI 576 ELECTROMYOGRAM SPECIFICATIONS

Equivalent input noise	150 nV (0.15 uV)
Minimum 50 Hz rejection	80 dB (irrespective of common mode rejection)
Common Mode Rejection Ratio	100 dB or better
Input impedance	220 k
Bandwidth	100 Hz to 500 Hz
Audio output	Variable repetition rate pulse output from inbuilt loud-speaker.
Power source	two 9 V batteries
Power consumption	20 mA per battery
Battery check	battery check switch indicates condition of batteries on meter

impedances as high as 1000 M! The reason is to reduce the effect of poor electrical contact between the electrodes and the skin. In a 1000 M input impedance a few thousand ohms difference between the electrode input impedances (that is, from each electrode to the instrument common or 'ground') goes unnoticed as it represents such a small percentage of the unit's input impedance. Input impedances in this order necessitate MOSFET devices which are relatively noisy in comparison with bipolar transistors at these frequencies.

I elected to use a much lower input impedance and to optimise the noise figure. This has the added advantage that readily available transistors could be used for the input stage.

The input impedance is limited by the base bias resistors of the input stage – in this case, 220 k for each input. At this input impedance, differences in electrode contact resistance with the skin are important, so care should be exercised to minimise this when attaching them.

Biasing the differential input stage is important and this is discussed in the "How it Works" section. One trimpot is used to set up the input stage for correct operation. Once set up, any of the component values may be varied by +/– 10% without affecting the CMRR.

Gain of the input stage is about 1000 (60 dB). Common mode signals will be reduced by the CMRR (about 100 dB, or better), the exact amount of reduction depending on the electrode attachment, as just mentioned, but the CMRR can be degraded quite a bit by this before it becomes a real problem. We experienced little difficulty attaching dry electrodes to dry skin on the forearm.

The choice of this type of first stage has resulted in a very low noise figure. The prototypes (we built two) had measured noise figures close to 150 nV (0.15 uV) at the input. This equals the performance of the best commerical units we have seen.

Immediately following the input stage is a 50 Hz notch filter to offset any increase in hum pickup due to contact resistance variations. This uses the same circuit as our Hum Filter (ETI 451), described on page 58, but omitting the preset adjustment.

There are two hum filters, we'll get around to the second shortly.

From the first hum filter the signal goes to a variable gain stage. This employs a 741 op-amp, the gain of which is controlled by a potentiometer mounted on the front panel. Gain is variable between 10 and 1000. This stage is fairly straightforward, although the circuit is a little unusual. See "How it Works" for a complete description.

Following this stage is the second hum filter, immediately preceding the bandpass filter. Signal levels at this stage are around one volt, excess hum on top of this can cause clipping and severe distortion in the succeeding stages.

The bandpass filter is centred at 250 Hz, around the middle of the frequency range of interest. Output from the firing muscle fibres consist of a broad 'noise' signal extending from a little below 100 Hz to about 1 kHz, although the largest amplitude portion of the muscle signal spectrum is between 100 Hz and 500 Hz. The bandpass filter attenuates noise and other signals outside the main area of interest, improving the signal to noise ratio of the instrument.

The output of the bandpass filter is available as a 'monitor output', via a coax socket on the rear panel of the instrument. This enables you to monitor the signal directly using an oscilloscope or via an audio amplifier.

To provide the required audible and visual feedback indications, the signals must undergo some processing to control the appropriate outputs.

From the bandpass filter the signal is mixed with a dc voltage that is varied by means of the Threshold control on the front panel, then fed to a precision half-wave rectifier. This stage rectifies any (ac) signal above the dc voltage set by the Threshold control. By setting the threshold just above the level of noise present, very small changes in muscle activity are made readily apparent. The output of this stage is a series of positive-going pulses from the muscle fibre signal.

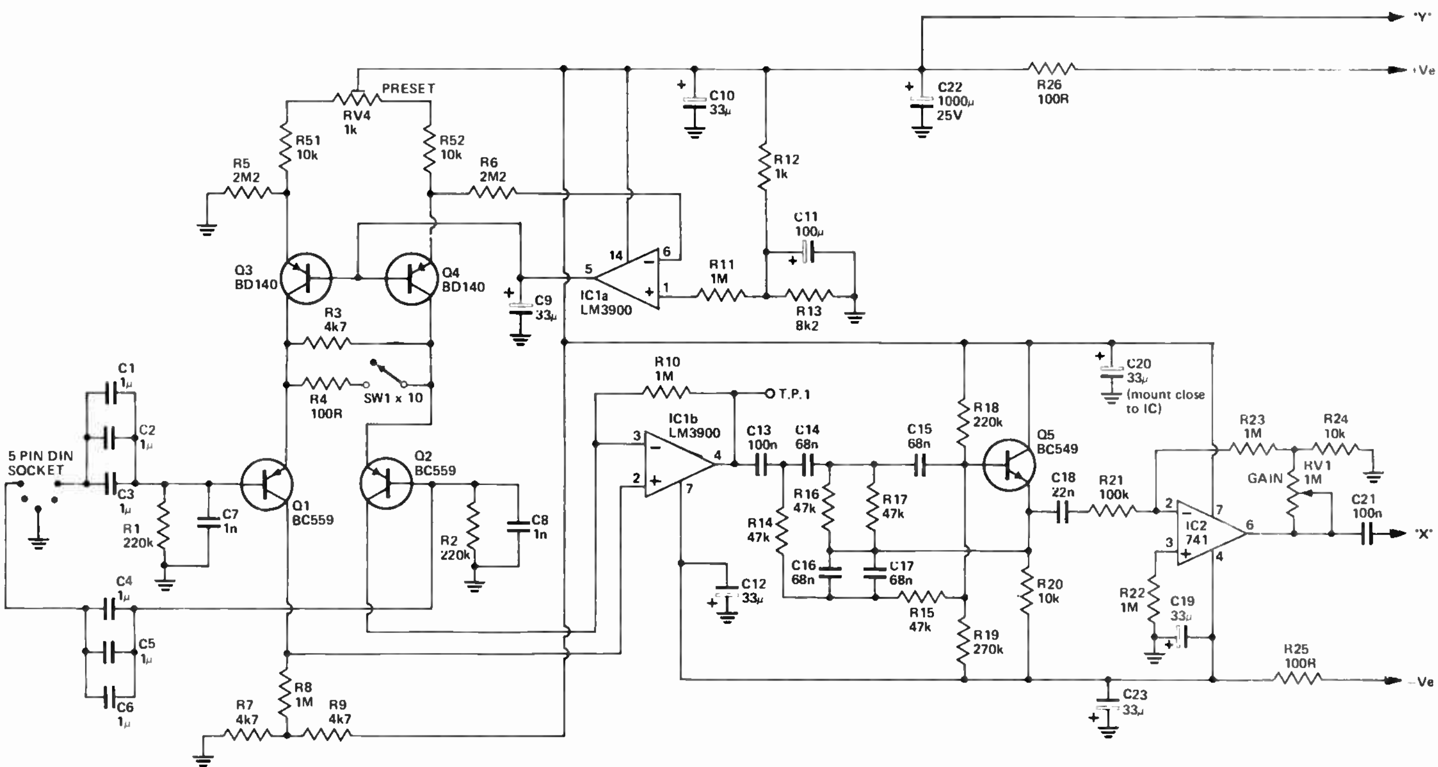
The meter drive stage follows the precision rectifier. This employs a 741 op-amp and an emitter follower stage with negative feedback from the emitter of the transistor. The positive-going pulses from the rectifier stage charge a capacitor, the voltage on this being a measure of the muscle activity as the signal varies above the threshold while the muscle is active.

To provide some integration of the muscle activity level, so that the meter and audible responses are not too rapid (as researchers have found undesirable in some instances), switched capacitors are provided at this point to provide integration times of about 0.5 second and 4 seconds – selected by a front panel switch.

The audible output is derived from the meter drive so that it corresponds with the visual feedback response provided by the meter. This consists of a voltage-controlled oscillator (VCO) that provides a series of pulses to drive a speaker. The VCO employs a 555 timer IC.

Originally, it was intended to use a tone for the audio output. However, battery consumption on the prototype was almost 150 mA – at best! Battery life would be very limited at this consumption. A class A audio output stage is necessary to provide a tone output, and these are quite inefficient. Using a pulse output enabled me to reduce the total current consumption to 20 mA.

Construction details and how to use the machine appear in the next part on page 112.



HOW IT WORKS – ETI 576

Since the circuit is fairly complex, a detailed analysis of its operation is best tackled by looking at the individual stages in turn, from input to output.

Differential input stage

Input signals from sensors on the body drive Q2 and Q1 which are arranged as a differential pair. Emitter current, and thus collector current, for Q1 and Q2 is derived from a precision constant-current source comprised of Q3, Q4 and IC1a. Transistors Q1 and Q2 share the current supplied by the constant-current source. If Q1 (for example) is driven harder, by an input signal, than Q2 then, while the collector current of Q1 increases, there will be a corresponding decrease in the collector current of Q2.

Now, the collectors of Q1 and Q2 are each connected to the input of IC1b, one amplifier in an LM3900 (a quad op-amp package). The amplifiers in the LM3900 package have the special feature that they amplify current differences applied to the inputs.

To ensure a high common-mode rejection ratio, the quiescent (no signal) collector currents of Q1 and Q2 must be held very close to a fixed amount. Hence, the precision constant-current source.

To derive this constant current source for Q1 and Q2 the two bases of Q3 and Q4 are driven by the output of IC1a. The non-inverting input (marked +) of IC1a is driven by a fixed voltage derived from a voltage divider (R12, R13) from the positive supply rail. C11 is a bypass capacitor to prevent supply rail variations modulating this reference voltage.

The inverting input (–) of IC1a is coupled to the emitter of Q4 placing this transistor in the feedback loop of IC1a. The op-amp (IC1a) will attempt to maintain the current flowing through its inputs at a constant level, thus maintaining the base-emitter current through Q4, and therefore the collector current, constant at nominally, 100 mA. Assuming Q3 has similar gain to Q4, its collector current will be the same. The 1k preset, RV4, allows adjustment of the two collector currents to offset any slight differences in gain.

The input stage gain is determined by the value of the resistance between the emitters of Q1 and Q2. The lower this resistance, the higher the gain. The 'x 10' switch simply connects a 100 ohm resistor in parallel with R3, increasing the gain.

Capacitors C7 and C8 ensure high frequency stability through bypassing the bases of Q1 and Q2 at frequencies above the range of interest.

To ensure good common-mode rejection ratio, it is essential that the bases of Q1 and Q2 each receive the *same* level of input signal. As the input is ac-coupled the characteristics of the input coupling capacitors must closely match each other. If stranded 10% capacitors are used the slightly different impedances of each will limit the common mode rejection. The solution we adopted was to use several capacitors in parallel so that the slight capacitance variations, and corresponding impedance variations, average out. It is important therefore that these six capacitors, C1-C6, are all the same type.

Supply rail decoupling for the input stages is provided by R25, R26 and C22, C23.

The hum filters

Two 50 Hz hum filters are employed, as can be seen in the block diagram, one immediately following the differential input stage, the other between the variable gain stage and the band-pass filter.

Both 50 Hz filters employ a 'twin-T' circuit – as used in our Hum Filter project, ETI 451, described on page 58. A detailed discussion of this circuit can be found in that article.

In the first hum filter, Q5 is connected as an emitter follower, the twin-T components connected to provide feedback at 50 Hz. In order to obtain a high circuit Q and thus good rejection at 50 Hz, the value of the resistance formed by R16 and R17 (parallelled) must be as close as possible to half the value of R14 and R15. As the latter are 47k resistors, the best way to obtain a value of half that is to connect two 47 k resistors in parallel.

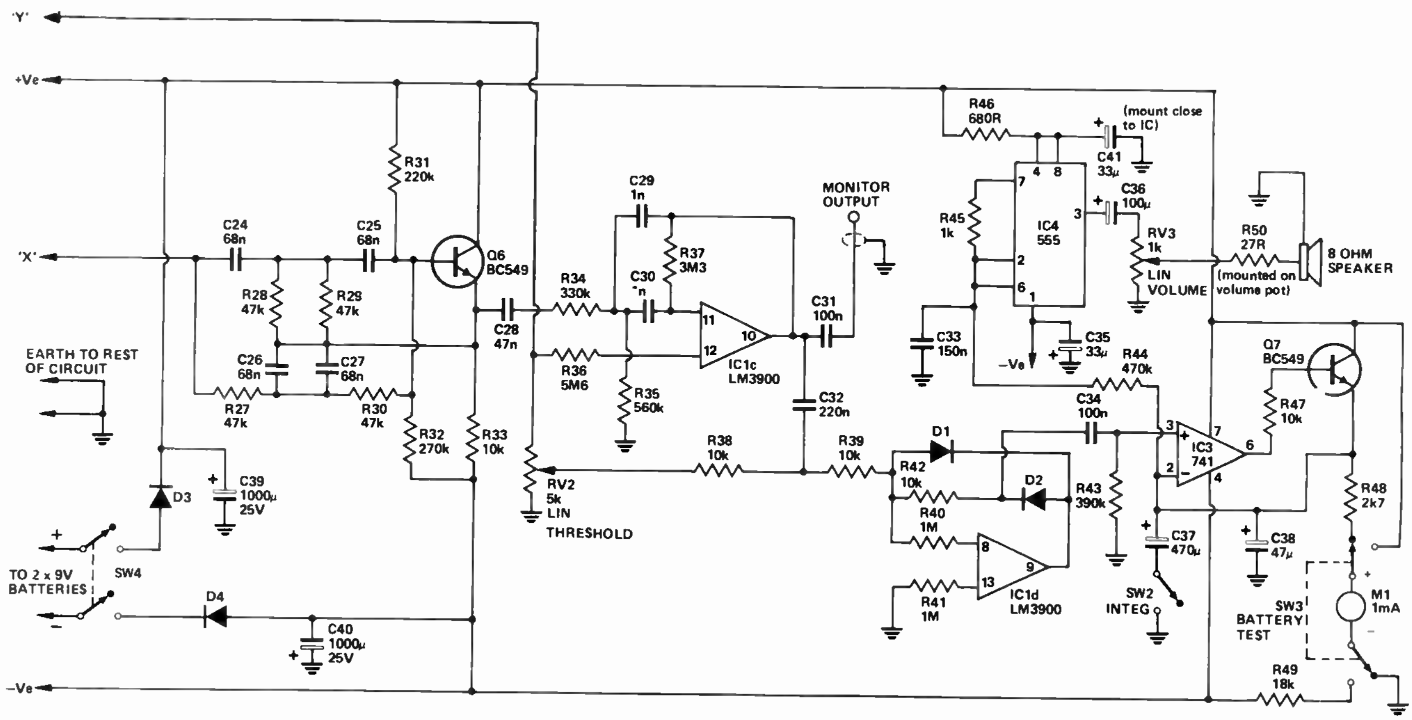
Similarly, for the second hum filter, Q6 is the active component and the filter consists of C24, 25, 26, 27 and R27, 28, 29 and 30. Resistors R28 and 29 form a resistance half that of R27 and 30 to provide good rejection at the notch frequency.

These stages provide a total of 20 dB rejection at 50 Hz.

Variable gain stage

Following the first hum filter is a variable gain stage employing a 741 op-amp. This is quite a conventional amplifier, gain variation being provided by RV1, a 1M potentiometer connected in the feedback path of the 741. RV1 is a front panel control. Gain is variable between 10 and 1000.

To avoid problems arising from large output offset voltages and unstable gain settings, the feedback for the 741 has been arranged via a voltage divider consisting of R23 and R24, the gain potentiometer being connected between the op-amp



output and the junction of these two resistors.

The gain of the circuits is given by the equation:

$$\text{GAIN} = \frac{R_{23} + \dfrac{R_{23}\,RV1}{R_{24}} + RV1}{R_{21}}$$

Bandpass filter

Signal levels at the output of the variable gain stage are around 1 V. Any hum exceeding this level could easily cause clipping in succeeding stages and the purpose of the second hum filter is to prevent this.

The bandpass filter employs one op-amp from the LM3900 package, IC1c. A filter network, consisting of R34, R35 and R37 and C29 and C30, is connected around a feedback path between the op-amp output and its inverting input. This provides a bandpass extending from 100 Hz to 500 Hz which encompasses the range of interest for the muscle fibre signals. At midband (250 Hz), the gain of this stage is roughly four.

A monitor output is taken from the output of IC1c so that the muscle activity waveforms (filtered) may be viewed on an oscilloscope if desired.

Threshold control

This consists of a precision rectifier that passes only the positive peaks of the signal that are greater than a preset dc voltage — determined by potentiometer, the threshold control on the front panel.

The output of the bandpass filter is mixed with a dc voltage derived via the positive supply rail by the potentiometer RV2. The resultant signal — the ac muscle activity signal superimposed on a dc voltage — is then applied to the input of the precision rectifier. This involves IC1d, D1 and D2 and resistors R39, 40, 41 and R42. The latter two resistors convert the current-differencing input of the LM3900 into a conventional voltage-input op-amp.

Positive-going signals of less than 0.6 V above the voltage present on the junction of R39 and R40 will be amplified by the full open-loop gain of IC1d. The output of this stage increases rapidly until D2 conducts, the stage then has only unity gain (x 1), determined by the ratio of R42 and R39.

Output from the precision rectifier is taken from the cathode of D2 and will consist of the amplified, positive-going part of the muscle fibre signals that are above the positive voltage set by the threshold potentiometer, RV2.

Diode D1 ensures that the gain of the stage remains at unity gain for the negative-going portions of the muscle fibre signals from the output of IC1c.

Meter drive

This consists of an op-amp (IC3) with an emitter-follower stage (Q7) connected in the negative feedback path. The emitter of Q7 drives the meter.

The threshold stage output is coupled to the input of IC3, a 741, via a 100n capacitor, C34. Resistor R47 limits the base current of Q7 to a safe value as the 741 will provide much more current than the transistor will stand! A signal from the output of the threshold circuit will be amplified by IC3, causing Q7 to turn on, charging C38. The meter is connected to 'read' the charge on C38, via R48. The more signal that appears above the threshold, the longer Q7 will be turned on, increasing the charge in C38, thus increasing the meter reading. The circuit will respond quickly to increasing input signals, showing a corresponding increase in the meter reading. As the signal decreases, with decreasing muscle activity, the meter reading decays at a rate depending on the capacitance between the emitter of Q7 and ground. This provides for some integration of the signal level variations.

The integrate switch, SW2, connects a 470 μF capacitor (C37) in parallel with C38 (47 μF). With this in circuit (integrate switch 'on'), the meter takes some four seconds to drop from full scale to zero.

Voltage-controlled pulse generator

This provides an audio output, consisting of a series of pulses, the repetition rate being an indication of muscle activity.

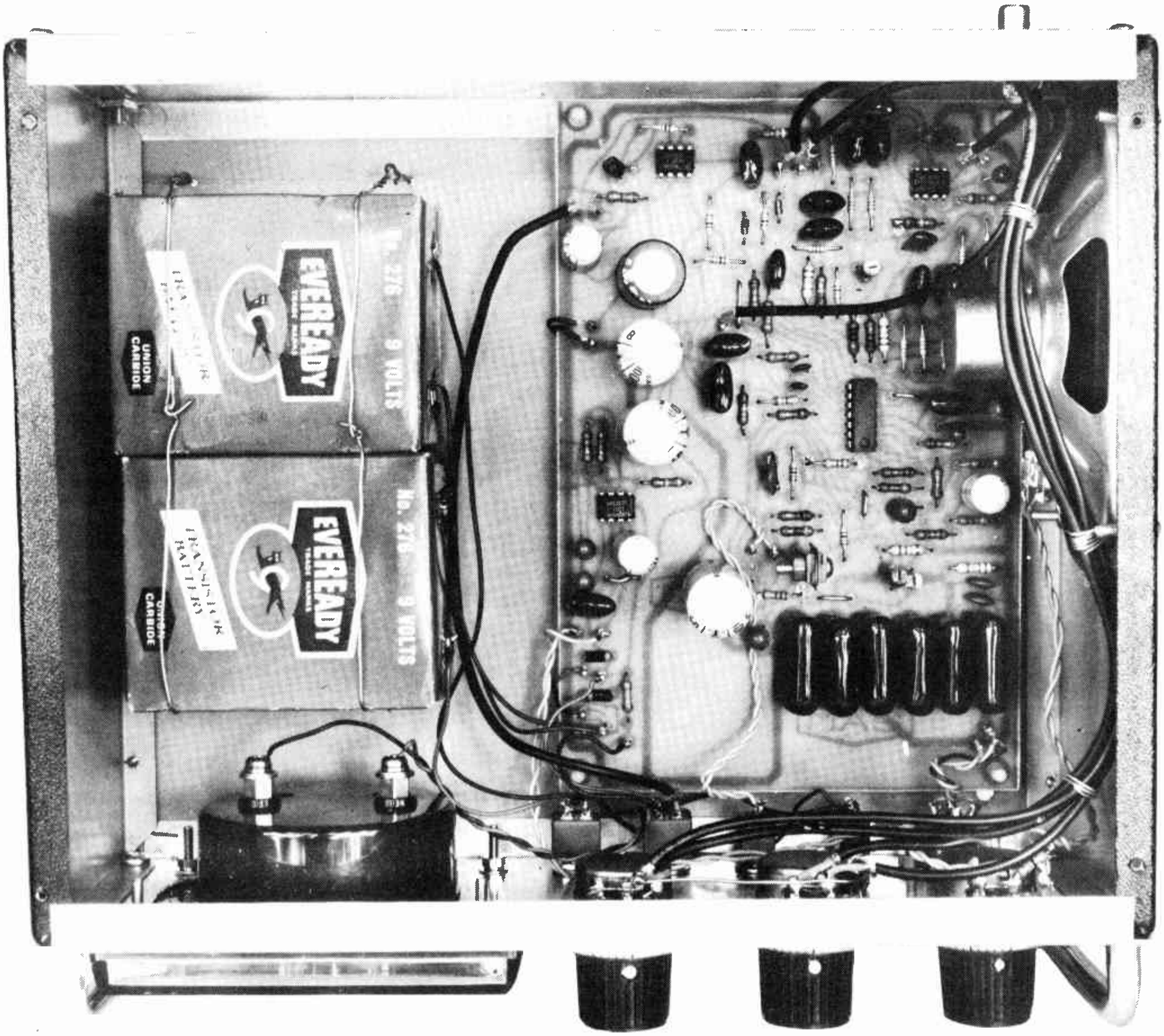
The emitter of Q7 is coupled to IC4, a 555 timer, via R44. Current through this resistor charges C33 until the voltage on pin 6 of IC4 reaches 2/3 of the voltage on pins 4 and 8. At this point, pin 7 of the 555, previously appearing as an open circuit, will conduct discharging C33 via R45. Once the voltage on pin 2 drops below 1/3 of that on pins 4 and 8, pin 7 returns to an open circuit condition, allowing C33 to charge again. In this manner, the 555 oscillates providing pulses on pin 3 to the speaker, via RV1 which serve as a volume control. As the voltage at the emitter of Q7 varies according to the variation in muscle activity signals, the rate at which C33 charges will vary. This varies the pulse repetition rate of the 555 oscillator in sympathy with the variations in muscle activity.

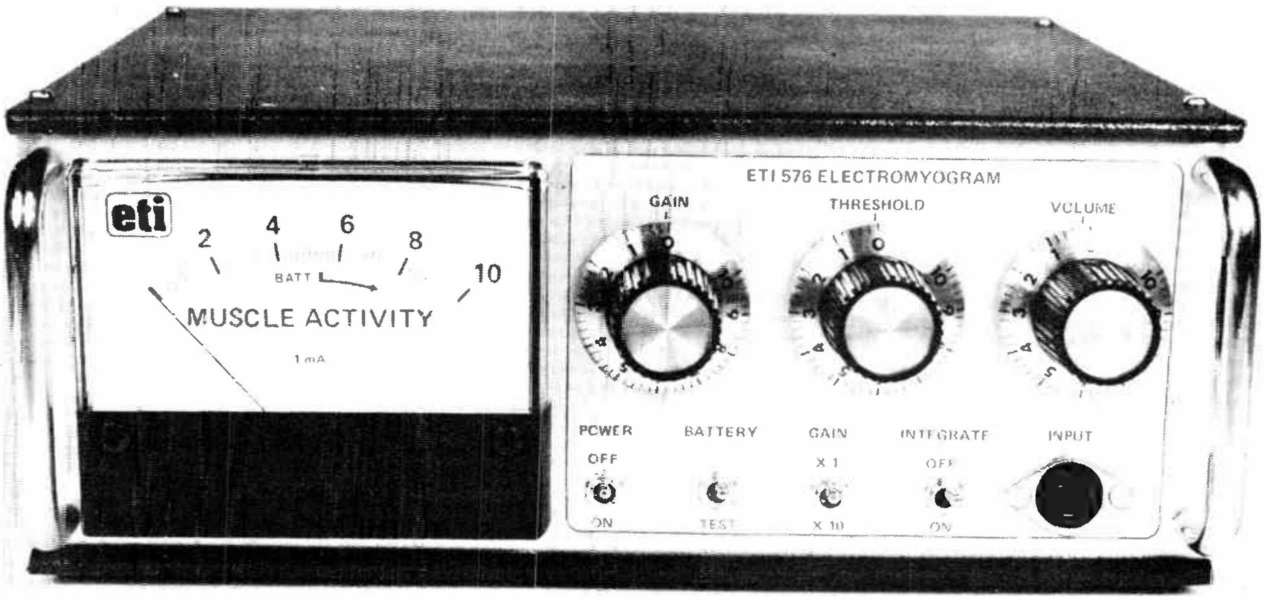
Project 576

The electromyogram — part 2.

David Tilbrook

In this article we present construction details and some suggestions on using the instrument.





OUR PROTOTYPE was housed in a Horwood instrument case measuring 254 mm wide by 203 mm deep by 102 mm high. These are available from quite a few component suppliers but any box with similar dimensions should suffice. The advantage of this particular case is that it is supplied with steel top, bottom and side panels which provide better shielding from stray hum fields than does aluminium.

Construction is best commenced with the pc board. This method of construction is recommended as layout of the various stages is critical to avoid feedback or interaction between stages as one LM3900 package does sterling service in several parts of the circuit!

Assembly of the pc board should start with the resistors and capacitors. I found it easier to leave the six 1 uF input capacitors until the input transistors (Q1-Q4) were mounted. Be sure to check the polarity of the electrolytic and tantalum capacitors.

Finish loading the pc board by inserting the diodes, transistors and ICs. The input transistor pair, Q1 and Q2, must be mounted so that their flat faces are touching to provide thermal coupling. The best way to do this, to avoid straining anything, is to solder only the collectors and emitters of Q1 and Q2 at first. Smear some thermal paste on the two flats and then tie the two transistors together using a link of enamelled (coil) wire – this prevents the possibility of shorts to the transistor leads should the loop slip off at some time. Tighten the loop by taking the ends in a pair of pliers and twisting until the transistors are held tightly together. Once this is done, solder the base leads.

The two BD140s, Q3 and Q4, also need to be mounted together. As they are in TO-126 packages they may be bolted together. It is necessary to use an insulating washer between them to prevent the collector contacts touching. Use thermal paste to improve the thermal coupling.

Once these devices are mounted, six 1 uF input capacitors may be soldered into place.

If you use pc board pins, the external connections to the board may be made after it is mounted in the case, otherwise, now is the time to attach all the leads going to the externally-mounted components.

As high gain stages are used in several places, the circuit is sensitive to noise or signals radiated from other parts of the board. The 555 VCO output can be especially troublesome, so use shielded cable to connect the output of the 555 to the volume control. The only resistor not mounted on the pc board (R50) is mounted between the wiper terminal of the volume control and one of the loudspeaker terminals.

There are a number of other connections that should be made with shielded cable and these are shown in the wiring diagram.

There is sufficient room inside the cabinet to accommodate a variety of 9 V batteries. The type of connection to the battery will depend on the particular style of battery used.

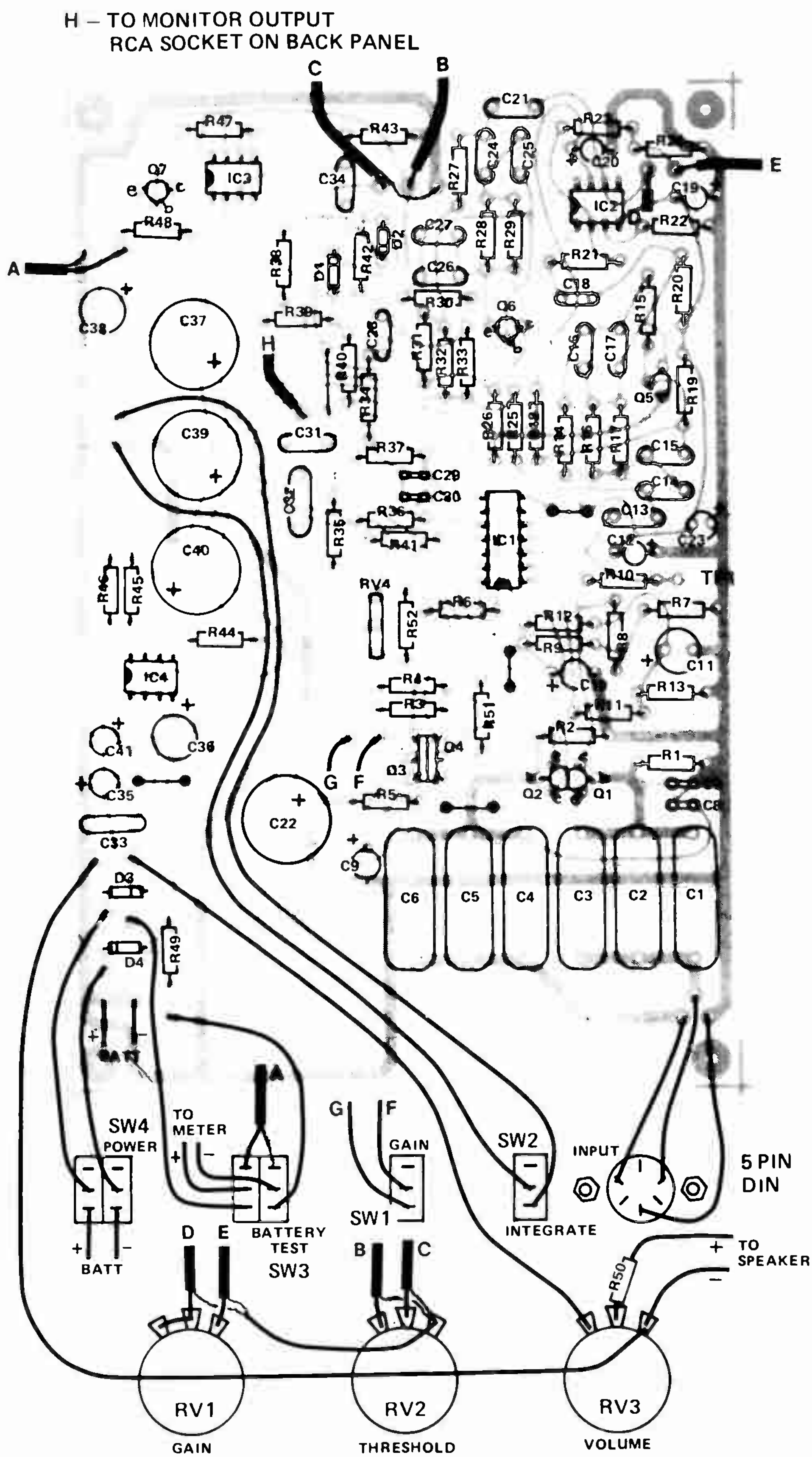
The speaker is mounted on one side of the cabinet and the monitor output (and RCA coax socket) is mounted on the back.

On the front panel, the switches should be mounted first, followed by the pots and the meter. Juggle the pc board into the case last.

Electrode construction

Although the common mode rejection of the input is better than 100 dB this will be degraded drastically if the contact to the skin is not good enough. To enable the input stage CMRR to effectively reduce 50 Hz hum it is necessary to ensure that the hum is exactly the same level on both inputs. For this reason the construction of the electrodes is very important.

The diagram on page 115 shows the electrodes we built. Three lengths of shielded cable were used (RG174 coax). The two input leads are made by soldering the centre conductor of the shielded cable to small metal discs about the size of 5c pieces. Cut the earth braid back enough so that it cannot touch the electrode. The braids of the two input cables are connected to pin 2 of the five-pin DIN plug (the grounded pin). This pin is also connected to the shield of the third cable which becomes the ground electrode. The centre conductor of this cable is not used and the other end of the braid is soldered to another metal disc. Use a slightly larger disc (about the size of a 10c piece) as this helps to ensure a good ground connection to the body.



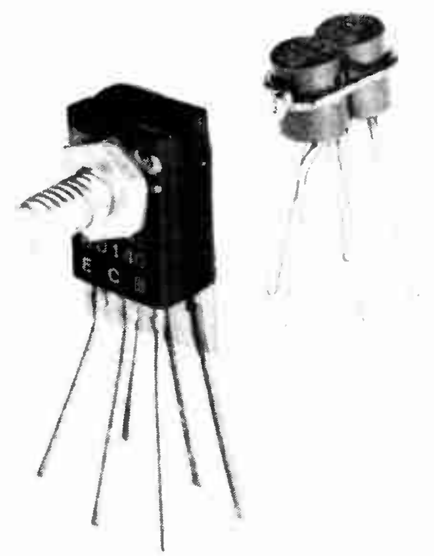
How to use it

Before powering up, check the pc board. Check the orientation of all the polarised components – electrolytic and tantalum capacitors, transistors, ICs and diodes. If everything is all right, switch the unit on with the battery switch in the test position. With 9 V batteries the meter should read about 9. If the battery switch is now switched off the meter should immediately fall to zero, provided the gain control is turned fully down. If the volume control is turned to full on a slow clicking should be heard. Now, measure the voltage (with respect to earth) at the test point (TP1) at the output IC1a (pin 4). With the x10 switch in the x1 position adjust the preset pot to obtain zero volts.

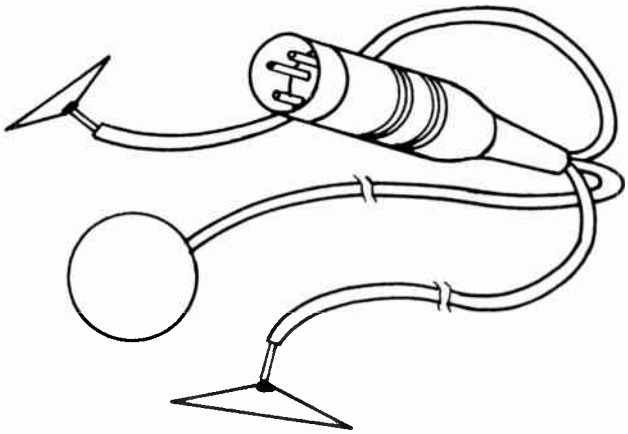
If the gain control is now increased, the meter reading will move along with the frequency of the clicks.

Now, advance the threshold control and the meter reading and click frequency should decrease. This threshold control works by varying the minimum signal required to cause a meter response. The higher the threshold control is set, the higher the input signal must be to cause a meter response. The threshold can be set just above the noise level so that even a very small input signal can be detected.

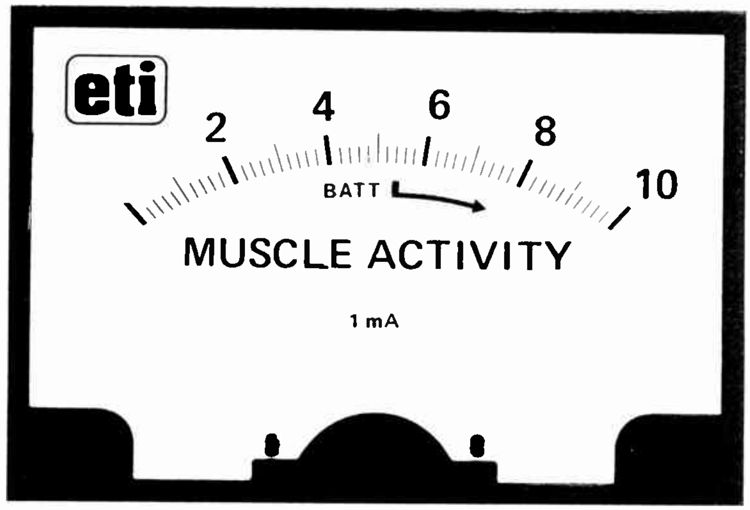
The electrodes can now be connected to the body and plugged in. The ideal way to secure the electrodes to your skin is to use a band of Velcro (Tm) tape, although we found Bandaids okay. If all three electrodes are placed reasonably close to each other along the inside of the arm (earth between the others) they can be secured in place all



Thermal stabilisation is achieved by mounting the input transistors together as shown and described in the text. Note the insulating piece between the BD140s.



The three electrodes.



Full size reproduction of the meter scale. The printed circuit board pattern is on page 157.

at once with a single wide band of Velcro wrapped right around the arm. Some electrode paste may be used between the electrodes and the skin to improve the contact. This is available from some distributing chemists and medical suppliers, although it is relatively expensive. We found moistening the electrode to be a good alternative.

Once the electrodes are attached to the arm and plugged into the EMG monitor a reading should be easily obtained. Start with the gain and threshold controls set fully anti-clockwise, the gain switch in the X1 position and the integrate switch off.

If the arm is tensed the meter should indicate muscle activity readily. With these settings the EMG is really acting as a strength meter. Relaxing the arm, the gain switch can be switched to the x10 position and the gain control slowly increased. With each gain increase, the threshold can be increased slightly to cancel any increase in noise that may have occured, although don't overdo the use of the threshold control until you are familiar with the unit as it is easy to cover up muscle activity as well as noise.

Eventually you should reach a stage such that the gain control can be set at maximum but with muscle activity held so low that the meter reads about 2 to 3.

This isn't easy! In fact the only person who has been able to do this so far has been Tom Benjamin, the author of our article on biofeedback, and quite a few of us have tried!

Some experimentation with electrode placement will indicate how to get good results on particular muscles.

For some background reading on EMG instruments, an article in the March/April issue of "Physiotherapy Canada" (published by the Canadian Physiotherapy Association) on EMG biofeedback, pages 65 to 72, gives an overview and a very comprehensive list of references. ●

PARTS LIST - ETI 576

Resistors all ½ watt, 5%

R1, R2 . . . . . 220k
R3 . . . . 4k7
R4 . . . . 100R
R5, R6 . . . . . 2M2
R7 . . . . 4k7
R8 . . . . 1M
R9 . . . . 4k7
R10, R11 . . . 1M
R12. . . . . . . 1k
R13. . . . . . . 8k2
R14–R17 . . . 47k
R18. . . . . . . 220k
R19. . . . . . . 270k
R20. . . . . . . 10k
R21. . . . . . . 100k
R22, R23 . . . 1M
R24. . . . . . . 10k
R25, R26 . . . 100R
R27–R30 . . . 47k
R31. . . . . . . 220k
R32. . . . . . . 270k
R33. . . . . . . 10k
R34. . . . . . . 330k
R35. . . . . . . 560k
R36. . . . . . . 5M6
R37. . . . . . . 3M3
R38, R39 . . . 10k
R40, R41 . . . 1M
R42. . . . . . . 10k
R43. . . . . . . 390k
R44. . . . . . . 470k
R45. . . . . . . 1k
R46. . . . . . . 680R
R47. . . . . . . 10k
R48. . . . . . . 2k7
R49. . . . . . . 18k
R50. . . . . . . 27R (mounted on volume pot)

Capacitors

C1–C6 . . . . . 1μ greencap
C7, C8 . . . . . 1n greencap
C9, C10 . . . . 33μ 16V tantalum
C11. . . . . . . 100μ 25V electro
C12. . . . . . . 33μ 16V tantalum
C13. . . . . . . 100n greencap
C14–C17 . . . 68n greencap
C18. . . . . . . 22n greencap
C19, C20. . . . 33μ 16V tantalum
C21. . . . . . . 100n greencap
C22. . . . . . . 1000μ 25V electro
C23. . . . . . . 33μ 16V tantalum
C24–C27 . . . 68n greencap
C28. . . . . . . 47n greencap
C29, C30. . . . 1n greencap
C31. . . . . . . 100n greencap
C32. . . . . . . 220n greencap
C33. . . . . . . 150n greencap
C34. . . . . . . 100n greencap
C35. . . . . . . 33μ 16V tantalum
C36. . . . . . . 100μ 25V electro
C37. . . . . . . 470μ 25V electro
C38. . . . . . . 47μ 25V electro
C39, C40. . . . 1000μ 25V electro
C41. . . . . . . 33μ 16V tantalum

Semiconductors

D1, D2 . . . . . IN914 or sim
D3, D4 . . . . EM401, IN4001 IN4004 or sim.
Q1, Q2 . . . . . BC559, BC179, DS559
Q3, Q4 . . . . . BD140
Q5–Q7. . . . . BC549, BC109, DS549
IC1 . . . . LM3900
IC2, IC3 741
IC4 555

Potentiometers

RV1 . . . . . . 1M linear
RV2 . . . . . . 5k linear
RV3 . . . . . . 1k linear
RV4 . . . . . . 1k vertical mounting trim pot

Switches

SW1, SW2 . . . SPST miniature toggle
SW3, SW4 . . . DPDT miniature toggle

Miscellaneous

M1 . . . . 1mA meter, 100 mm x 80 mm, square face MRA 65B or similar;
5-pin DIN socket; 8 ohm small speaker; panel mounting RCA socket; two 9V batteries type 276 or 2364; knobs, instrument case Horwood 203 x 102 x 254 mm or similar; power cord and plug.

THEATRICAL LIGHTING CONTROLLER

Introduction to Techniques

First part of a series describing a high quality dimming system suitable for schools or the theatre. Modules with ratings of 10 amps (2.5 kW) and 20 amps (5kW) will be available along with a comprehensive control desk.

SINCE THE EARLY DAYS of the theatre the need for lighting has been all-important. Just as important has been the need for control of that lighting. This ranges from very crude initially to very sophisticated today, often with a computer doing the controlling in the creation of special moods and effects.

The first types of dimmer used, of which there still some examples in older theatres, was a variable resistance type which used either a variable or switched power resistor in series with the load. With small loads a wire wound resistor or a carbon pile was used while larger loads used a tank of saline solution with a central electrode which was raised or lowered in the liquid, effectively changing the resistance. This type of dimming, while reasonably effective, dissipated a lot of power which made life uncomfortably hot for the operator, as to minimise mechanical linkages the dimmers themselves were often in the control room.

Electronics

With the advent of electronics, life was a little bit easier. The use of phase controlled dimming using thyratrons and later SCRs and Triacs reduced the heat dissipation dramatically (if you'll excuse the pun) and also allows the control to be physically separate from the dimmer. Besides being easier for the operator performances were greatly enhanced by the much better control available.

Today the use of phase control is almost universal as it is simple, reliable and cheap. Another method in use today is by magnetics; this type has the advantage of generating no RFI but unfortunately is expensive.

The problem of RFI is common to all phase control circuits, but can usually be reduced to acceptable levels by the use of a choke and several capacitors. For RFI the choke need not be very large, but one other effect of phase control is the audible rattling of the lamp filament (especially with the larger globes) which is due to the sudden application of power, and the magnetic field so produced, each half cycle. This can be cured by reducing the rate of rise of current by using a larger choke.

Type casting

We have given some schematic diagrams of types of dimmers which have been used previously. Fig. 1 is the oldest type comprising simply a variable resistor in series with the load. The second (Fig. 2), probably the most common type in use today (mainly in homes) is very simple but lacks the versatility needed for theatrical work.

The third type (Fig. 3) is in common use and while still very simple does have many good features. These include having the control potentiometer isolated from the mains voltage and also a modified control curve to give a better input-output voltage relationship. Synchronization is referred to the zero crossing of the mains voltage, making the unit more suitable for driving inductive (fluorescent) loads; this also eliminates hysteresis which occurs with the simple dimmers.

One problem which has arisen in recent years is caused by the control tones used by councils to turn on and off the hot water units in homes. These are usually around 1050 Hz (it varies from council to council) and 15 V or so in amplitude on top of the 240 V 50 Hz mains voltage. This causes synchronization problems when using a simple

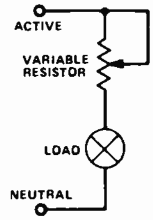


Fig. 1.

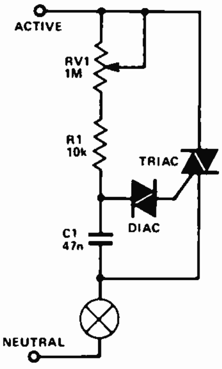
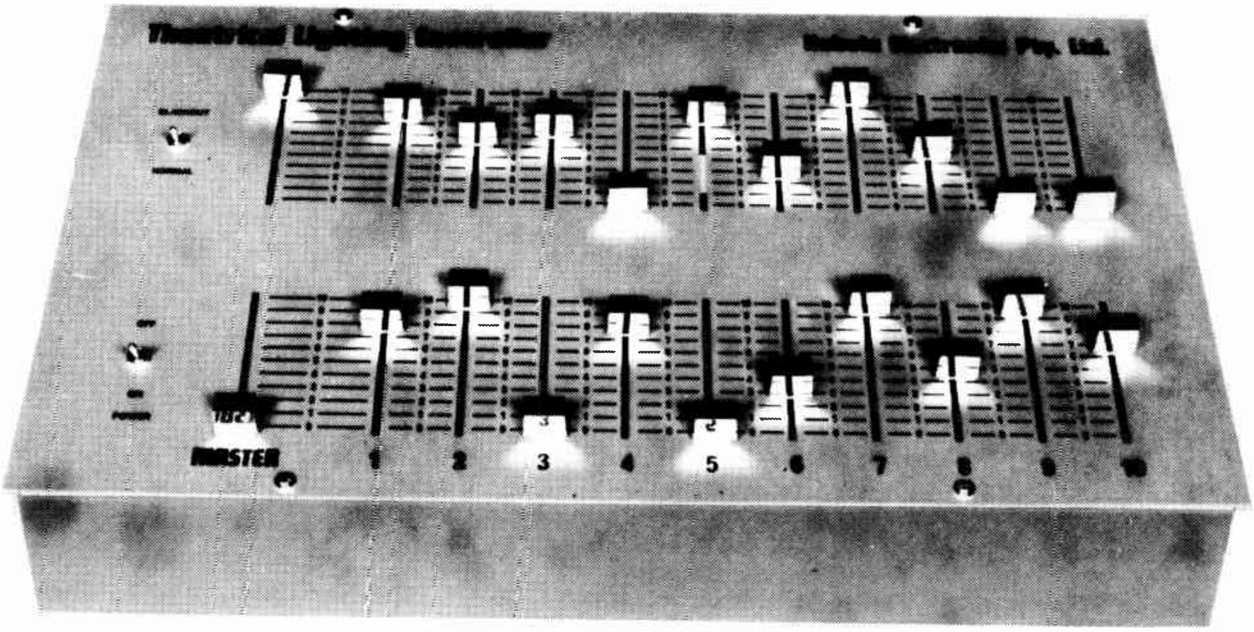


Fig. 2.



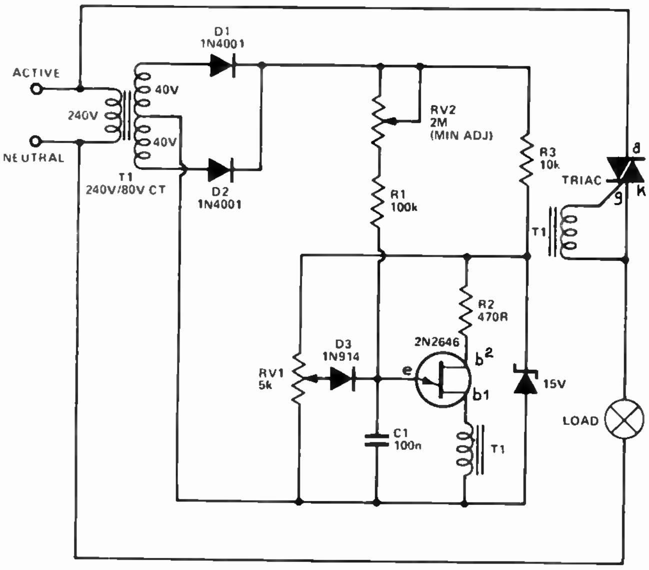


Fig. 3.

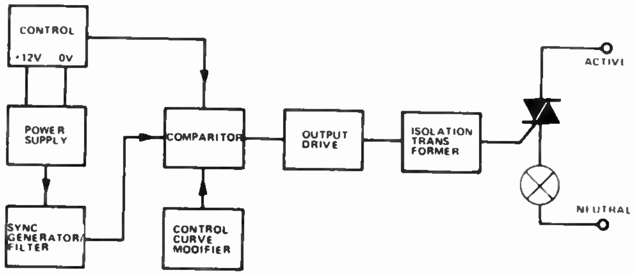


Fig. 4. Block diagram of the dimmer module.

zero crossing technique especially as the tone is not phase-locked to the mains. The effect of this tone is a slight rise and fall in light level as the tone beats with the 50 Hz mains. This is especially noticeable on fluorescent loads at low levels.

The dimmer to be described here is more complex than most previously described but a great deal of effort has been taken to ensure that all these problems have been solved. A low pass filter, with phase correction, is used to remove the control tones and ensure accurate synchronization. The control curve is also modified to give a subjectively more linear response and it has the ability to drive a fluorescent load without requiring a ballast resistor. Both the maximum and minimum light levels are adjustable without interaction giving reliable and predictable output. This is especially necessary if a dimmer fails for some reason and is replaced by a spare unit.

The dimmer as described is a modular system with units plugged into a standard 19" rack. This unfortunately pushes up the price, however the increased convenience makes it worthwhile especially in situations where a fairly large number of units is used. What we will be describing is a high quality professional dimming system at a lower cost than currently available units.

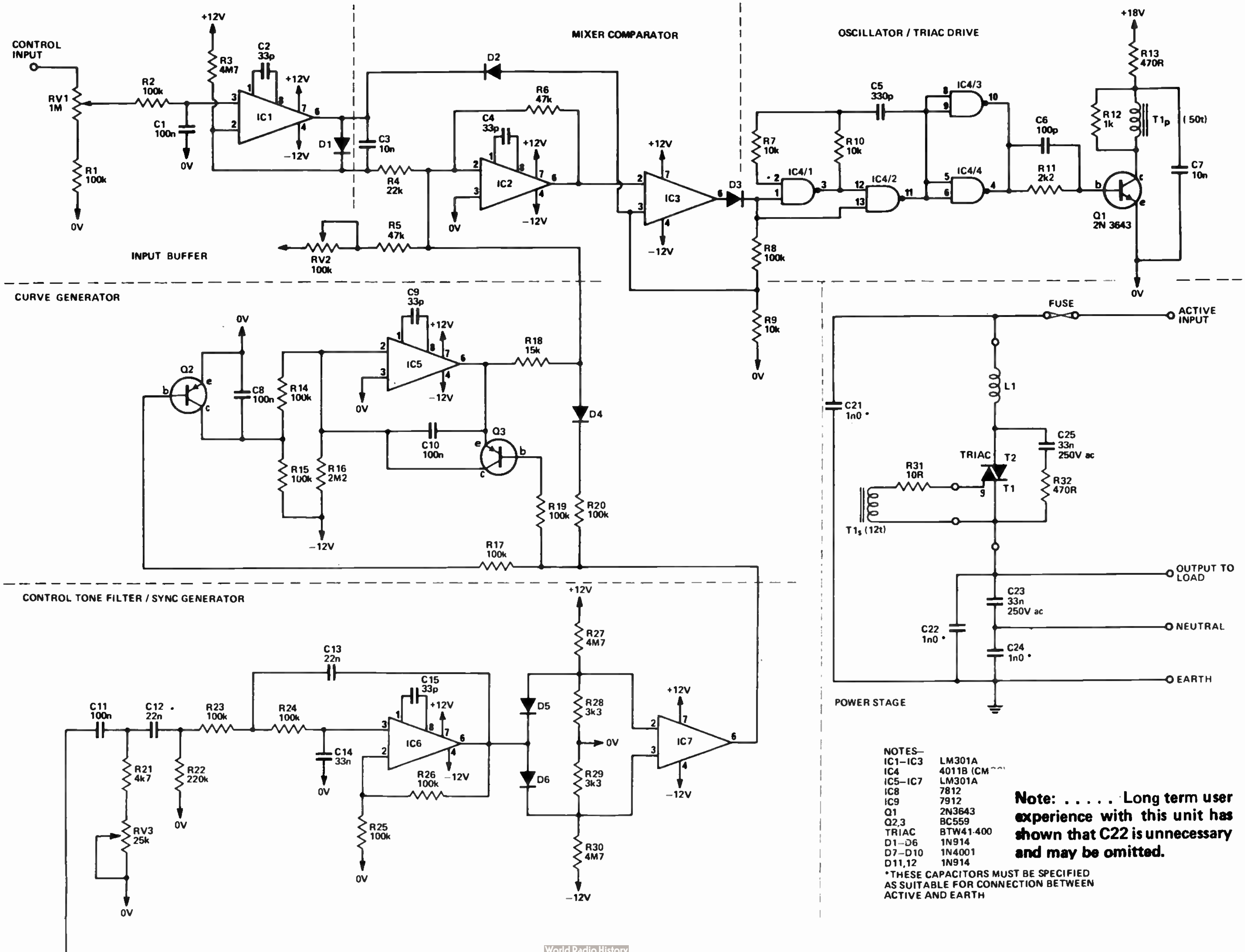
The Protection Racket

The protection of SCRs and Triacs, especially Triacs, is usually difficult as they tend to fuse faster than the fuse purportedly protecting them. The use of a cheap Triac which requires an expensive fuse to protect it is false economy. We have used a large rugged Triac (40 A device for the 20 A dimmer) which allows economical fuses to be used, especially for the 10 A version.

On the control side we will be describing a panel with two sets of long sliders per dimmer with two master controls which allow the next scene to be set up then faded in when required. A digital memory which can 'prerecord' scenes and recall them on demand may be published later.

Next we will give the constructional details of the dimmers and control desk.

THEATRICAL LIGHTING CONTROLLER



NOTES—

IC1–IC3	LM301A
IC4	4011B (CM
IC5–IC7	LM301A
IC8	7812
IC9	7912
Q1	2N3643
Q2,3	BC559
TRIAC	BTW41-400
D1–D6	1N914
D7–D10	1N4001
D11,12	1N914

*THESE CAPACITORS MUST BE SPECIFIED AS SUITABLE FOR CONNECTION BETWEEN ACTIVE AND EARTH

Note: . . . . . Long term user experience with this unit has shown that C22 is unnecessary and may be omitted.

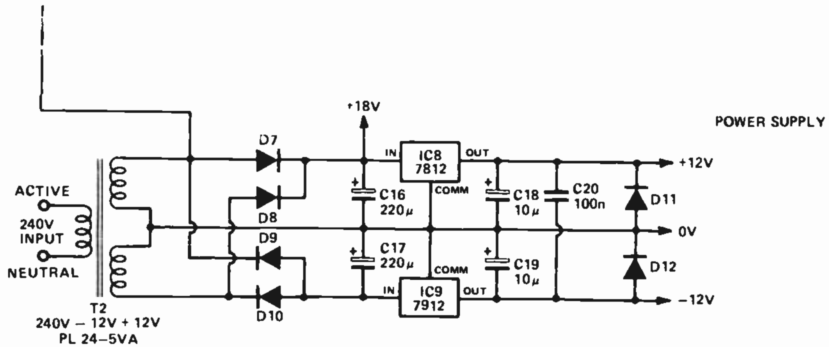


Fig. 1. The circuit diagram of the complete dimmer module.

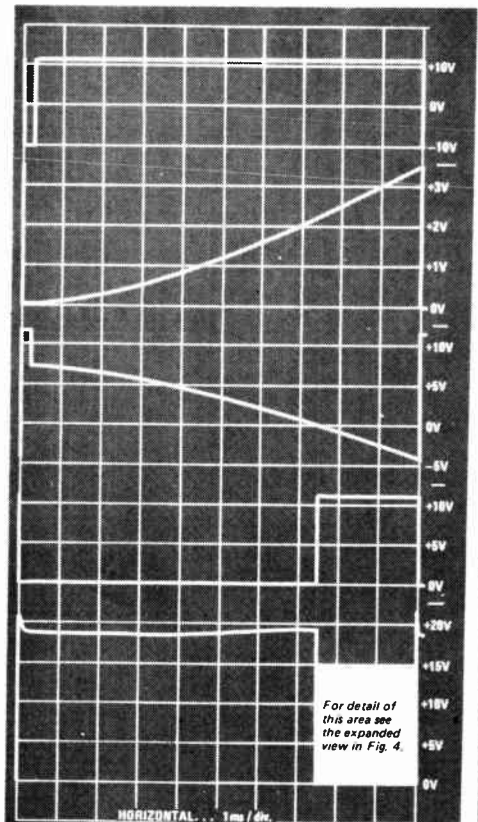


Fig. 2. Waveform taken on our 5 beam oscilloscope? No we cheated to show the phase relationships between various waveforms. Waveforms from the top are:
sync pulse (output of IC7)
curve generator (output of IC5)
mixer output (output of IC2)
oscillator control (pin 1, 13 of IC4)
transformer drive (collector of Q1)

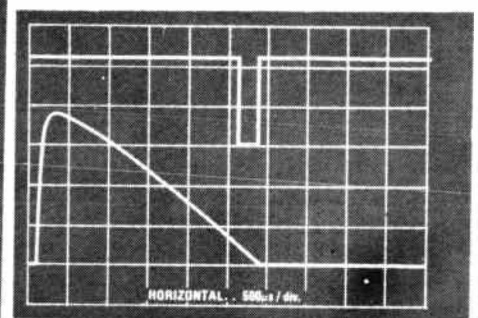


Fig. 3. Waveform showing relationship between the end of the half cycle and the sync pulse.

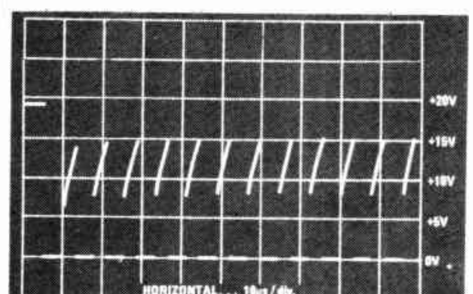


Fig. 4. An expanded view of the transformer drive waveform showing the collector voltage of Q1.

HOW IT WORKS – ETI 588

To help explain the operation the circuit can be broken into seven sections.

1. Power supply

This is a simple full wave rectifier which gives about ± 18V after being filtered by C16 and C17. Using 3 terminal regulators this is reduced to ± 12 volts which is needed for the circuitry.

2. Control tone filter and sync generator

As the name implies this removes the control tones that the supply authority superimposeson the mains voltage. These are normally about 1050 Hz and can cause problems by upsetting synchronization of dimmers. The filter is a low pass type comprising IC6 and associated components. As filters always alter the phase relationship this is corrected using phase shift networks. C11/R21 and C12/ R22. Potentiometer RV3 is used to ensure the phase shift is zero (at 50 Hz) with normal component variations. If the output of IC6 is between +0.6 volts and −0.6 volts, neither D5 nor D6 will be forward biased sufficiently to change the input voltages to IC7 so its output will be −10 volts. As the output voltage of IC6 is a 'clean' 50 Hz sine wave of about 6 volts amplitude this will only occur at a small region about the zero crossing point. At all other times the output of IC7 will be +10 volts. The result is a negative pulse, about 250μ s wide, at the zero crossing point of the 50Hz.

3. Curve generator

This produces the output shown in Fig. 6. When the sync pulse occurs, transistors Q2 and Q3 discharge capacitors C8 and C10. Immediately on release of the sync pulse the output of IC5 begins to ramp up slowly due to R16 charging C10. However, while initially the voltage across R14 is zero and therefore does not affect the charging of C10, as C8 begins to charge due to R15 its effect becomes more and more dramatic. A curve is necessary as it gives a better input/output voltage relationship but the curve must be reproduceable hence the circuit used.

4. Input buffer

This serves two purposes; firstly, it allows a megohm input impedance and secondly it detects when the input voltage falls below 0.1 volt and turns the dimmer output completely off. This allows the minimum light control to be turned up to give a better control range, ie with the filaments just glowing, yet have them off if the control voltage is reduced to zero.

If the voltage is above 0.1 volt the diode D1 will lift the voltage on pin 2 of IC1 to equal that of the input on pin 3. However if the voltage falls below this level, the voltage on pin 2 will remain at about 0.1 volt due to R3 and the output of IC1 will go to about −10 volts.

5. Mixer-comparator

IC2 mixes the input voltage, the output of the curve generator the sync pulse and the minimum adjustment potentiometers. This gives the waveform shown in Fig. 2 with the input voltage and the minimum adjustment only moving the curve up and down without altering the shape. When the output of IC2 falls below zero volts the output of IC3 goes from −10V to +10 volt with D3 and R8/9 providing about 1 volt of positive feedback. The voltage has to rise to above 1 V to force the output back to −10 volts. The diode is necessary to ensure that the voltage at the input of the oscillator IC4 remains within the supply voltage of the IC. (+12V, 0V)

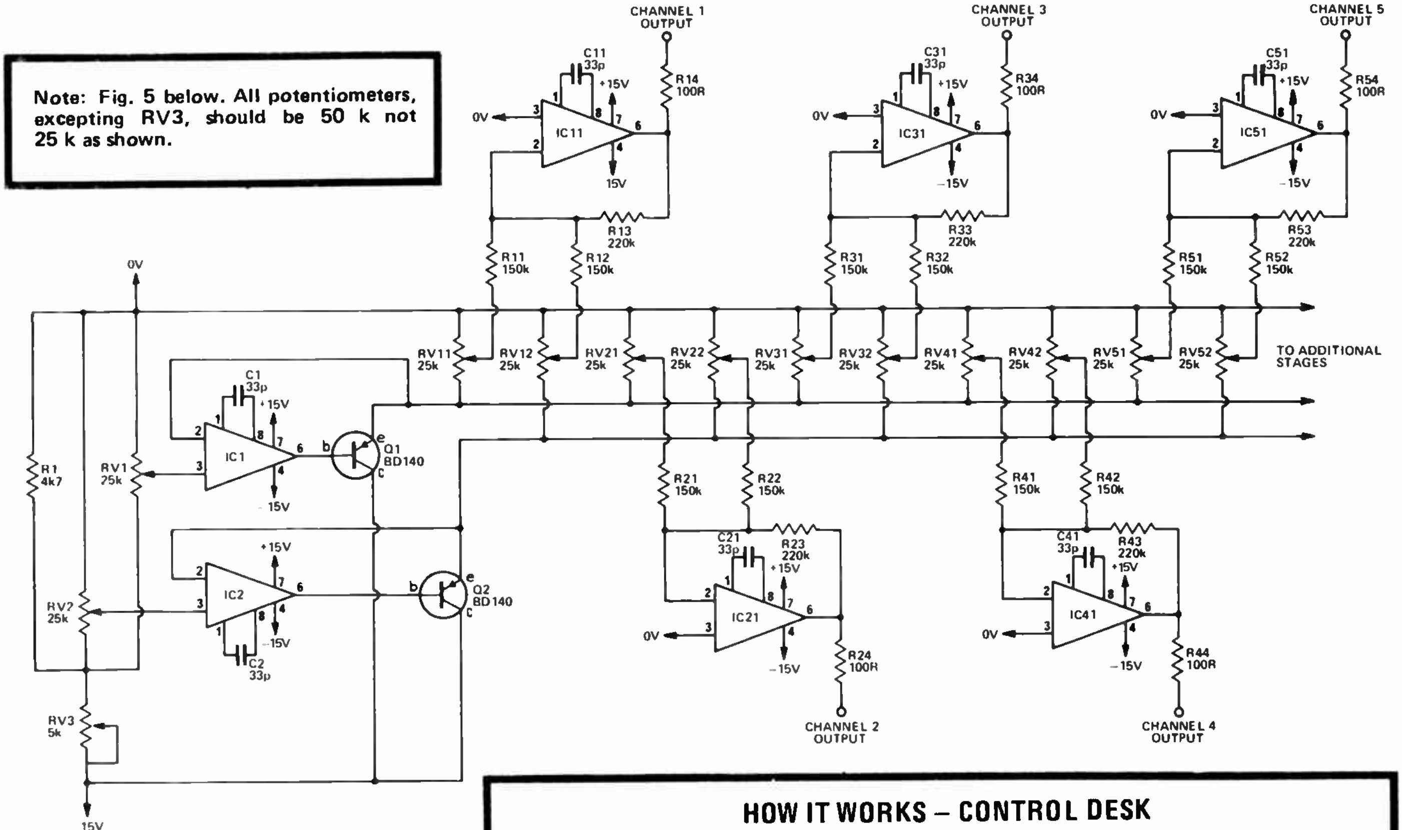
6. Oscillator/triac drive

A CMOS oscillator IC4 is used to drive Q1 which supplies the energy for the pulse transformer T1. The oscillator will only operate when the control inputs (pins 1 and 13) are at +10 V. The frequency is controlled by C5 and is set at about 150 kHz. Resistor R13 provides current limiting for the pulse transformer while R12 prevents the reverse voltage damaging Q1 if the load on the secondary load (the triac) becomes disconnected.

7. Power stage

This is simply a triac with a choke in series to prevent both RFI and 'filament rattle' and a fuse to protect against short circuits. Capacitors are also used as bypasses to help prevent RFI.

Note: Fig. 5 below. All potentiometers, excepting RV3, should be 50 k not 25 k as shown.



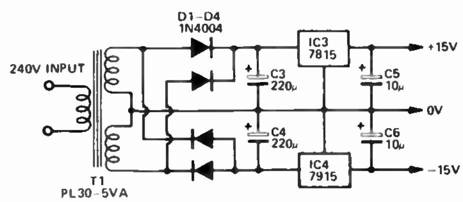


Fig. 5. The circuit diagram of the control desk.

HOW IT WORKS – CONTROL DESK

There are two controls for each dimmer along with two master controls. The master controls vary the voltage on the individual level control potentiometers from 0V (no light) to –8 volts (full light). Normally one master will be at maximum and the second at zero. The outputs of the two controls for each dimmer are added by an operational amplifier, referred to 0V. As one set of potentiometers has 0V on both of its ends it can be varied without changing the output allowing it to be set for the next scene. By varying the master controls together, but in opposite directions, the complete lighting set up can be smoothly varied from one scene to the next.

As we need +12V out to drive the dimmers the supply voltage of the control desk is ±15 volts.

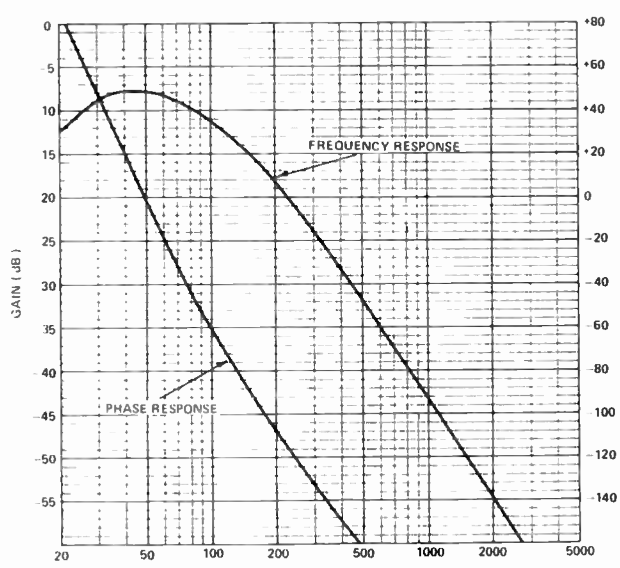


Fig. 6. The frequency and phase response of the control tone filter.

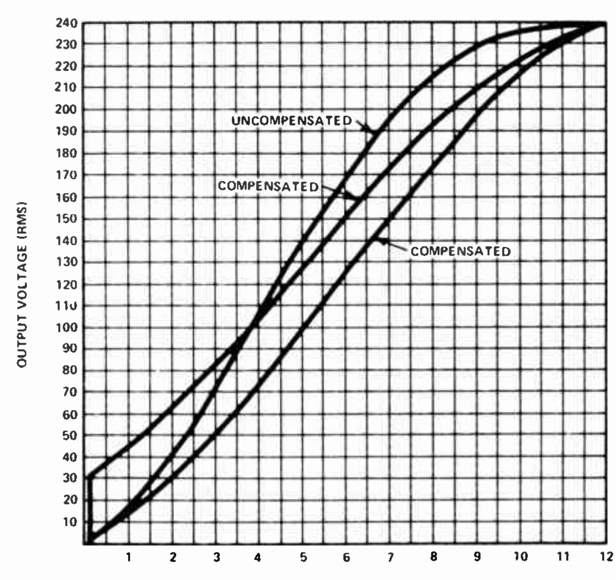
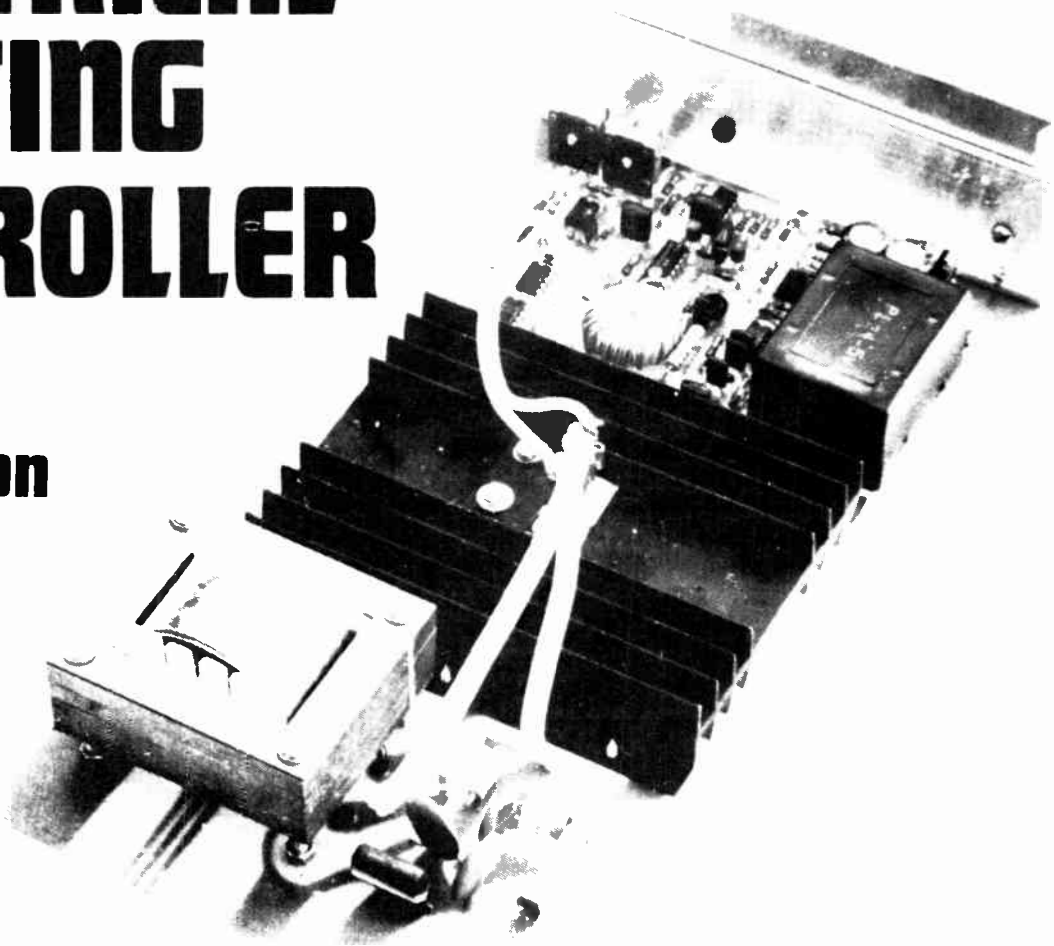


Fig. 7. The input-output relationship with the minimum adjustment at two different levels compared with a non compensated control curve (linear phase angle control).

THEATRICAL LIGHTING CONTROLLER

Construction



Mechanical construction of the dimmer module. Note that it is simply a large PC board (305 x 165 mm) with all components mounted on it. Large edge connectors specially designed for the purpose are used for high current terminals. For the 20 A unit a double sided board is used for twice the contact area and a different fuse is used.

Dimmer Module

ASSEMBLE THE PC board with the aid of the overlay (Fig. 1, page 122). The heatsink should be drilled and tapped for the triac to allow easy replacement if ever necessary. Note that the mounting of the fuse is different for the 10 and 20A dimmers.

The choke is bolted onto the PC board using the long clamping bolts, preferably using rubber grommets in the holes in the pc board (they may have to be drilled out to do this). The leads from the choke should be bent such that they go into the holes provided without going near the mounting bolts which are at earth potential. The leads can now be soldered (both sides on the 20A unit).

The pulse transformer can now be wound according to Table 1. Be careful when winding this transformer not to damage the insulation on the wire as there is 240V between windings. The transformer is mounted using a 19mm long 6BA bolt with a 12mm dia. piece of pc board material acting as a clamp.

After soldering the power transformer in, melt the plastic studs which protrude through the PC board to give mechanical support. We also recommend some epoxy between the transformer and the PC board.

The printed circuit boards for the two versions of the dimmer board (ETI 588/10 for the 10A version and ETI588/20 for the 20A board) are identical in layout and differ only in that the connector end of the 20A board is double sided to present a greater area of contact with the connectors.

The component numbering system used on the controller drawings is designed to indicate which channel a particular component is part of. The dimmer board pcb is too large to publish, however it can be obtained free (send large, stamped, addressed envelope) to ETI, 15 Boundary St, Rushcutters Bay, 2011 (quote project No 588).

THEATRICAL LIGHTING CONTROLLER

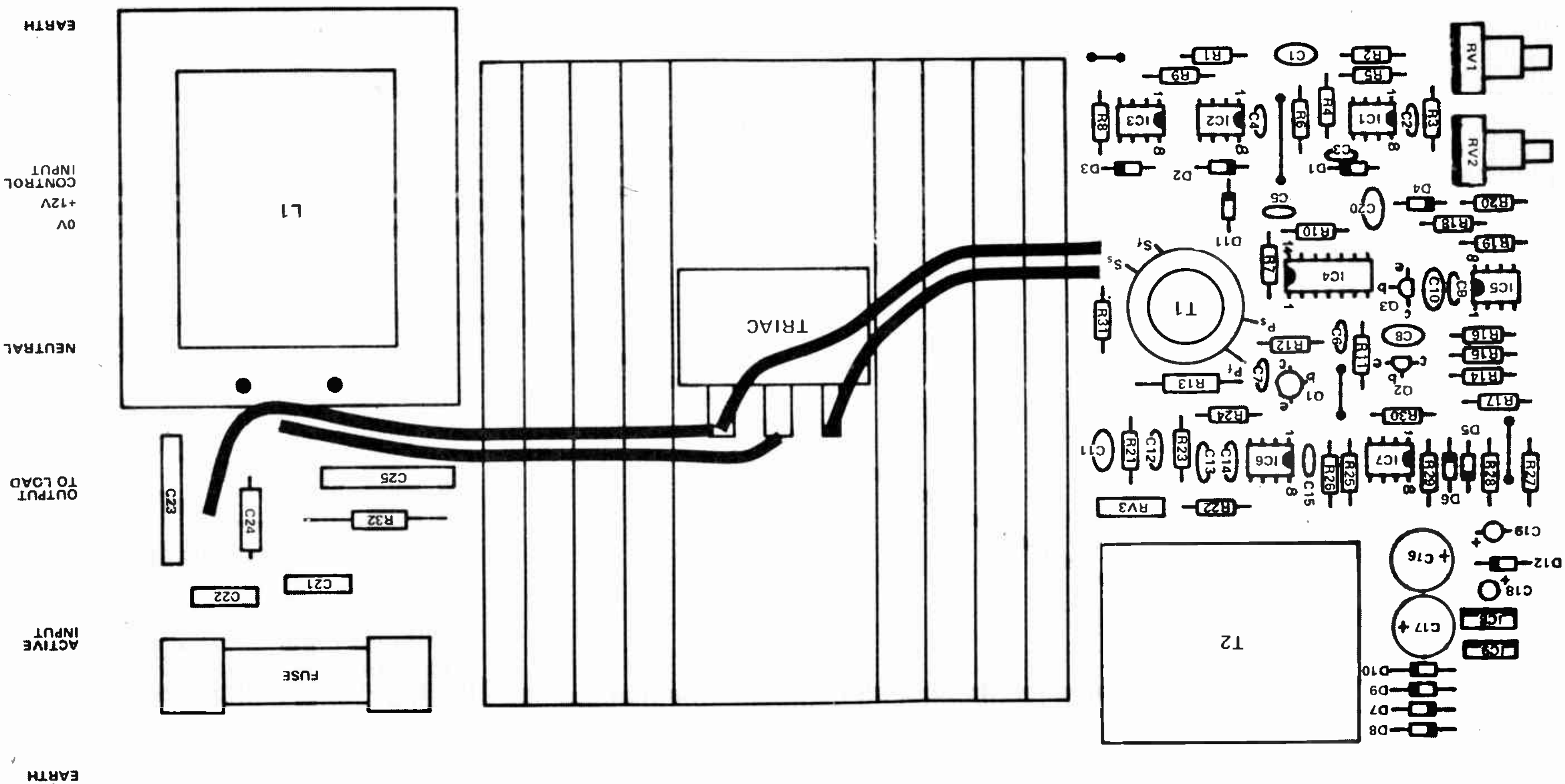


Fig. 1. Component overlay for the dimmer board, ETI588.

PARTS LIST – ETI 588

Resistors all ½W 5%
- R1,2 . . . . . 100k
- R3 . . . . . . 4M7
- R4 . . . . . . 22k
- R5,6 . . . . . 47k
- R7 . . . . . . 10k
- R8 . . . . . . 100k
- R9,10. . . . . 10k
- R11. . . . . . 2k2
- R12. . . . . . 1k
- R13. . . . . . 470R 1W
- R14,15. . . . 100k
- R16. . . . . . 2M2
- R17. . . . . . 100k
- R18. . . . . . 15k
- R19,20 . . . . 100k
- R21. . . . . . 4k7
- R22. . . . . . 220k
- R23–R26 . . 100k
- R27. . . . . . 4M7
- R28,29 . . . . 3k3
- R30. . . . . . 4M7
- R31. . . . . . 10R
- R32. . . . . . 47R 1W

Potentiometers
- RV1 . . . . . . 1M lin rotary
- RV2 . . . . . . 100k lin rotary
- RV3 . . . . . . 25k trim

Capacitors
- C1. . . . . . . 100n polyester
- C2. . . . . . . 33p ceramic
- C3. . . . . . . 10n polyester
- C4. . . . . . . 33p ceramic
- C5. . . . . . . 330p ceramic
- C6. . . . . . . 100p ceramic
- C7. . . . . . . 10n polyester
- C8. . . . . . . 100n polyester
- C9. . . . . . . 33p ceramic
- C10,11 . . . . 100n polyester
- C12,13 . . . . 22n polyester
- C14 . . . . . . 33n polyester
- C15 . . . . . . 33p ceramic
- C16,17 . . . . 220μ 25V electro
- C18,19 . . . . 10μ 25V electro
- C20 . . . . . . 100n polyester
- *C21,22 . . . . 1n0 polyester
- C23 . . . . . . 33n 250V ac
- *C24 . . . . . . 1n0 polyester
- C25 . . . . . . 33n 25V ac

* These capacitors must be specified as suitable for connection between active and earth.

Semiconductors
- IC1–IC3 . . . LM301A
- IC4 . . . . . . 4011B (CMOS)
- IC5–IC7 . . . LM301A
- IC8 7812
- IC9 7912
- Q1 . . . . . . 2N3643
- Q2,3 . . . . . BC559
- TRIAC BTW41–400
- D1–D6. . . . 1N914
- D7–D10 . . . 1N4001
- D11,12. . . . 1N914

Note: BTW 41-400 is superceded by Philips OT 156 or 157. These have TO3 style package but leads are at top and mounting surface is isolated.

Miscellaneous
- Transformer (T1) see text
- Transformer (T2) PL24/5VA
- Metal bracket
- Front panel

Additional components for 10A module
- PC board ETI 588/10
- 100mm 35D heatsink
- 10 Amp choke
- 10 Amp fuse (ceramic body '0' size)
- Fuse holders

Additional components for 20A module
- PC board ETI 588/20
- 100mm 40D heatsink
- Three 30mm long spacers
- 20 Amp choke
- 20 Amp fuse Philips A25X 20 Amp-trap
- 2 fuse holders Philips F30–2

PARTS LIST – ETI 588C

For 10 way 2 preset console

Resistors	all ½ W, 5%
R1	4k7
R11,12	150k
R13	220k
R14	100R
R21,22	150k
R23	220k
R24	100R
R31,32	150k
R33	220k
R34	100R
R41,42	150k
R43	220k
R44	100R
R51,52	150k
R53	220k
R54	100R
R61,62	150k
R63	220k
R64	100R
R71,72	150k
R73	220k
R74	100R
R81,82	150k
R83	220k
R84	100R
R91,92	150k
R93	220k
R94	100R
R101,102	150k
R103	220k
R104	100R
Potentiometers	
22 off.	50k lin. 60mm slide
RV3	5k trim
Capacitors	
C1,2	33p ceramic
C3,4	220μ 50 V electro
C5,6	10μ 25 V electro
C11,21,31,41	33p ceramic
C51,61,71,81	33p ceramic
C91,101	33p ceramic
Semiconductors	
IC1,2	301A
IC3	7815
IC4	7915
IC11,21,31,41	301A
IC51,61,71,81	301A
IC91,101	301A
Q1,2	BD140
D1–D4	1N4001
Miscellaneous	
PC board	ETI 588C
Transformer	PL30/5VA
Box and front panel	
Knobs to suit	

TABLE 1

WINDING DETAILS OF PULSE TRANSFORMER T1

CORE	PHILIPS 4322-020-36630 97150
PRIMARY	50 TURNS PLASTIC COVERED HOOK-UP WIRE
SECONDARY	12 TURNS PLASTIC COVERED HOOK-UP WIRE

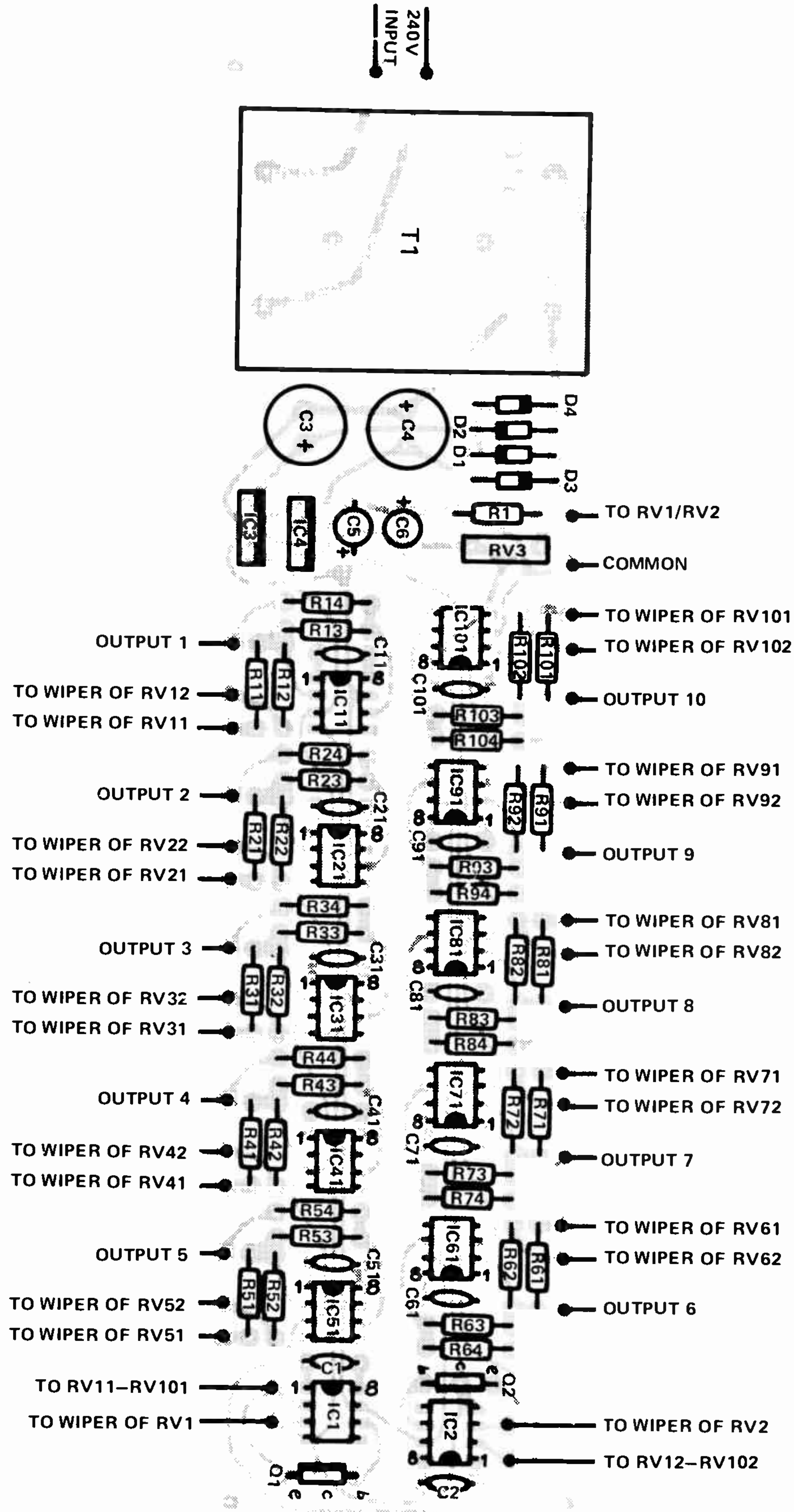
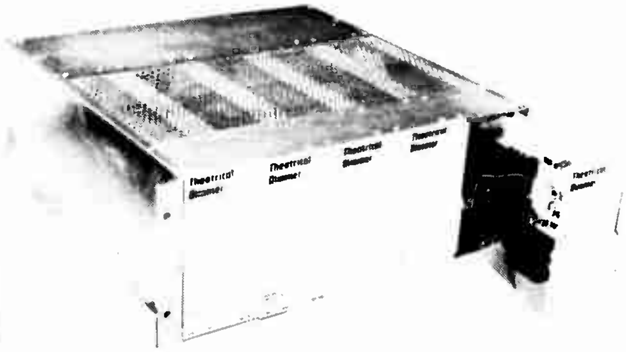
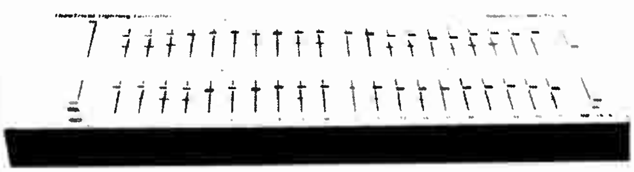


Fig. 2. Component overlay for the controller board, ETI588C.
Printed circuit board pattern is on page 159.

LIGHT DIMMING BY NEBULA





	KIT tax free	KIT tax paid	BUILT tax free	BUILT tax paid
10Amp module	65.00	74.75	95.00	109.25
20Amp module	74.00	85.10	104.00	119.60
5 way housing	145.00	166.75	P.O.A.	P.O.A.
10 way control desk	125.00	143.75	185.00	212.75
20 way control desk	195.00	224.25	275.00	316.25
10 way 10Amp with 10 way desk	1020.00	1173.00	1390.00	1598.50
10 way 10Amp with 20 way desk	1090.00	1253.50	1460.00	1679.00
20 way 10Amp with 20 way desk	1980.00	2277.00	2680.00	3082.00

For 20A modules add $9.00 each ($10.35 tax paid)
10 and 20A modules may be mixed in the same housing.

COMING SOON
New 12 way dimmer set suitable for "on the road" work as well as theatres utilizes all the proven features of the 588 system such as control tone suppression and curve modifier

NEBULA ELECTRONICS PTY. LTD.
15 BOUNDARY STREET,
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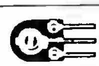
POTS 40c
(LINEAR ¼" ALUM. SHAFT

Linear potentiometers rotary carbon
500 Ohm, 1K, 5K, 10K, 25K, 50K, 100K, 250K, 500K, 1M, 2M.

Quality Large red LEDS well difused wide viewing angle.
15c each, $1.40 per 10, $110/K
Quality MOUNTING CLIPS 3c ea. ea. $2.70/100

LEDS
$12 a 100
15c each

Best value
No brag
Just fact



TRIMPOTS 14c
$12 a 100 (10mm)
Values: 100, 500 Ohm, 1K, 2K, 5K, 10K, 50K, 100K, 250K, 500K, 1M, 2M

Trade/govt./S.T. exempt. welcome.
Send for special lists (e.g. $30 a 100 pots and $99 a 1000 LEDs plus tax if applicable. Small quantities also.

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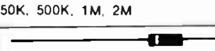
13c

METAL CAN TRANSISTOR
BC 107 BC 108 BC 109
13c
10 for $1.20 100 for $11



1 Amp. DIODES
50V 1N4001 - 6c
100V 1N4002 - 7c
400V 1N4004 - 8c
1000V 1N4007 - 11c
10% off 100 SAME

$3½ a 100 SIGNAL DIODE **IN4148**

$29 a 1000 **4c each**

(per 100 prices in brackets)

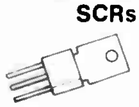
Cap.	16V	25V	50V
0.47uF	4c($3½)	5c($3¾)	6c($4)
1, 2.2, 3.3, 4.7, 10uF	5c($3½)	6c($3¾)	7c($4)
22uF	6c($3¾)	7c($4)	8c($5)
33uF	8c($4)	9c($5)	10c($6)
47uF	9c($5)	10c($6)	11c($7)
100uF	10c($6)	12c($7)	14c($11)
220uF	12c($8)	16c($10)	35c($17)
470uF	16c($12)	22c($16)	45c($30)
1000uF	22c($18)	30c($25)	75c($50)

4c ELECTROS
(UPRIGHT)

4c POLYESTER
FILM CAPS
E12 10% 100V

.001 - 4c	.01 — 5c	.1 — 10c
.0012 - 5c	.012 — 6c	.12 — 11c
.0015 - 5c	.015 — 6c	.15 — 12c
.0018 - 5c	.018 — 6c	.18 — 14c
.0022 - 5c	.022 — 6c	.22 — 15c
.0027 - 5c	.027 — 6c	.27 — 16c
.0033 - 5c	.033 — 7c	.33 — 18c
.0039 - 5c	.039 — 7c	.39 — 19c
.0047 - 5c	.047 — 7c	.47 — 20c
.0056 - 5c	.056 — 8c	
.0068 - 5c	.068 — 8c	All values
.0082 - 5c	.082 — 9c	in uF
	10% off 100 same uF	

SCRs



C106Y1
40c
C122E
$1.20

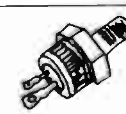
SCRs:

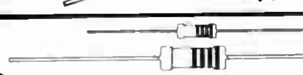
0.8A	30V	C103Y	— 35
0.8A	200V	C103B	— 60
4A	30V	C106Y1	— 40
4A	400V	C106D1	— 75
8A	400V	C122D	— $1.05
8A	500V	C122E	— $1.20

TRIACS:

6A 400V SC141D	— $1.30
10A 400V SC146D	— $1.50
DIAC ST2	— 35
Chart to identify leads	
Plus trigger info.	— 10c

25 A 400V
SC260D TRIAC
C37D SCR
EA. **$2.50**





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5% E12.2.2 Ohm to 4M7
1½ c each ¼w or
90c a 100 same Ohms
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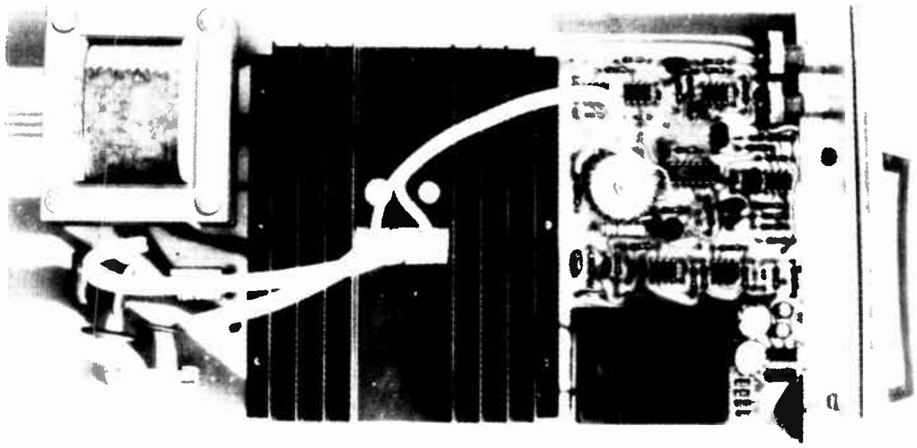
THEATRICAL LIGHTING CONTROLLER



WE FINALISE the series on dimmers with the mechanical description of the control desk. Unfortunately the mechanical drawings of the rack are too complicated to reproduce here and some parts, like the 20 A edge connector, are only available through Nebula Electronics Pty. Ltd. If the dimmer modules are not required to be plugged in the total cost can be reduced by connecting directly to the modules and mounting them in a box. In the 20 A unit the heavy wires should be bolted on to the appropriate pads to ensure contact to both sides of the board.

One modification we have made to the control desk is the addition of a black-out switch which allows all lights to be blacked out without moving the master control. This is simply done by switching the supply voltage on the master potentiometers from the -8V supply as set by RV3 to 0V. RV3 should be adjusted such that with one master at maximum, the second at minimum and one individual control at maximum that its output voltage should be + 10 volts.

With the dimmer module the trim potentiometer has to be adjusted so that the output pulse from IC7 occurs at the very end of each half cycle as shown in Fig. 3 (page 119). This is easiest set using an oscilloscope although an approximate setting can be made without one.

If the dimmer is connected up to a reasonably heavy load and adjusted for about 1/3 level it will probably be found that with RV3 at one end the light level is not stable and tends to flash. This is caused by the sync pulse occuring after the end of the half cycle and the trigger pulses from the previous half cycle triggering the next. The trim potentiometer RV3 should be turned back about ¼ turn from the position at which this effect stops.

When adjusting the maximum and minimum levels the minimum should be adjusted first. Note that the control potentiometer must be slightly up off zero to get any light and minimum should be adjusted at this point. The maximum should be adjusted with both the master and individual control at maximum and set to the point where the light level is just starting to drop.

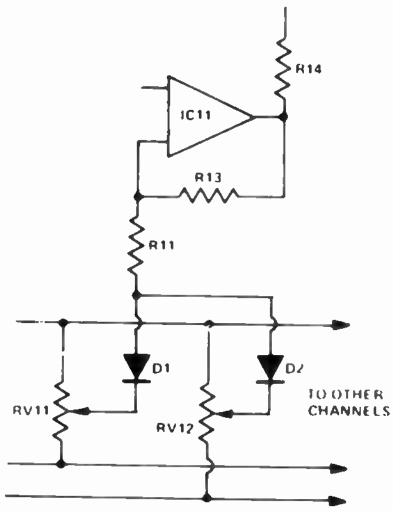
Dimmer modification

We are indebted to the reader who phoned this suggestion in to Nebula Electronics. Unfortunately, he didn't leave his name.

Resistors R12, R22, R32 . . . . . . et cetera are removed and the two diodes shown are added, one pair to each channel. This gives the dimmer the same operating format as commercial ones.

To explain: In most dimmers, the value of the master setting is multiplied by each individual fader and the *maximum* of the values from the two masters is used for the output. In the ETI 588, however, the *sum* is used instead of the maximum.

For example, if on Channel 1 both channel faders are at maximum, Master A is at half maximum and Master B is at zero, on the ETI dimmer *before* modification the output on Channel 1 will rise as Master B is moved from zero to half. After modification it will only start to rise after Master B passes the half-way mark.



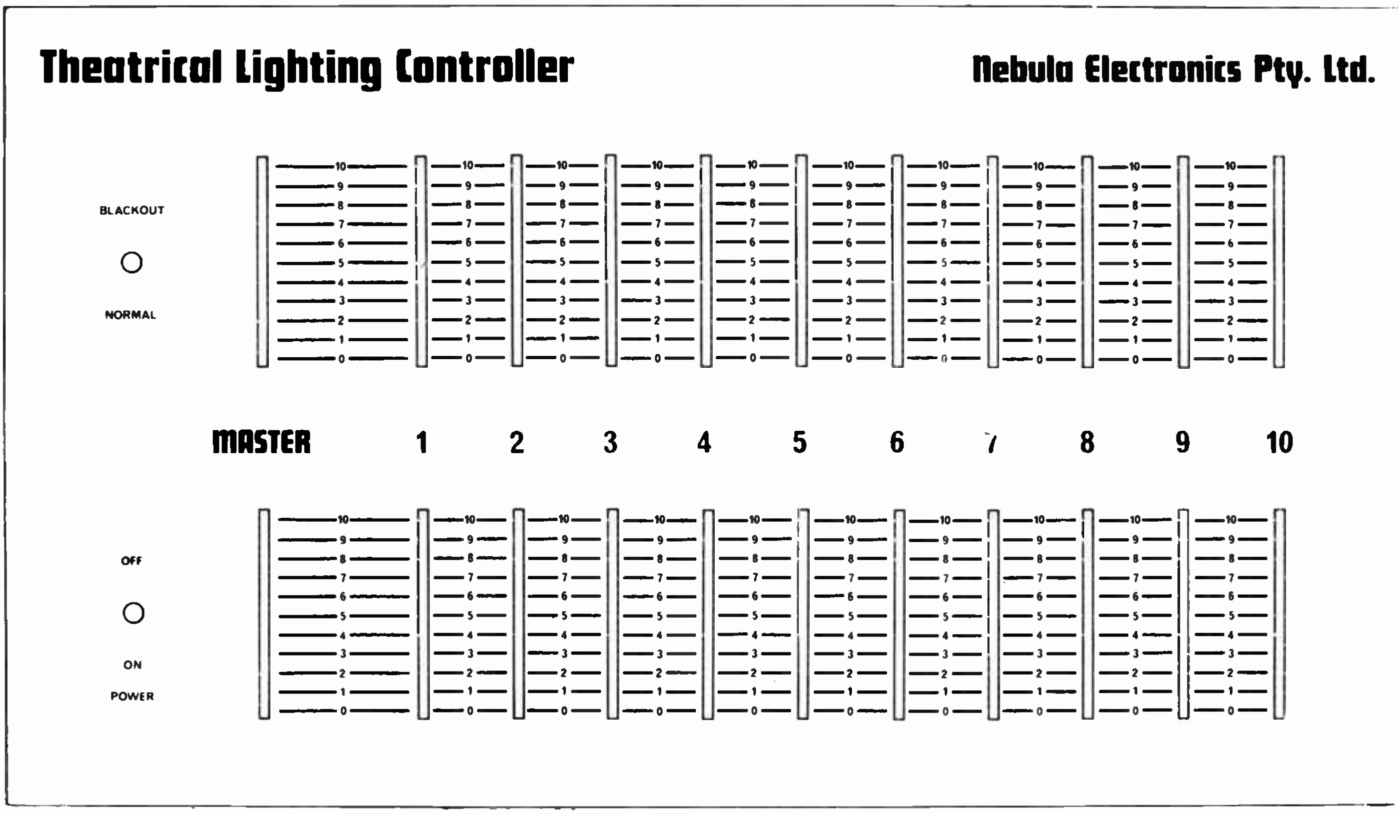


Fig. 1. The front panel artwork for the 10 way control desk. Full size is 440 mm x 250 mm.

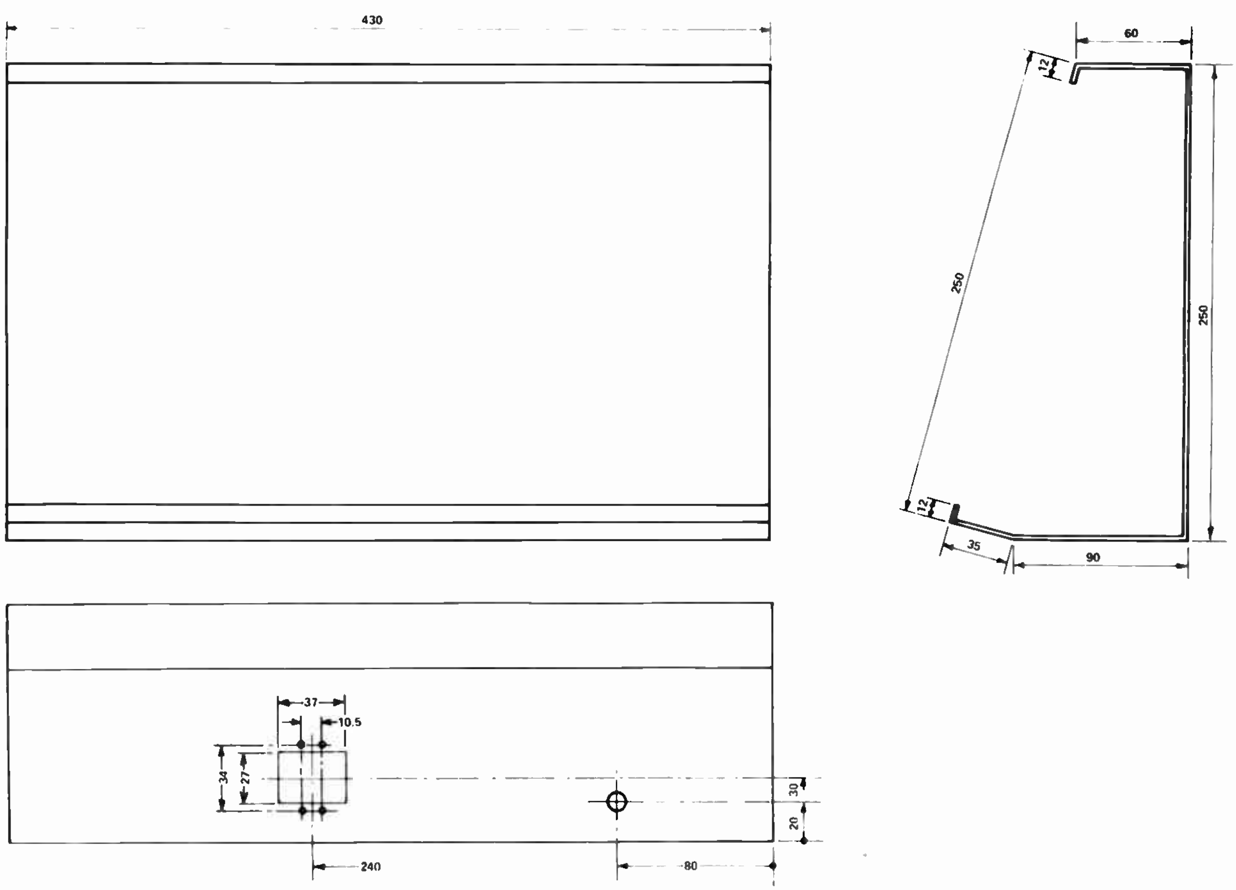


Fig. 3. The control desk box dimensions.

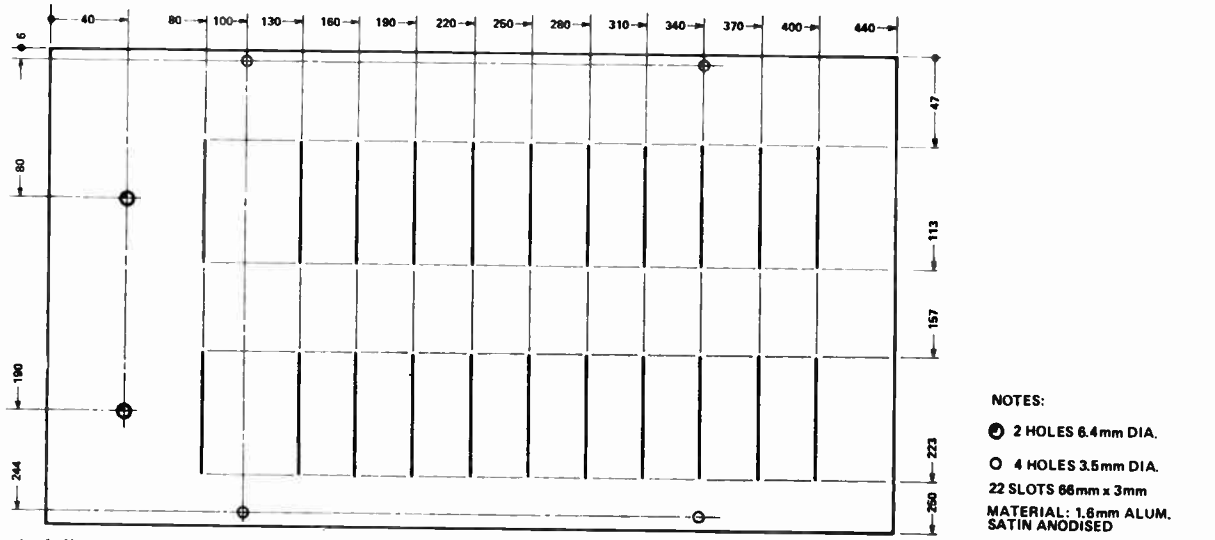


Fig. 2. The mechanical dimensions for the front panel.

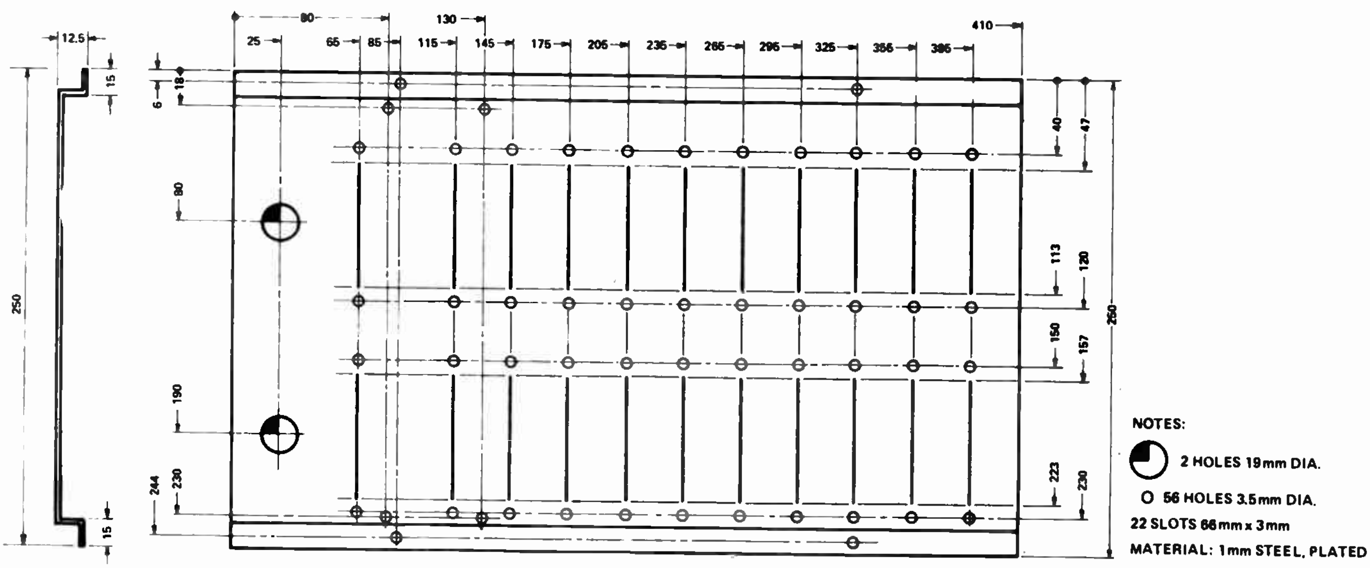


Fig. 5. The potentiometer support panel.

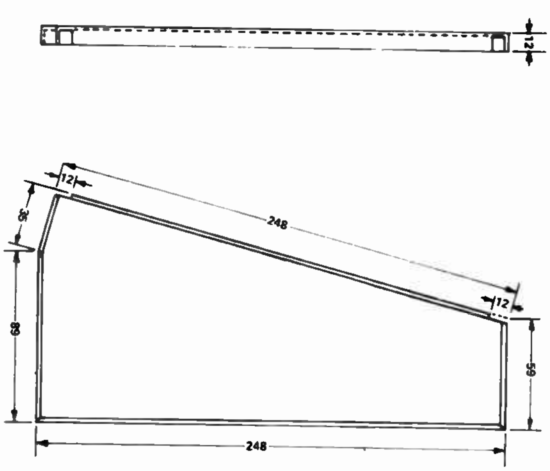
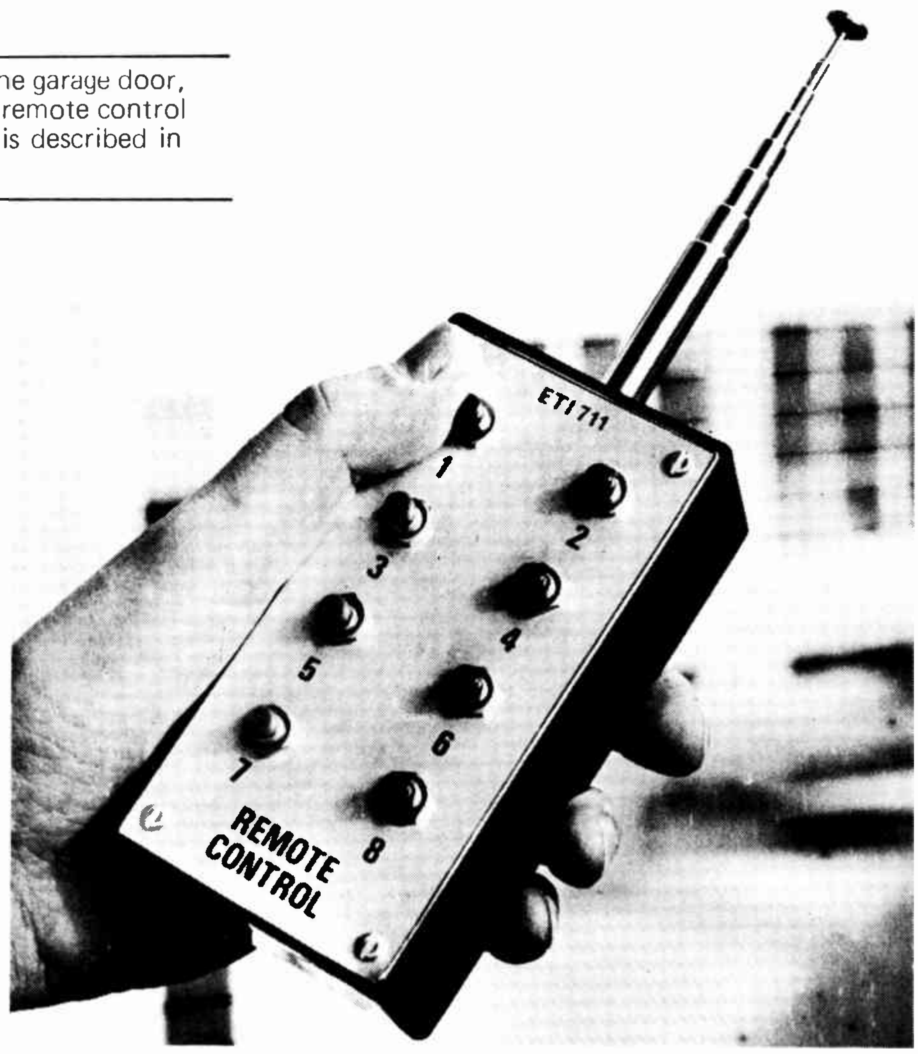


Fig. 4. The end pieces for the box. These should be fitted into the ends of the box as shown in Fig. 3. The two ends should be of opposite hands.

REMOTE CONTROL TRANSMITTER

Operate up to eight devices such as the garage door, curtains or outside lighting with this remote control system. The accompanying receiver is described in the next article.



THERE YOU ARE IN YOUR CAR nice and dry but now you have to get out and open the garage door — and this means getting soaked. How nice it would be if you only had to press a button in your car to open the garage door. Commercial garage door openers are one answer to the problem but they cost a bomb, so we wondered if we could help. Although we can't cover the mechanical aspects, due to the variations in types of doors etc, it is possible to design a suitable electronic control system. We will also leave the detailed mechanics of motors and driven mechanisms to the builder.

Actually the electronics for opening a door by means of a remote-control radio link are relatively inexpensive, and we soon realised that by spending only a couple of dollars more the transmitter can be extended to control up to eight different devices! This means that such a controller can be used to not only open garage doors, but to switch the television on and off, to open curtains or to control lighting or sound systems etc. Can you imagine the impression that such a device will make when entertaining your friends?

This article describes the transmitter part of the system and the next article covers the receiver/decoder.

The transmitter is designed to operate on any one of the fifteen odd channels allocated for this purpose in the 27 MHz band. The transmitter is capable of activating any of 8 different devices (or switching on and off four devices). Any combination of these two modes may be used, eg six devices activated and one device on and off. With a suitable antenna the device will operate over a range of up to five hundred metres (depending upon the terrain) with the half watt of input power provided. With a short piece of wire as an antenna reliable operation can be expected at ranges up to 30 or 40 metres.

Coding This is by means of a sixteen-bit word having bit allocations as follows: The first bit is a synchronization pulse, the next seven are part of the key code, the next three bits select the desired channel out of the 8 available and the last five bits are the remainder of the key code (12 key-code bits in all). The 12 bits allocated to the key code provide 2^{12} or 4096 possible codes and this, coupled with the choice of one of the 15 odd channels available, gives a total number of 61,440 combinations. Thus the chances of anyone cracking your code, or of a similar transmitter triggering your unit, are remote indeed. The 'security' of the unit is therefore far higher than most commercial units which typically offer only 72 key combinations. This is another pay-off of the extra cost of multi-channel control.

The key code used must be wired in by the constructor with appropriately positioned links on the printed-circuit board. Probably the best way to select a key code is to first pick any number between 1 and 4096 and then convert it to its binary equivalent (12 bits) and fit the links accordingly. When the receiver is also wired to the same key code only your transmitter will operate it.

As the transmitter operates by providing a burst of pulses for only about one quarter of a second the chances of anyone determining what frequency you are on, let alone what your key code is, are negligible.

Construction

Using a small amount of Araldite glue the coil formers to the printed-circuit board in the positions as indicated on the overlay. The coils are now wound with 24 B&S enamelled-copper wire in the following manner: Clean one end of the wire and solder it into one of the holes for the particular coil being wound. Now wind ten turns (close spaced) around the former as neatly as possible (to ensure uniformity of inductance) and then pass the end of the wire back through the second hole in the printed-circuit board, scrape the enamel off the wire and solder into position. Do this for each coil.

Next mount all components to the board commencing with resistors and capacitors and finishing with the transistors and integrated circuits. Take care to orientate any polarised components correctly and also to solder to the tracks on both sides of the board where necessary. Select your own key code as mentioned earlier and wire it in by linking the appropriate terminals to the line marked 'H' for a '1' or to the line marked 'L' for a '0'. Note that on the overlay the links are shown connected to both lines. This is done to prevent constructors from following the wiring pattern on our prototype. The terminals should be connected to one line or the other as required by your code — never to both lines. The bit positions of the code are indicated by the number next to each link on the overlay.

Coil L2 is the only one that is air-cored. All the other coils are fitted with slugs which should be prevented from moving after adjustment by locking them with a thin strip of rubber or Teflon.

When the board is completely assembled check both sides carefully to ensure that all joints have been soldered and that all components and links are in their correct positions. If an oscilloscope is available it is possible to check the operation of the board at this time by

SPECIFICATION ETI 711

FREQUENCY	26.957–27.282 MHz crystal controlled
INPUT POWER TO FINAL STAGE	500 mW
TRANSMISSION TIME	<250 mS
CHANNEL SEPARATION RECOMMENDED	⩾15 kHz
NUMBER OF DEVICES THAT CAN BE OPERATED	8
KEY CODE	4096 (12 bit binary)
TOTAL KEY COMBINATIONS	>100,000
RANGE (depends on terrain)	500 metres (aerial up) 50 metres (aerial down)
POWER SUPPLY	9 V battery
SUPPLY CURRENT	50 mA (transmitting) 60μA (stand by)

connecting a temporary link between pin 1 of IC4/1 and the +9 volt line (a larger battery should be used for continuous operation). Now observe the output at pin 11 of IC4/4 which should be a train of pulses which cycle repetitively. If the unit appears to be functioning correctly mount the board into the bottom of the box and then mount the antenna/battery bracket and the antenna as shown in the photographs. Mount the push buttons to the front panel and wire them as shown on the component overlay. The transmitter is now ready for alignment.

Alignment

Connect a temporary link between pin 1 of IC4/1 and the +9 volt line so that the code generator runs continously. Measure the current drawn by the transmitter by inserting an ammeter in series with one of the battery leads. With the antenna fully extended the current should be at least 20 mA if the RF oscillator is running. Using a non-inductive tuning tool adjust the slug in L6 so that it is about half way out of the former and then adjust L4's slug for maximum current. Readjust L4 and L6 slugs for maximum current. This gives maximum drive to transistor Q1. Now with the antenna still fully extended adjust the slug of L1 for minimum current. This corresponds to maximum power output.

Note that the small 9 volt battery specified will not last long under continuous running. Therefore a larger battery or a separate power supply should be used when doing this initial alignment.

That completes the alignment at this stage. Further alignment may be necessary when the receiver has been constructed.

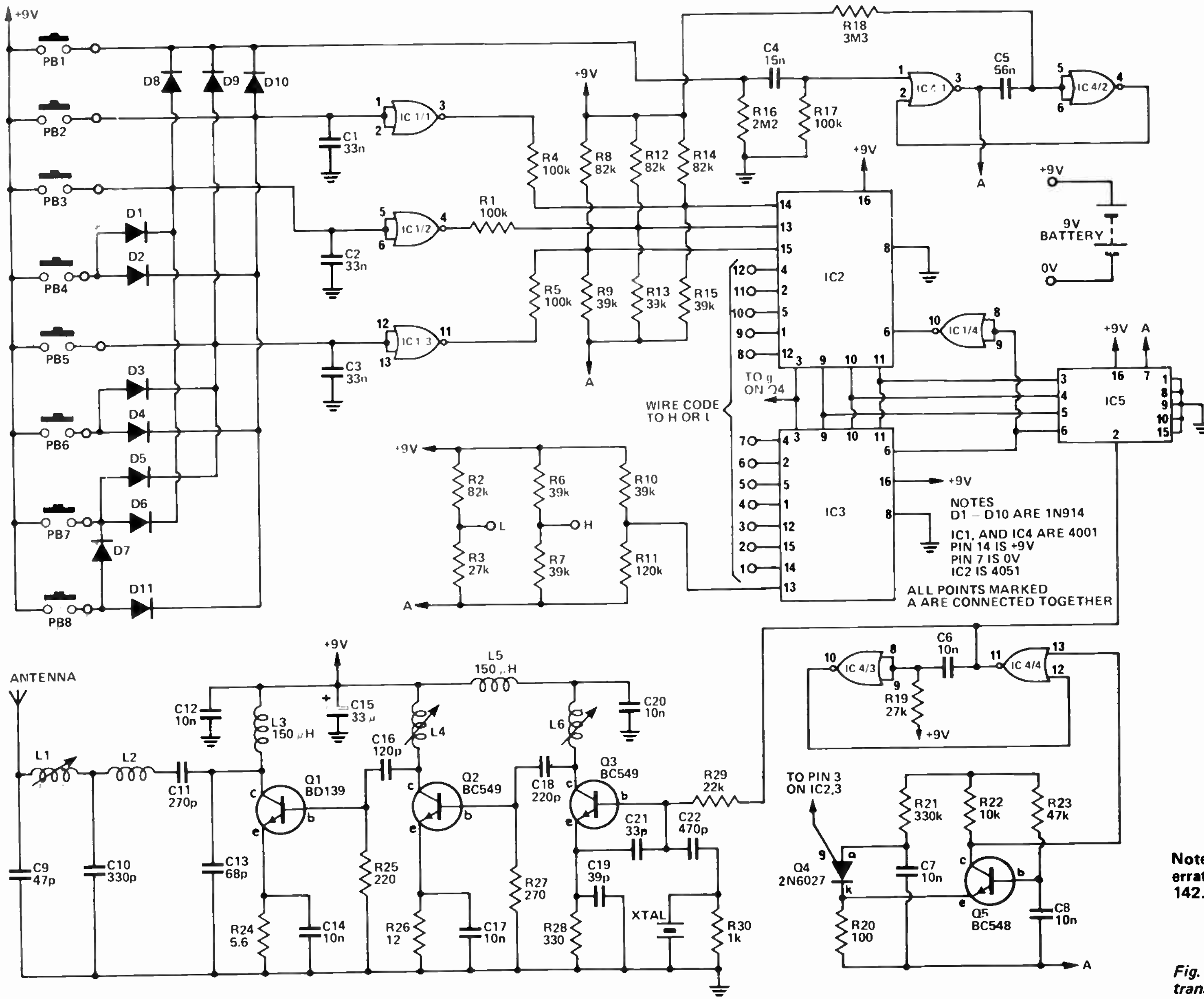
Operation

As said before the 16 bit word of the transmitter consists of a sync pulse, a 12-bit key code and a three-bit channel-select code. The sync pulse is 5 milliseconds long and the other pulses are pulse-width coded at 2 milliseconds duration for a '1' or 0.8 milliseconds duration for a '0'. A fixed off time of 0.24 milliseconds is employed.The first complete word allows the receiver time to settle down,the second word is used to enable the receiver by means of the key code,and the third word initiates operation of the device.Further words, if any,are ignored

The mode of operation of the transmitter is best understood by reference to the block diagram. A 27 MHz oscillator is keyed on and off by two monostables, one which determines the total transmission time and one which determines the short off periods during the transmission.

When one of the push buttons is pressed a positive pulse is generated which triggers the on-time monostable which in turn switches power to all the current consuming sections of the circuitry for a period greater than three complete cycles of the 16 bit code. The

REMOTE CONTROL TRANSMITTER



Note: Before proceeding, check errata for this project, on page 142.

Fig. 1. Circuit diagram of the complete transmitter

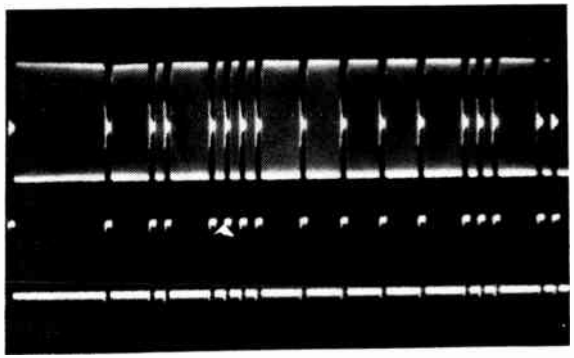


Fig. 2. One complete code word of 16 bits. At top is the gated CW as seen in the IF strip of the receiver whilst the bottom trace shows the output from the detector. The 4.8 millisecond sync pulse is at the left and is followed by the code word 1010001111110010. The beginning of the next sync pulse can be seen on the right.

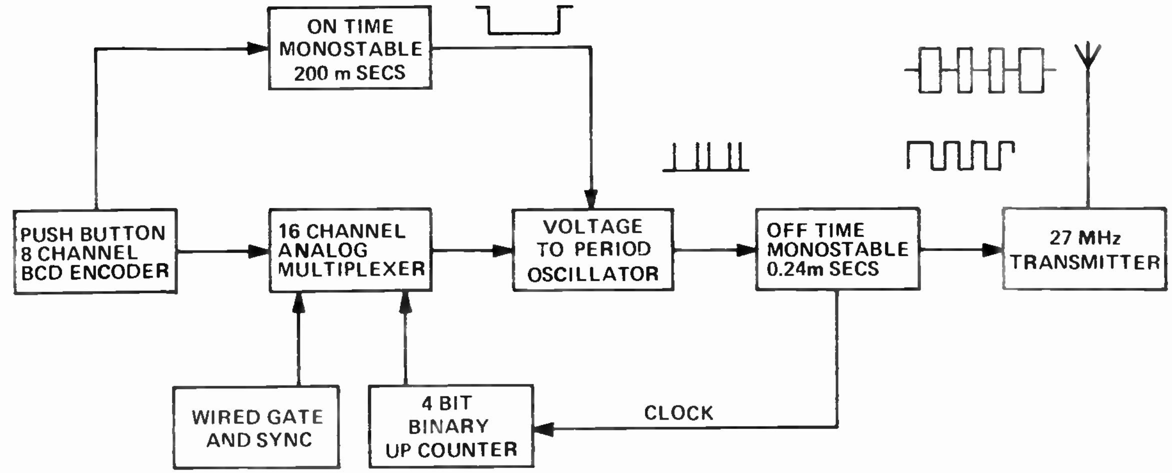


Fig. 3. Block diagram of the transmitter showing basic operation of unit.

How it works — ETI 711A.

When any one of the eight push buttons is pressed a positive voltage transistion is fed, via appropriate diodes in the diode matrix D1 to D10, to the differentiating network R16, C4 and R17. The positive going pulse produced by the network triggers the monostable formed by gates IC4/1 and IC4/2 and point 'A' which was at +9 volts is pulled down to zero volts. When point 'A' is pulled down to zero the following events occur: IC5, which was held reset by the +9 volts previously at point 'A', is released ready to commence counting; resistors R9, 13 and 15 are pulled down to zero volts allowing the binary code present at the outputs of IC1, 2&3 to be fed to IC2. R3, R7 and R11 are pulled down to zero volts thus producing 2.4 volts and 4.5 volts at points 'L' and 'H' respectively and 6.6 volts at the junction of R10 and R11 which is fed to pin 13 of IC3. Pin 3 of IC3 therefore drops to 6.6 volts (as set by R10, R11) and after C7 has charged via R21 (such that the anode voltage exceeds that on the gate) the PUT will fire.

The firing of the PUT produces a narrow pulse at its cathode which is amplified by the common-base amplifier Q5. Capacitor C7 again charges via R21 and the PUT fires every time the voltage at its anode exceeds the voltage its gate. The PUT therefore produces a train of narrow pulses; the period between the pulses is determined by the voltage at the gate of the PUT. Now as the multiplexer ICs, IC2 and IC3, scan through the input channels the output voltage at pin 3 will track whatever input voltage is selected. It will be 6.6 volts for the sync pulse, causing the PUT to provide a 4.8 millisecond period, it will be 4.5 volts for a '1', giving a 2 millisecond period; it will be 2.4 volts for a 'O' giving a 0.6 millisecond period.

The output from Q5 is thus a train of narrow pulses with a variable time interval between them, depending upon which multiplexer input is selected.

These pulses are used to trigger the 'off time' monostable IC4/3 and IC4/4. The output from the 'off time' monostable is normally high during the 'on time' period, when point 'A' is low. The oscillator is therefore normally on during this period. The 'off time' monostable, when triggered by the narrow pulses from Q5, produces lows. These each disable the oscillator Q3 for a period of 0.24 milliseconds, as set by the time constant of R19 and C6.

The 'off time' pulses are also fed to IC5 (a 4520 up-counter) which, when normally connected, increments on the positive edge of the input pulse. However, as it is required to trigger on the negative edge of the 0.24 millisecond pulse the enable input (pin 2) of the device is used for clocking instead. The outputs from IC5 are used to drive the multiplexer IC2 and IC3 so as to sequentially sample the inputs from the push-button matrix and from the wired key code.

In effect then the oscillator turns on when any push button is pressed and then turns off and on until at least three full code words have been transmitted and then switches off completely at the end of the period programmed by the 'on time' mono IC4/1 and IC4/2. As the other two stages of the transmitter operate in class C there is no power drawn by the transmitter except when a code bit is being transmitted.

The RF oscillator's collector is tuned by L6 to the crystal frequency and the output from Q5 is coupled to a class C driver stage Q2 which in turn feeds the power output stage Q1 via the tuned circuit L4 and C1. The RF output is taken to the antenna via the series resonant circuit L2 and C11, and is matched to the antenna via the pi matching network C9, L1 and C10.

sections of the circuitry which use CMOS are left permanently connected, as the current consumption of these devices (in the off state) is only 60 microamps from the 9 volt battery supply.

The particular button which is pressed causes a three-bit binary code to be generated and this together with the wired key-code is sampled by a 16-channel analogue multiplexer. The multiplexer is driven by a binary up-counter. The sequentially sampled code is now fed to a voltage-to-period converter where the various-width pulses are generated. These pulses drive the off-time monostable which gates the 27 MHz oscillator off for 0.24 milliseconds. This monostable also increments the binary counter, thus selecting the next input on the multiplexer. In this way the 16 bits are selected in turn and the unit cycles continuously until the on-time monostable switches off.

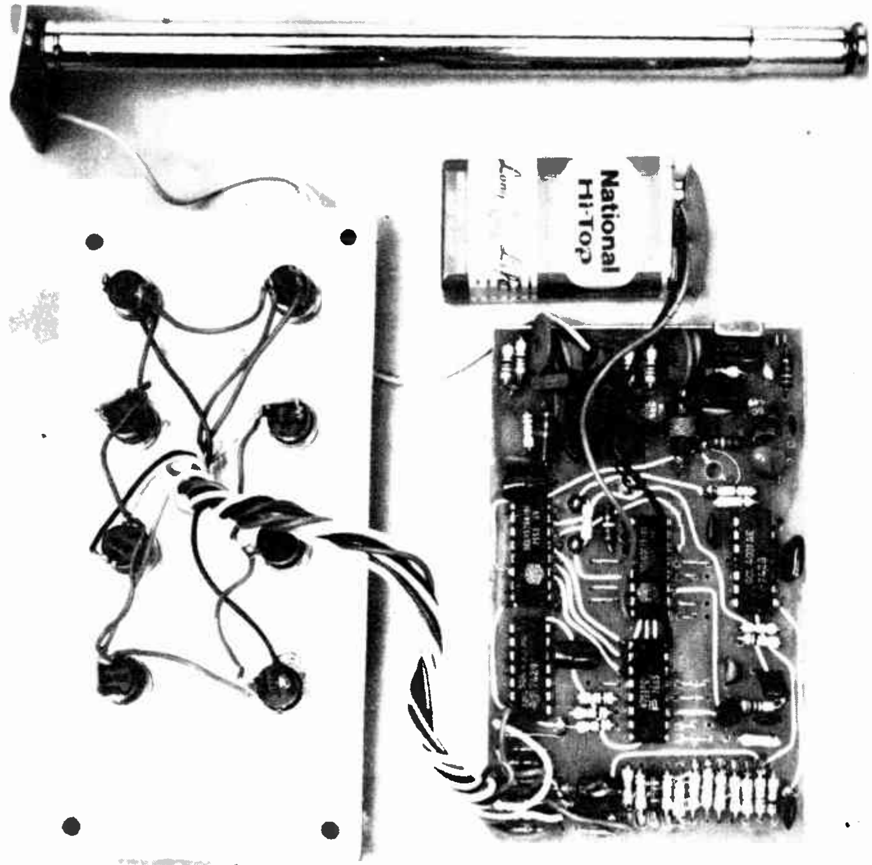


Fig. 5. The completed transmitter before installation in the box.

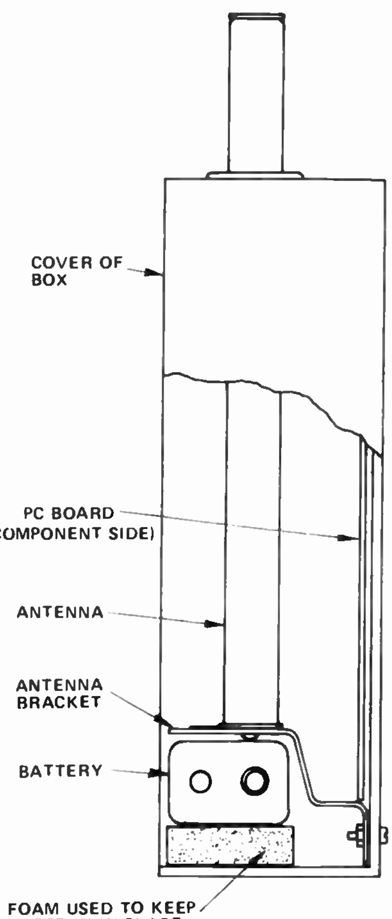


Fig. 4. Method of mounting the antenna and the battery by means of an aluminium bracket.

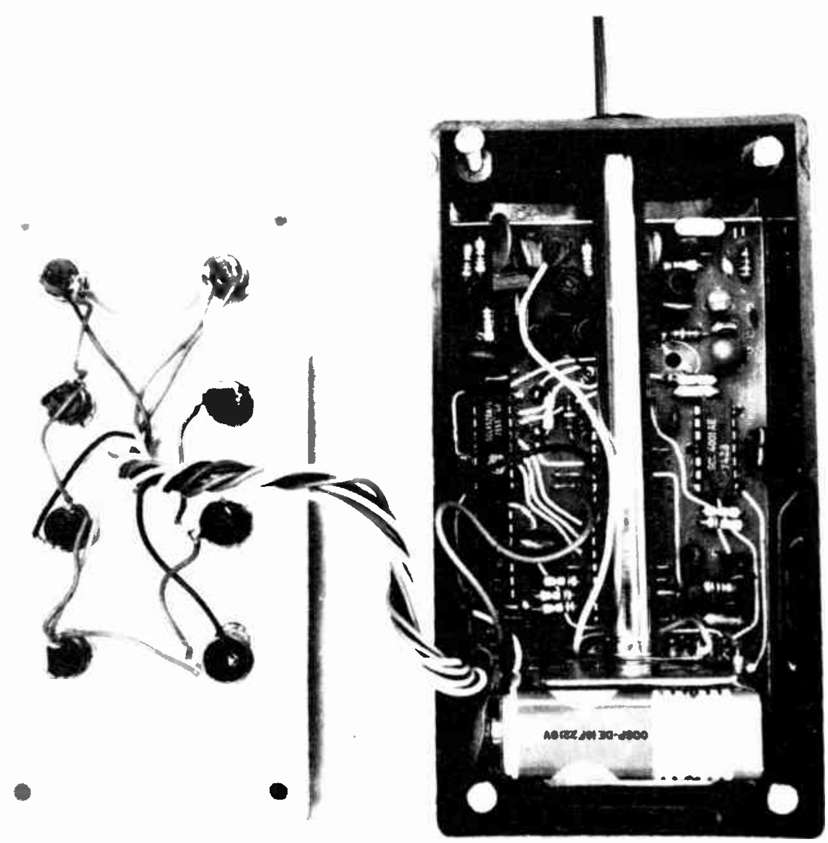


Fig. 6. The transmitter installed in the box. Note the method of mounting the antenna and the battery.

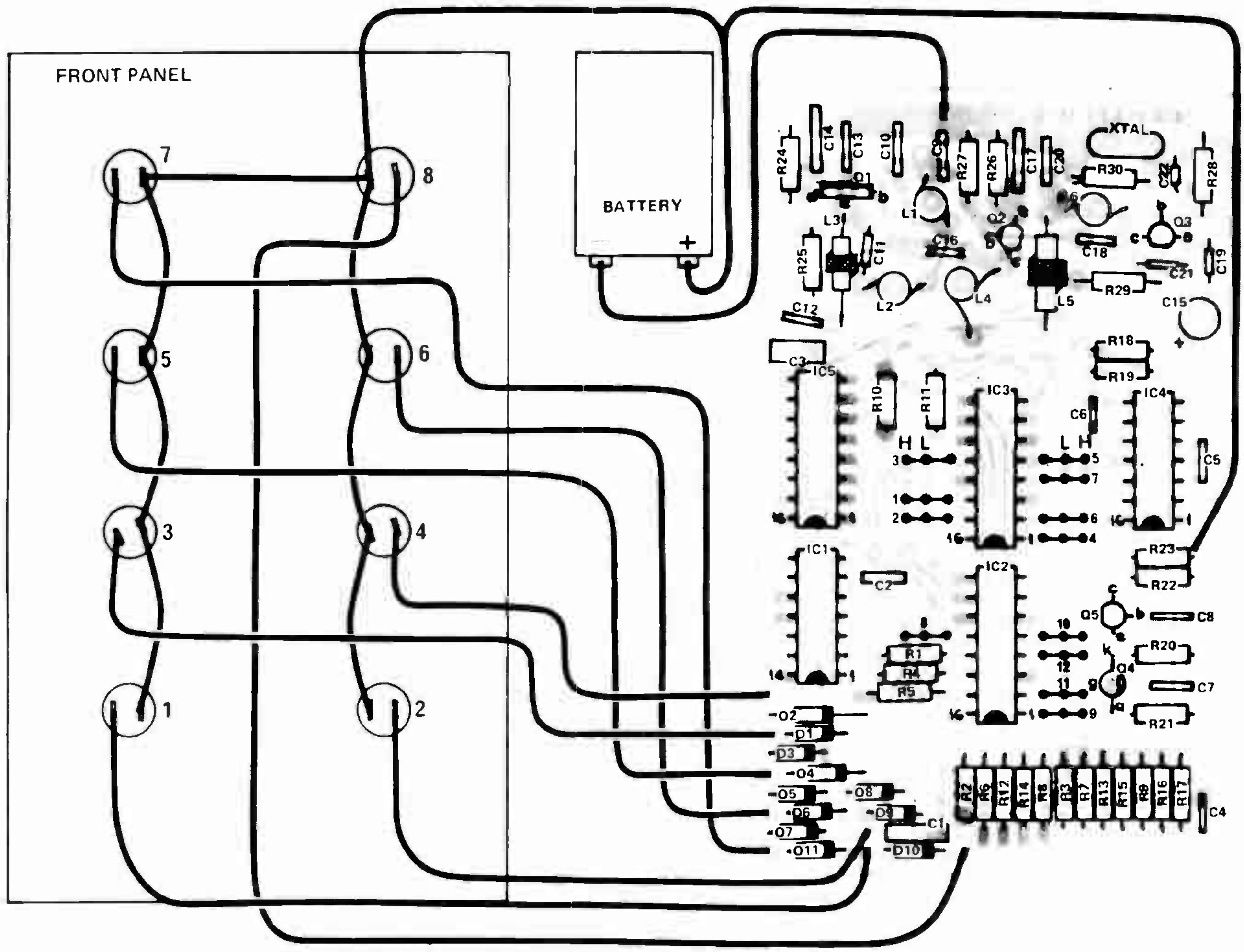


Fig. 7. Component overlay and wiring diagram. Note the links from IC2 and IC3 to the 'H' or 'L' lines. You must decide on the code word to be used and link to one or the other as detailed in the text. Overlay is shown larger than full size for clarity.

PARTS LIST ETI 711

Resistors

R1	100k	¼W	5%
R2	82k	"	"
R3	27k	"	"
R4,5	100k	"	"
R6,7	39k	"	"
R8	82k	"	"
R9,10	39k	"	"
R11	120k	"	"
R12	82k	"	"
R13	39k	"	"
R14	82k	"	"
R15	39k	"	"
R16	2M2	"	"
R17	100k	"	"
R18	3M3	"	"
R19	27k	"	"
R20	100 ohms	"	"
R21	330k	"	"
R22	10k	"	"
R23	47k	"	"
R24	5.6 ohms	"	"
R25	220 ohms	"	"
R26	12 ohms	"	"
R27	270 ohms	"	"
R28	330 ohms	"	"
R29	22k	"	"
R30	1k	"	"

Capacitors

C1-C3	33n		polyester
C4	15n		"
C5	56n		"
C6 – C8	10n		"
C9	47p		ceramic
C10	330p		ceramic
C11	270p		"
C12	10n		"
C13	68p		"
C14	10n		"
C15	33μ	16V	electro
C16	120p		ceramic
C17	10n		"
C18	220p		"
C19	39p		"
C20	10n		"
C21	33p		"
C22	470p		"

Semiconductors

D1 – D11	1N914 or similar
IC1	4001
IC2, 3	4051
IC4	4001
IC5	4520
Q1	BD139
Q2, 3	BC549
Q4	2N6027
Q5	BC548

Switches

PB1 – PB8	Miniature push buttons

Coils

L1,2,4,6	10 turns of closely spaced 24 gauge tinned copper wire wound on 5 mm diameter, 18 mm long coil formers (Neosid 722/18) with 6 mm long coil slugs.

Note L2 has no slug (Neosid 4 x .05 x 6/F29)
3 PTFE Locking Strips

L3, L5	150μH R.F. chokes

Miscellaneous

PC board ETI 711
Aluminium bracket to Fig. 4
Plastic box
Front panel to fig 10
Telescopic antenna
9 volt battery
2 6BA x 3/8 bolts & nuts
Battery clip
27 MHz crystal in the band 26.975 MHz to 27.282 MHz.

REMOTE CONTROL TRANSMITTER

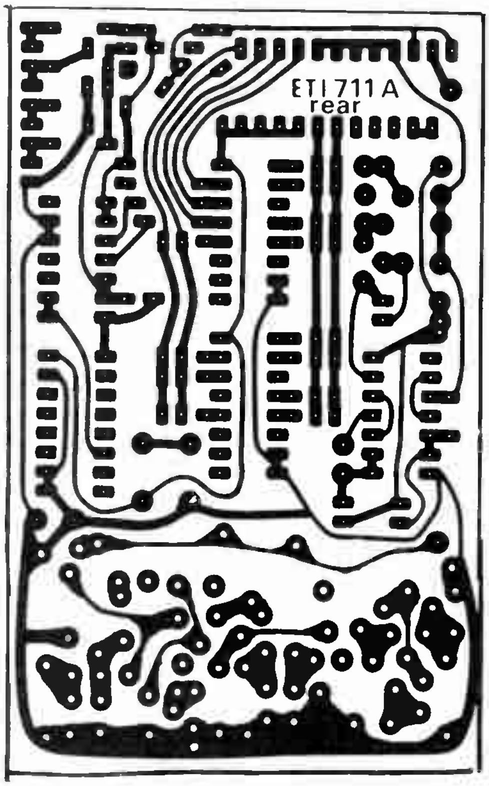


Fig. 8. Printed circuit layout for the rear side of the transmitter board. Full size 100 x 62mm

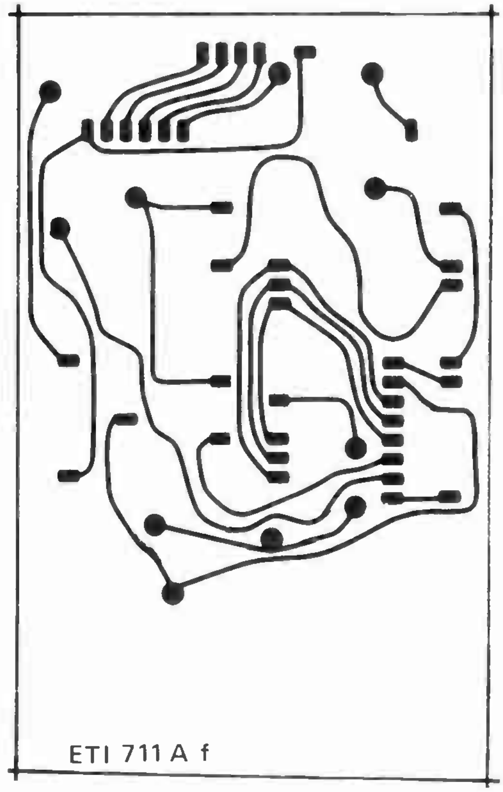


Fig. 9. Printed circuit layout for the component side of the transmitter board. Full size 100 x 62mm

REMOTE CONTROL RECEIVER

A brief description of the receiver which is used in conjunction with the remote control switch transmitter described in the previous article.

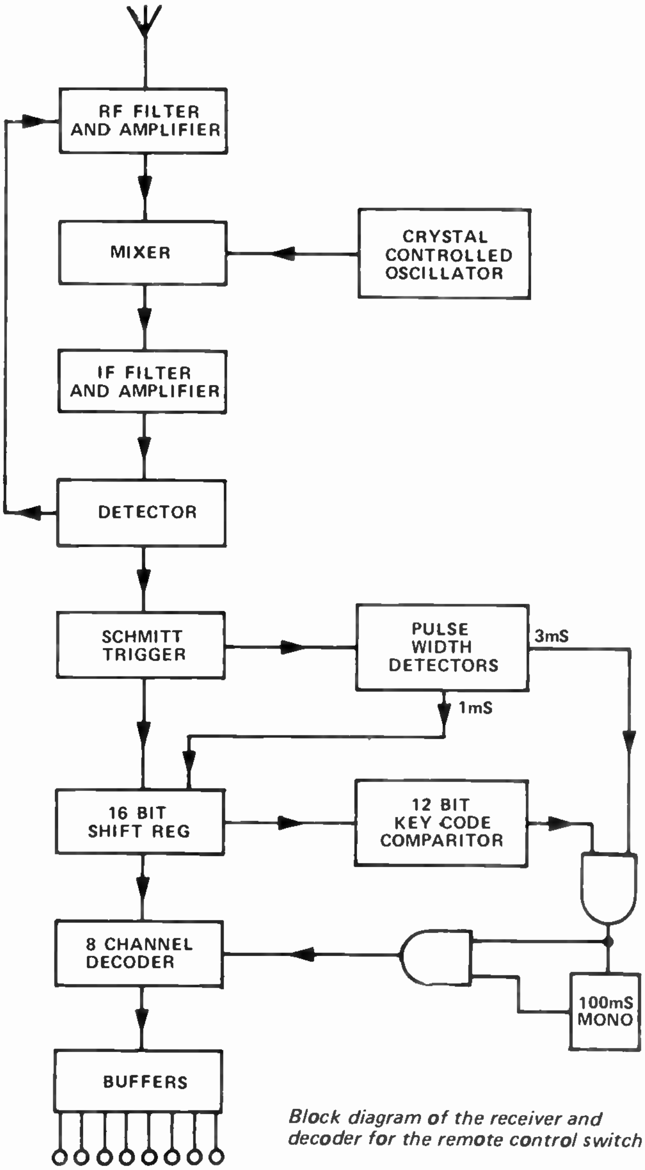
The Receiver.

The receiver is a conventional superhet design which incorporates an RF filter and amplifier, a crystal-controlled oscillator, a mixer, a ceramic IF filter, IF amplifier, and a detector to recover the AM component. An AGC circuit is also incorporated to control the gain of the RF stage in order to prevent overload of the receiver when the transmitter is operated in close proximity to it.

The decoder.

The output of the detector is squared up by a Schmitt-trigger circuit, the output of which is a pulse train in the transmitter which keys the oscillator. This output clocks a sixteen-bit shift register. The output from the Schmitt trigger is also fed to a pair of pulse-width detectors. The first of these is called the '1 ms' detector. If the pulse from the Schmitt is less than 1 ms the detector produces a '1', if the pulse from the Schmitt is greater than 1 ms it produces a '0'. Remember that the pulse train consists of a series of 0.5 or 1.5 ms pulses for the code word and a 5 ms pulse for synchronisation. Thus the '1 ms' detector feeds a series of '1's or '0's into the shift register as determined by the received code word.

The output of the shift register is connected to 12 exclusive-OR gates which compare the received code with the receiver's particular 12-bit key code.



Block diagram of the receiver and decoder for the remote control switch

Whenever a match is found between the wired-key code and that received an output from the comparator goes low. As the output of the shift register is continuously changing there may be several points at which the key code is correct. For example a code of 101010101010 will be correct at every second step. However the correct sequence of pulses is now selected by means of the sync pulse. The sync pulse is detected by a 3 ms pulse detector which provides a '1' output whenever a pulse longer than 3 ms is detected, and a '0' when the input pulse is shorter than 3 ms.

Now if a sync pulse is detected and at the same time the output of the key-code comparator is low (indicating a key-code match has been detected) a 100 ms monostable will be triggered. When the next sync pulse is detected, providing that the comparator is still low, it will be connected to the input of the 8 channel decoder. The control signals, which determine to which of the 8 channels that the sync pulse is fed, come from three of the bits in the 16-bit code.

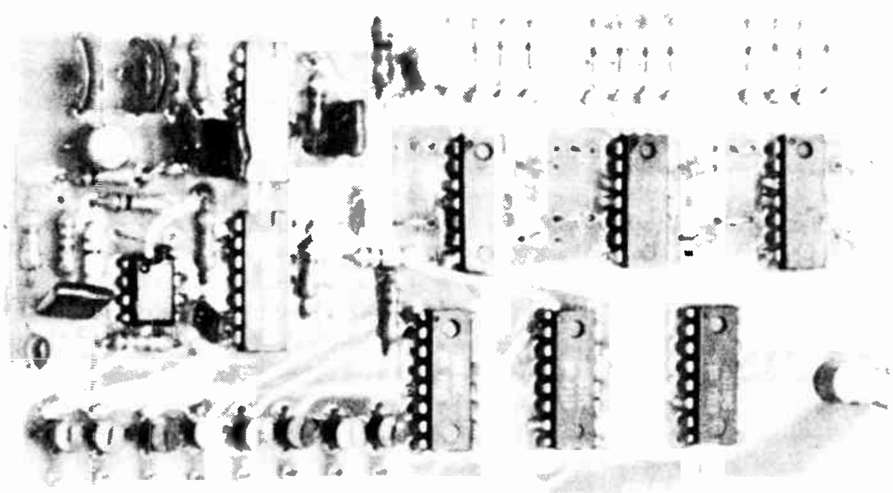
The sync pulse thus appears at one of the 8 outputs of the decoder, each output being buffered by a transistor. These individual outputs may be used to drive relays or any other device as required. However as it is only a pulse of about 1 ms duration, latching circuitry must be used.

REMOTE CONTROL RECEIVER

A full description is given of construction of the receiver and decoder sections of the remote switch system. This article describes the relay circuitry and power supply.

Fig. 1. The receiver board completed.

Fig. 2. The completed decoder board.



Construction

The receiver and the decoder are built on separate printed-circuit boards. As layout can be critical with the RF circuitry of the receiver and as the decoder section is fairly complex, we strongly recommend that the published pcb designs be used. Whilst we make no claim that these layouts are the *only* ones that may be used, or indeed that they are the best that can be devised, at least you can be sure that if you use them correctly the system will work.

The Receiver. Commence assembly of the receiver by glueing the coil formers onto the ETI 711R board (on the underside) using quick-drying epoxy cement. To wind the coils solder one end of the wire into one of the holes provided and then wind ten and a half turns (close wound) onto the coil. Now return the other end of the wire through the second hole and solder into position. Wind all coils in an identical fashion and fit all of them except L4 with slugs.

Now fit the remaining components to the board taking care to correctly orient diodes, transistors and electrolytic capacitors. The capacitors used should be of the disc-ceramic variety as these perform better than other varieties at the high frequencies used. Note particularly that BC548 and 559 transistors from different manufacturers have different pin connections; connections for the Philips variety are shown on the overlay.

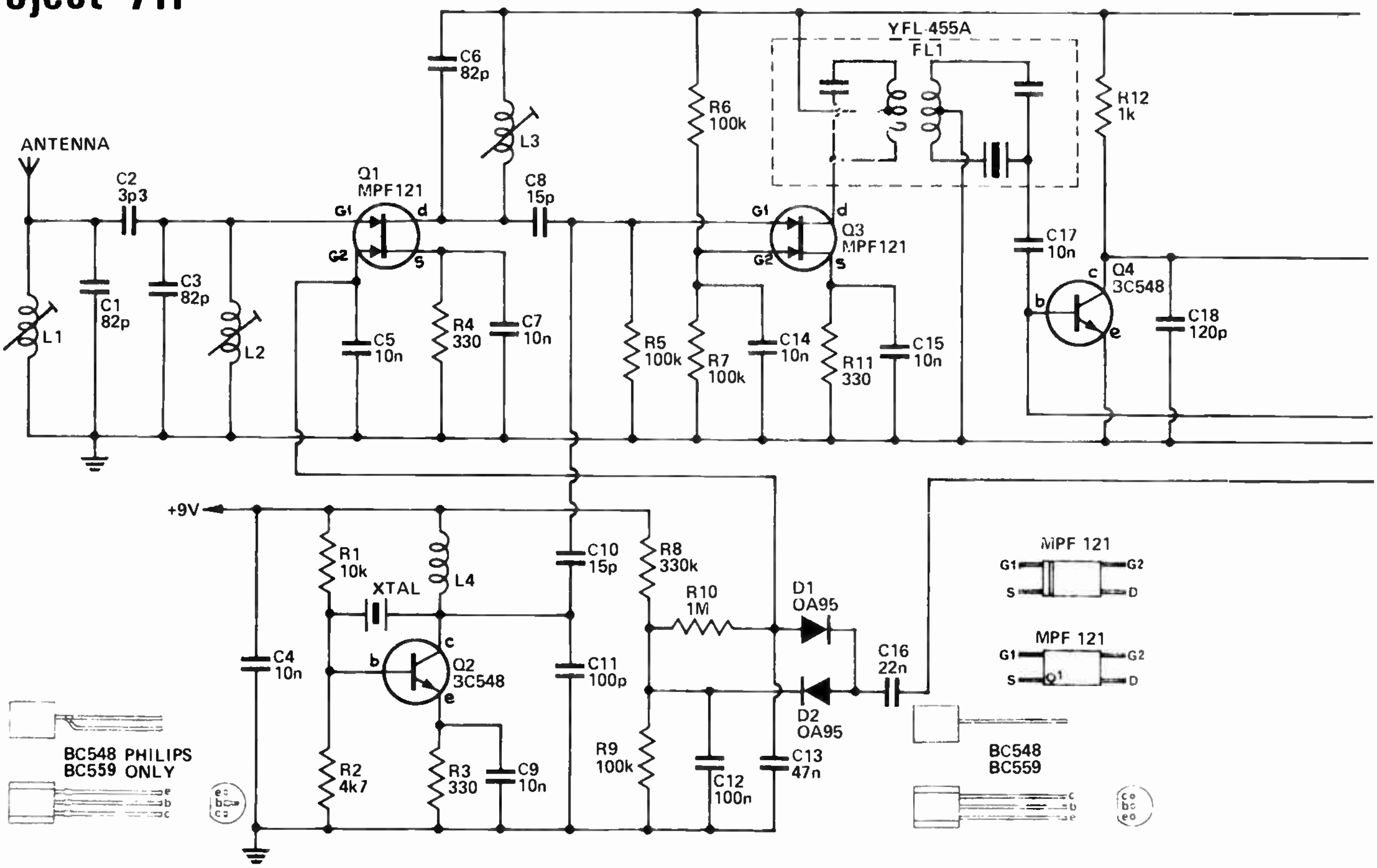


Fig. 3. Circuit diagram of the receiver.

How it works – ETI 711R

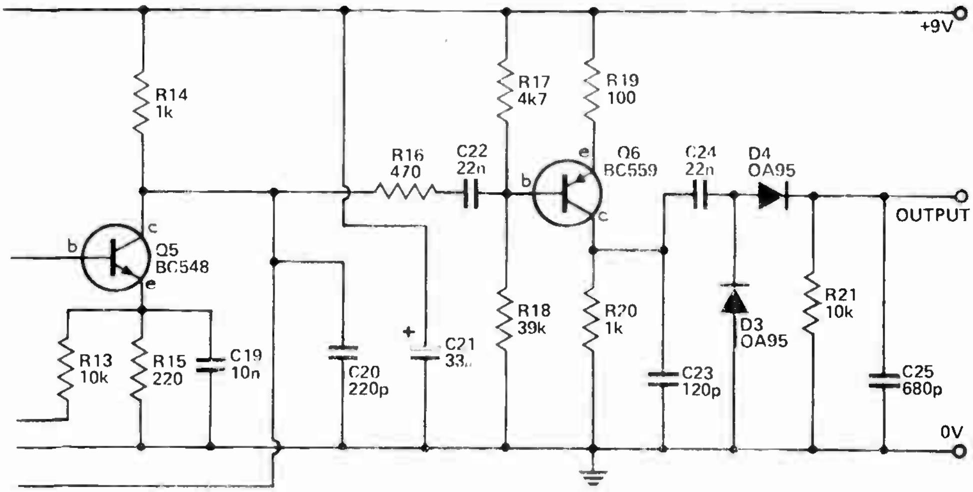
The remote switch receiver is a fairly conventional superhet design, which operates as follows:

The signals picked up by the antenna are put across the filter formed by L1, C1 and L2, C3 which rejects all signals outside the 27 MHz band. Signals within the band are now amplified by the dual-gate FET Q1 which has automatic gain control applied to the second gate. The drain load of Q1 is the tuned circuit L3, C6 which is also tuned to the 27 MHz signal. The output from the RF amplifier stage, Q1, is now coupled into gate 1 of transistor Q3 which together with associated components forms the mixer stage. The second gate of this transistor is biased to half-supply voltage and does not have gain control applied to it.

A crystal-controlled oscillator is formed by the transistor Q2, the crystal and other associated components. The frequency of oscillation is determined by the crystal and should be 455 kHz above the transmitted frequency. The output signal from the oscillator is applied to the mixer stage, Q3. Here it is mixed with the input signal. The output from Q3 is a mixture of signals; the main ones are the oscillator frequency, the signal from the transmitter, the sum of these two frequencies (54 MHz) and the difference of these two frequencies (455 kHz).

The drain load for Q3 is a 455 kHz filter which will pass only that frequency to the IF amplifiers Q4 and Q5. The IF stage has deliberately been kept simple as very long-range operation is not required and the consequent alignment problems are greatly reduced. The output from Q5 is rectified by D1 and D2 in order to produce a dc voltage which is proportional to signal strength. This voltage forms the AGC voltage which is applied to the second gate of Q2. With no signal the voltage at the gate of Q1 is about two volts and as the input signal rises (and consequently the ouptut from Q5 rises) the voltage on Q1's gate reduces and may eventually go negative. Thus the gain of Q1 is reduced with increasing input signal level, thereby stabilising the output level for changes in input signal level.

One further stage of amplification is provided by Q6 before the IF is detected by D3 and D4. The transistor Q6 normally operates in the limiting mode, that is, it is hard on or hard off except when the signal is very low. The signal is full-wave detected by D3 and D4 and the time constant of R21 and C25 is long enough to reject the 455 kHz but short enough to develop a voltage across C25 proportional to the modulation on the signal. Further filtering to remove 455 kHz is performed on the decoder board.



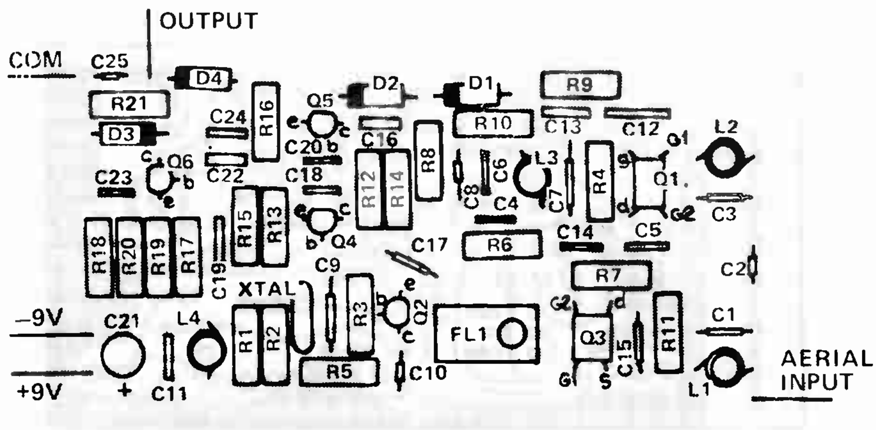


Fig. 4. Component overlay for the receiver.

TABLE 1
Coil winding details

Coil Former	Neosid 722/1B
Slug	Neosid 4 x .05 x 6/f29 plus PTFE locking strips
Winding	10½ turns close-wound of 24 B&S enamelled copper wire

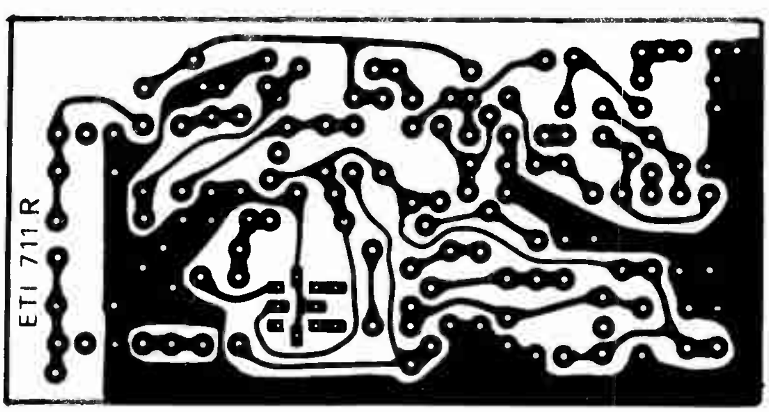


Fig. 5. Printed-circuit layout for the receiver. Full size 100 x 51 mm.

Parts List – ETI 711R

Resistors all ¼ W 5%

R1	10 k
R2	4 k7
R3,4	330
R5-R7	100 k
R8	330 k
R9	100 k
R10	1 M
R11	330
R12	1 k
R13	10 k
R14	1 k
R15	220
R16	470
R17	4 k7
R18	39 k
R19	100
R20	1 k
R21	10 k

Capacitors

C1	82 p ceramic
C2	3 p3 "
C3	82 p "
C4,5	10 n "
C6	82 p "
C7	10 n "
C8	15 p "
C9	10 n "
C10	15 p "
C11	100 p "
C12	100 n "
C13	47 n "
C14,15	10 n "
C16	22 n "
C17	10 n "
C18	120 p "
C19	10 n "
C20	220 p "
C21	33 μF 16 V electro
C22	22 n ceramic
C23	120 p "
C24	22 n "
C25	680 p "

Semiconductors

Q1	MPF131
Q2	BC548
Q3	MPF121
Q4,5	BC548
Q6	BC559
D1-D4	OA95 or similar

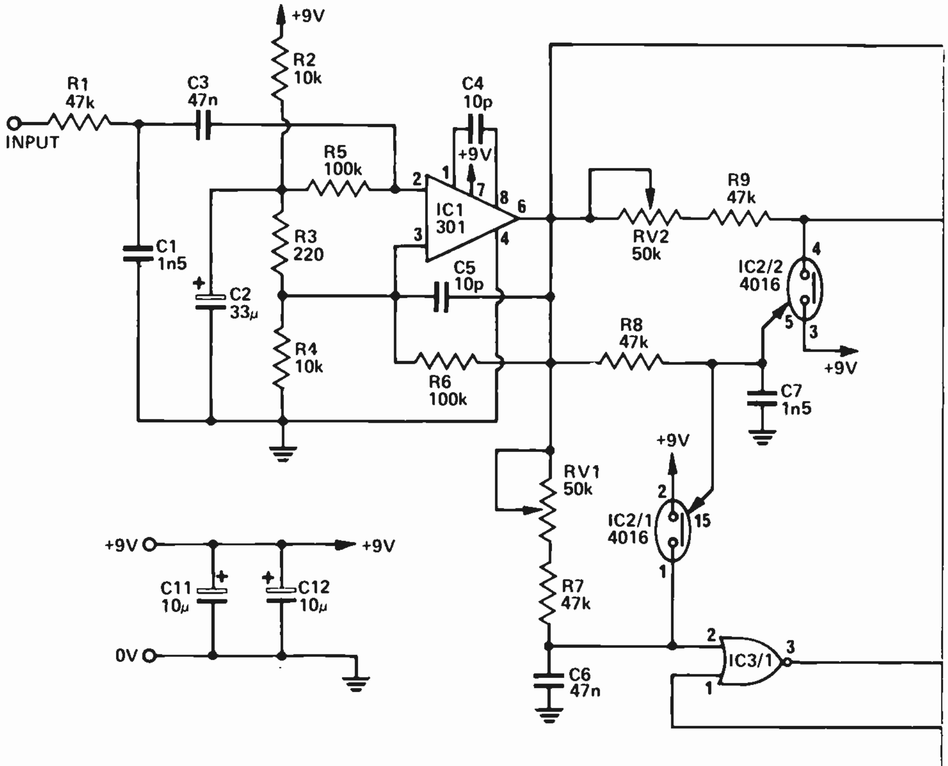
Inductors

L1-L4	see table 1

Miscellaneous
FL1 Filter YFL-455A
pc board ETI 711R
Xtal 27 MHz band 455 kHz above transmitter frequency

The Decoder. The decoder is built on the ETI 711D board. This board is double-sided (that is there is a copper pattern on both sides) but the holes are not plated-through. It is therefore important to solder the component to *both* sides of the board wherever necessary. Note that all the ICs, with the exception of the LM301, are CMOS devices and therefore should be handled as little as possible. The devices will be supplied mounted in conductive foam and should not be removed from this until you are ready to insert them into the board. Use a small soldering iron and solder quickly and cleanly. Check to make sure that the pins have been soldered to the tracks on both sides of the board and that there are no solder bridges between tracks.

The links to ICs 4, 5 and 6 must now be connected so that the decoder has the same key code as the transmitter. Link to the track closer to the IC for a '1' and to the track further from the IC for a '0'.



Receiver alignment

Once the receiver has been completed it should be aligned using the following procedure:

1. Disconnect capacitor C16.
2. Connect a short aerial to the receiver (300 mm of hook-up wire).
3. Connect an audio amplifier to the output terminals of the receiver via a series 10k resistor.
4. Also connect a dc voltmeter to the output terminals, again via a series 10 k resistor.
5. Connect the power supply and switch on.
6. On the transmitter connect pins 1 and 16 of IC4 to obtain continuous transmission of the code sequence (use a larger battery or separate power supply as detailed in the article on the transmitter).
7. The antenna on the transmitter should be kept short, not fully extended.
8. If all is as it should be the pulse train output from the receiver should be heard on the amplifier and a deflection should be obtained on the dc voltmeter.
9. Adjust L3 for peak output. However it will be necessary to move the transmitter further and further away so that the output does not exceed one volt dc (to avoid saturation). Continue this process until no further improvement is obtainable with tuning L3.
10. Again peak the output by adjustment of L1 and L2 and when no further improvement is obtainable make a final adjustment to the IF filter. Now readjust L3 for a final peak.
11. Switch off the receiver and the transmitter, reconnect capacitor C16 and then disconnect the amplifier and the meter.

Decoder adjustment

Before making any adjustments to the decoder make absolutely sure that the codes wired into the transmitter and the decoder are identical. Set the potentiometers to their mid positions (Normally no readjustments will be necessary).

Correct operation of the decoder may be observed by connecting a LED to each output transistor as follows: For each transistor connect one end of a 100 ohm resistor to plus nine volts and the other end to the anode of an LED. Connect the cathode of the LED to the transistor output. When a button on the transmitter is pressed one of the LEDs will flash. If the transmitter is running continuously then one of the LEDs will glow continuously. If this doesn't happen then check out the operation of the decoder with an oscilloscope as follows:

Checking with an oscilloscope

1. Check the output from the receiver to ensure that a pulse train is present of at least 100 mV amplitude peak-to-peak.
2. Check the output from IC1 (pin 6). It should be a squared-up version of the output from the receiver (see waveforms 1a and 1b).
3. With a sharp knife or razor blade cut the track between R14 and the cathodes of the diodes. A narrow cut is required because it must be rejoined later by soldering.

Parts List — ETI 711D

Resistors	all ¼ W 5%
R1	47 k
R2	10 k
R3	220
R4	10 k
R5,6	100 k
R7-R9	47 k
R10	10 k
R11	100 k
R12	4 M7
R13	2 k2
R14	10 k
Variable Potentiometer	
RV1,2	50 k trim
Capacitors	
C1	1 n5 polyester
C2	33 µ
C3	47 n polyester
C4,5	10 p ceramic
C6	47 n polyester
C7	1 n5 "
C8	10 n "
C9	1 n5 "
C10	47 n "
C11,12	10 µ 16 V electro
Semiconductors	
IC1	LM301
IC2	4016 (CMOS)
IC3	4001 (CMOS)*
IC4,5,6	4030 (CMOS)
IC7,8	4015 (CMOS)
IC9	4051 (CMOS)
Q1-Q8	BC548 or similar
D1-D12	1N914 or similar

pc board ETI 711D

**This IC must be one made by Solid State Scientific SCL 4001A or Signetics HEF4001P*

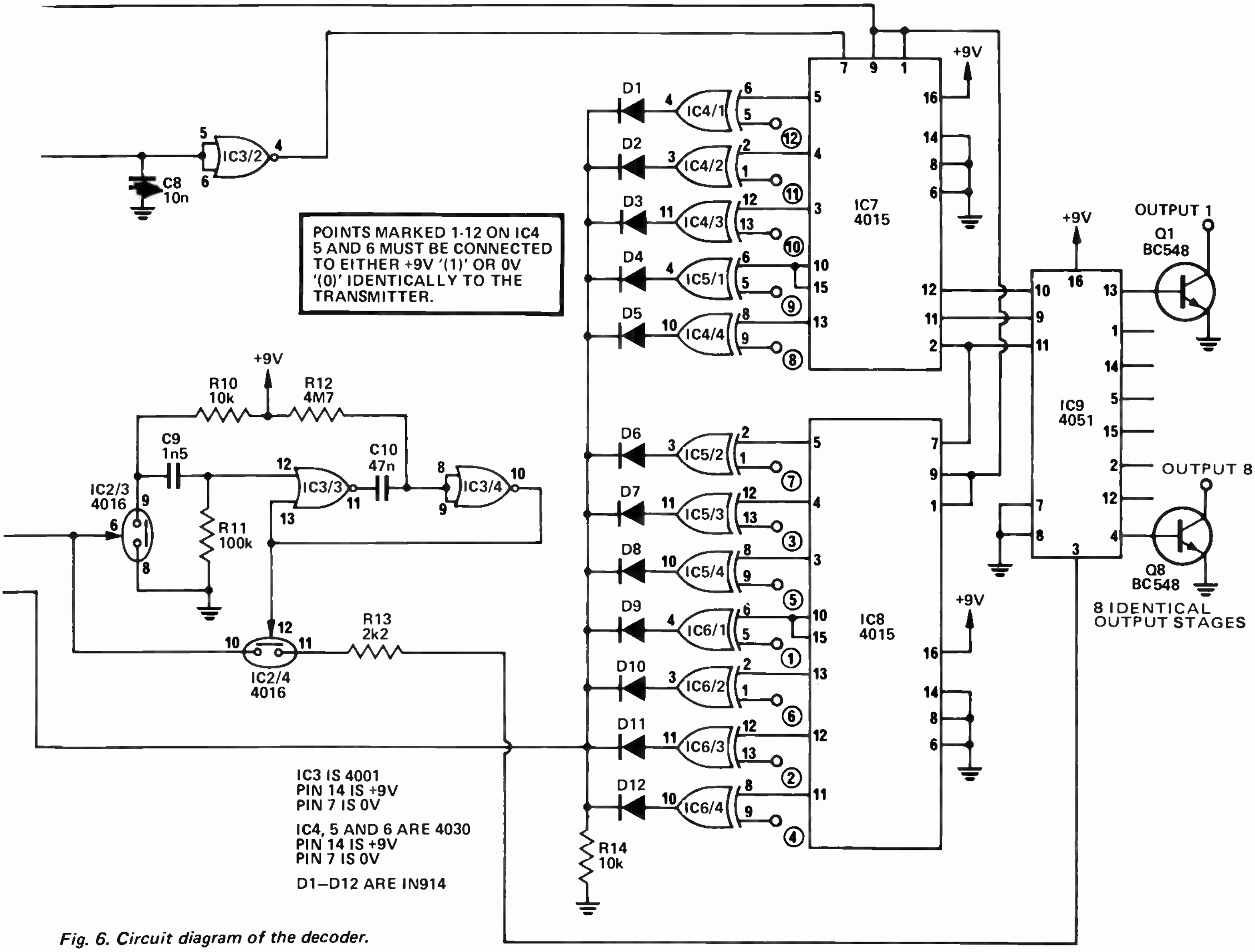


Fig. 6. Circuit diagram of the decoder.

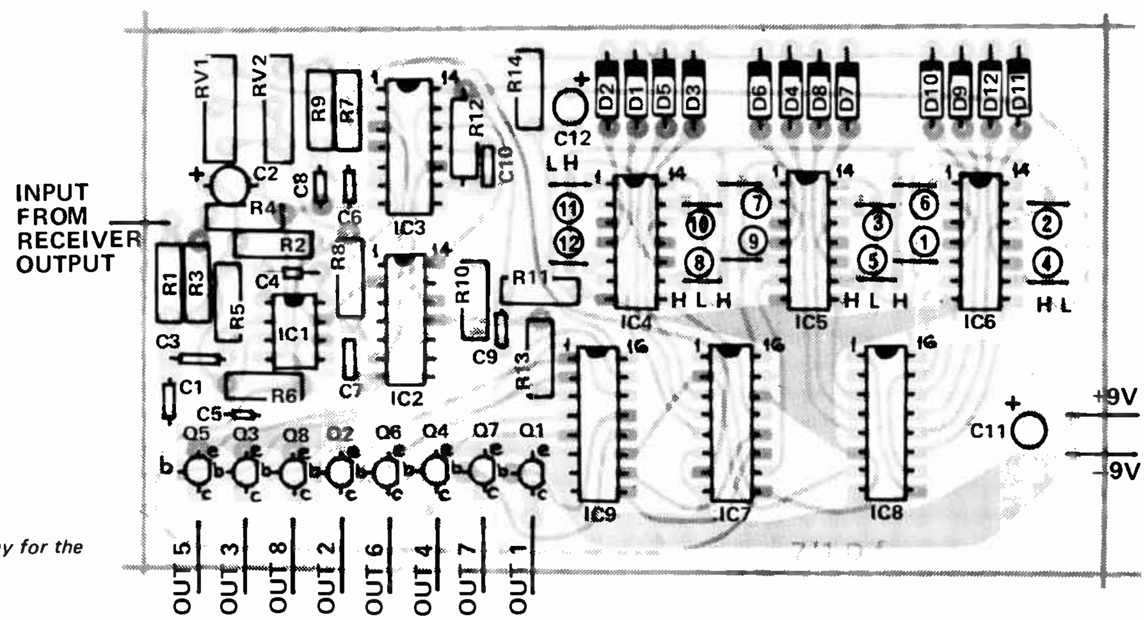


Fig. 7. Component overlay for the decoder.

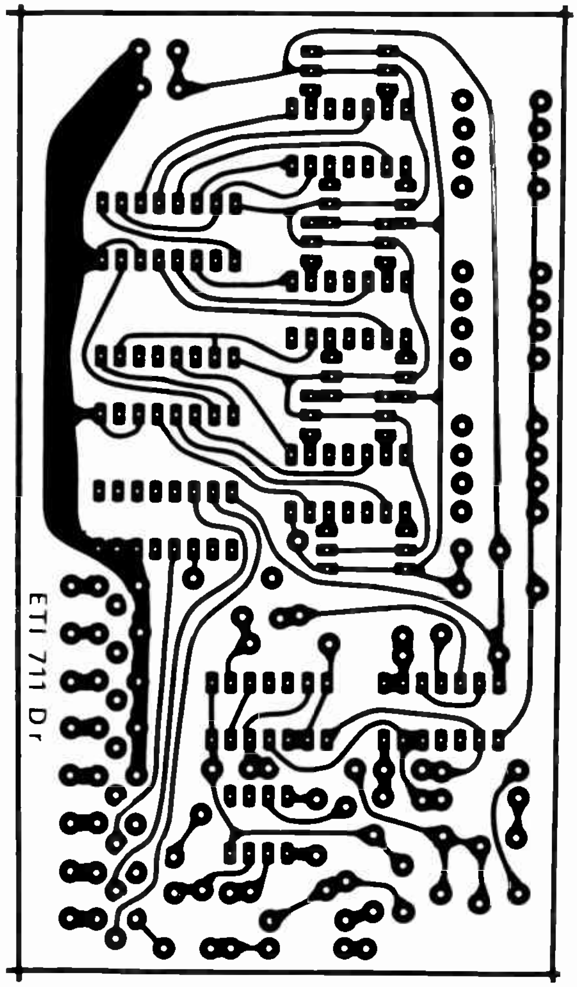


Fig. 8a. Non-component side of the decoder board. Full size 127 x 69 mm.

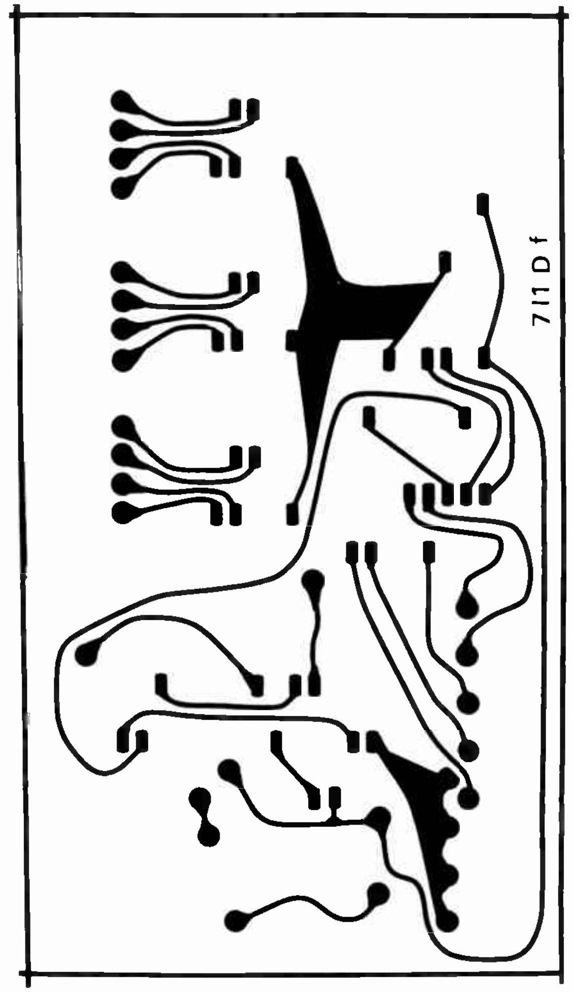


Fig. 8b. Component side.

4. Look at pin 3 of IC3/1 with the oscilloscope. A positive-going pulse should be observed which is about 1 ms wide and re-occurring about every 30 ms or so (depending on word length). This is the synchronising pulse. RV1 should be adjusted for correct detection of this pulse. At one extreme of RV1 all the pulses will be detected together with the sync pulse. And at the other extreme no pulses will be detected at all. Adjust RV1 so that only the sync pulse is correctly detected.

5. Use this pulse to sync the oscilloscope and adjust the timebase of the oscilloscope so that one complete frame of the code word can be seen in a single sweep.

6. Look at the output of IC1 (pin 6) and the complete pulse train should be visible. This can easily be checked against that expected. The sequence of the pulses within the train is detailed in the errata printed on this page.

7. Look at the output of IC3/2 (pin 4). This should be low when the input pulse is short and high when the input pulse is long. RV2 can be used to adjust this stage for correct operation.

8. If the system is still not working trigger the oscilloscope from the positive edge of the sync pulse and expand the trace to about half a millisecond per division.

9. Look at the output from each stage of the shift register. During the sync pulse these outputs should be steady 'high' or 'low' as set by the wired link code.

10. Rejoin the track which was previously cut and if the unit is still not working check the voltage at pin 10 of IC3/4. This should be mostly at +9 volts. There should be a series of 100 ms pulses but the IC is retriggered rapidly on each sync pulse. If it is not check for faults around IC3/3 and IC3/4.

ERRATA

a) The copper track between C3 and C12, nearest the edge of the board, should be broken to remove the short which otherwise exists across C3.
b) The resistor R11 is connected to 0V rather than to point 'A' as it should be. This causes the off-state current to be higher than it should be (60 microamps). To correct this disconnect R11 from the zero volt line and connect it by a link to Pin 3 of IC4 (point 'A'). This reduces the off-state supply current to less than one microamp.
c) On the circuit diagram pins 9 and 11 on IC3 are shown reversed to that used on the printed-circuit board. The only difference that this makes is to the order of transmission of the code. Using the numbers on the circuit diagram and the overlay the code sequence is— Sync, 4,2,6,1,5,3,7,B,A C,8,9,10,11,12. The letters A,B and C represent the information code.
d) On the circuit diagram the line joining R21,22 and 23 should be shown connected to +9V.

How it works — ETI 711D

The function of the decoder board is to take the detected signal from the receiver, check the pulse train for correct key code and, if a match is found, turn on one of eight transistors as determined by the additional word. The respective transistor is then used to control an external relay or other device as required.

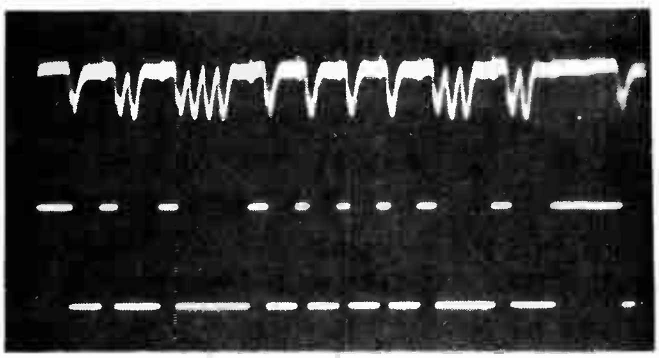
The input signal from the receiver is filtered by R1 and C1 to remove any remaining 455 kHz and is then applied to IC1 which is connected as a Schmitt trigger. The output of IC1 is therefore a squared up version of the pulse train from the transmitter. The output of IC1 is normally low and goes high for the 200 micro-second off time of the transmitter.

As there are three different lengths of pulse in the transmission these must be separated at this stage. This is performed by IC3/1 and IC3/2. When the output of IC1 is high IC2/1 and IC2/2 are turned on thus clamping C6 and C8 to plus nine volts. When IC1 goes low, IC2/1,2 turn off and C6 and C8 discharge via R7, RV1 and R9, RV2. After about one millisecond the output of IC3/2 goes high (as the input will be below the threshold) and after three milliseconds IC3/1 goes high. Both of these pulse lengths are conditional on the output of IC1 not going high during this period.

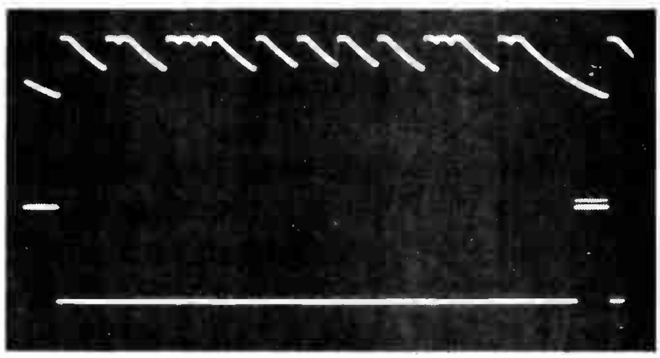
When the output of IC1 goes high it clocks the 16 bit shift register formed by IC7 and IC8 and whatever is at the output of IC3/2 is clocked into the shift register. If the pulse is less than one millisecond a '0' will be clocked in, if the pulse is greater than one millisecond a '1' will be clocked in. With a shift register the data is moved through each stage in turn and is eventually lost out the end. Therefore the series of ones and zeros set up by the input code are clocked continuously into the shift register.

The outputs of the shift register are connected to the exclusive OR gates of IC4, 5 and 6. The outputs of the exclusive OR gates are connected, as per the selected transmitter key code, to either +9 or 0 V. The output of an exclusive OR gate will be low when both inputs are the same, (ie, 1, 1 or 0, 0) and high if the inputs are different (ie 1, 0 or 0, 1). The outputs of the exclusive OR gates are ORed by diodes D1 to D12 so that the junction R11 will be high unless all twelve of the outputs from the shift register agree with the keyword in code. If the code is symmetrical in any way this may occur at numerous points throughout the transmission. This output is therefore passed back to IC3/1 enabling it only if the code and sync pulse sequence is correct. This means that although a sync pulse may be present, the output of IC3/1 will not register it unless a correct code has also been detected.

When a correct code has been detected and a sync pulse is received, the output of IC3/1 will go high for about one millisecond during which time IC2/3 will be turned on. After IC2/3 turns off capacitor C9 couples the edge to R11 and the monostable formed by IC3/3, 4 is triggered. The output on pin 10 therefore goes high for about 150 milliseconds. The first pulse out of IC3/1 is coupled through IC2/4 and R13 to pin 3 of IC9 which is a one of eight analogue switch, thus turning on one output of this IC and its associated output transistor for about one millisecond. The three information outputs from the shift register (pins 2, 11 and 12) determine which of the eight transistors are turned on. These three outputs are driven by the code set up when pressing a particular button in the transmitter.

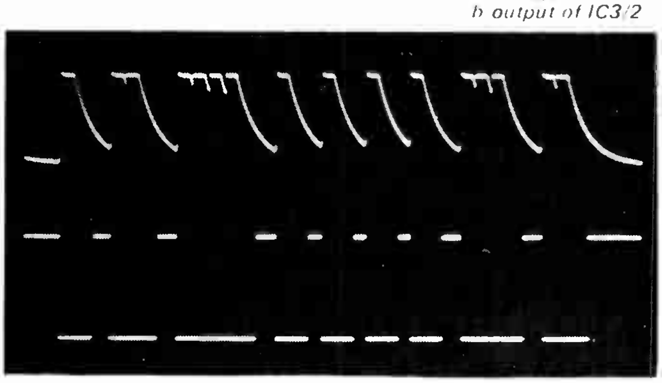


1a input to decoder
b output of IC1

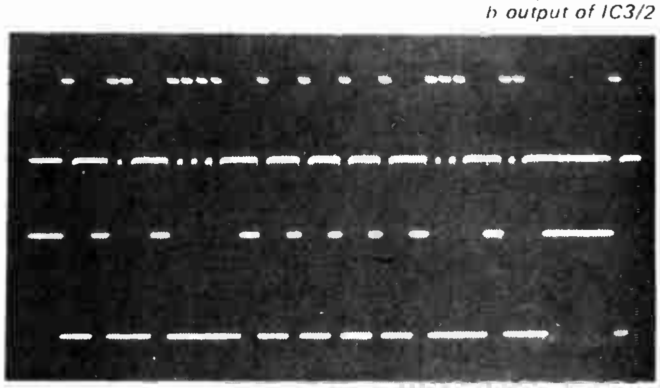


3a voltage across C6
b output of IC3/1

2a voltage across C8
b output of IC3/2



4a output of IC1
b output of IC3/2



REMOTE CONTROL

The fourth and final part of our 8-channel remote switch system. Having described the transmitter and receiver sections we now look at the receiver power supply and the relay drive circuits.

IN THIS FINAL ARTICLE ON THE Remote Switch' unit we describe the remaining sections of the receiver – the power supply and the relay drive circuits. There are two versions of the relay drive circuitry, the first (called 'Single Control') is used where a command on one channel is used to perform two different functions, on alternate commands. For example, when controlling a motor the first command on the channel causes the motor to go one way and a second command **(on the same channel)** causes the motor to reverse.

The second relay system (called 'Double Control') uses a command on one channel to switch a device 'on' and a second command **on a different channel** to switch the device off. The first system thus gives 'on' and 'off' by successive presses of a single button, whilst the second system uses separate buttons for 'on' and 'off'.

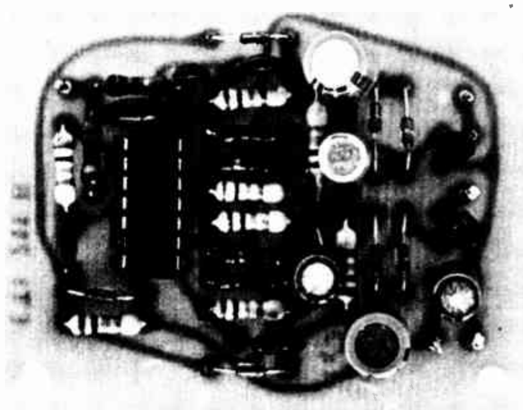
Construction

The receiver and decoder are best built into a metal box together with the power supply. As there are only a few components in the power supply these are mounted onto a tag strip.

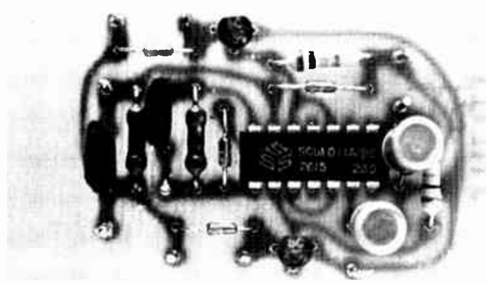
The relays will normally be operated remotely and it is therefore necessary to terminate the outputs of the decoder in a terminal block on the rear of the unit. The '0' volt and +12 volts should also be made available on this terminal block for use by the relay circuits.

The relay-drive units will normally be mounted close to the device being controlled and possibly housed in a small box attached directly to the controlled motor, etc. For this reason constructional requirements will vary greatly depending on the application and hence it is pointless for us to try to give housing details for these. Housing of the relay-drive boards is therefore left up to the constructor.

To connect the relay-drive units the '0' volt and +12 volt lines and the appropriate control channel lines from the decoder must be connected to the relay circuits using wiring which will not cause too much voltage drop. The voltage drop will depend on the length of line and on the size of the relay being used. If a number of relays are being used in the same location the power supply to them may be commoned to save wiring costs.



Finished printed-circuit board for the single-control driver.



Completed double-control relay driver.

REMOTE CONTROL

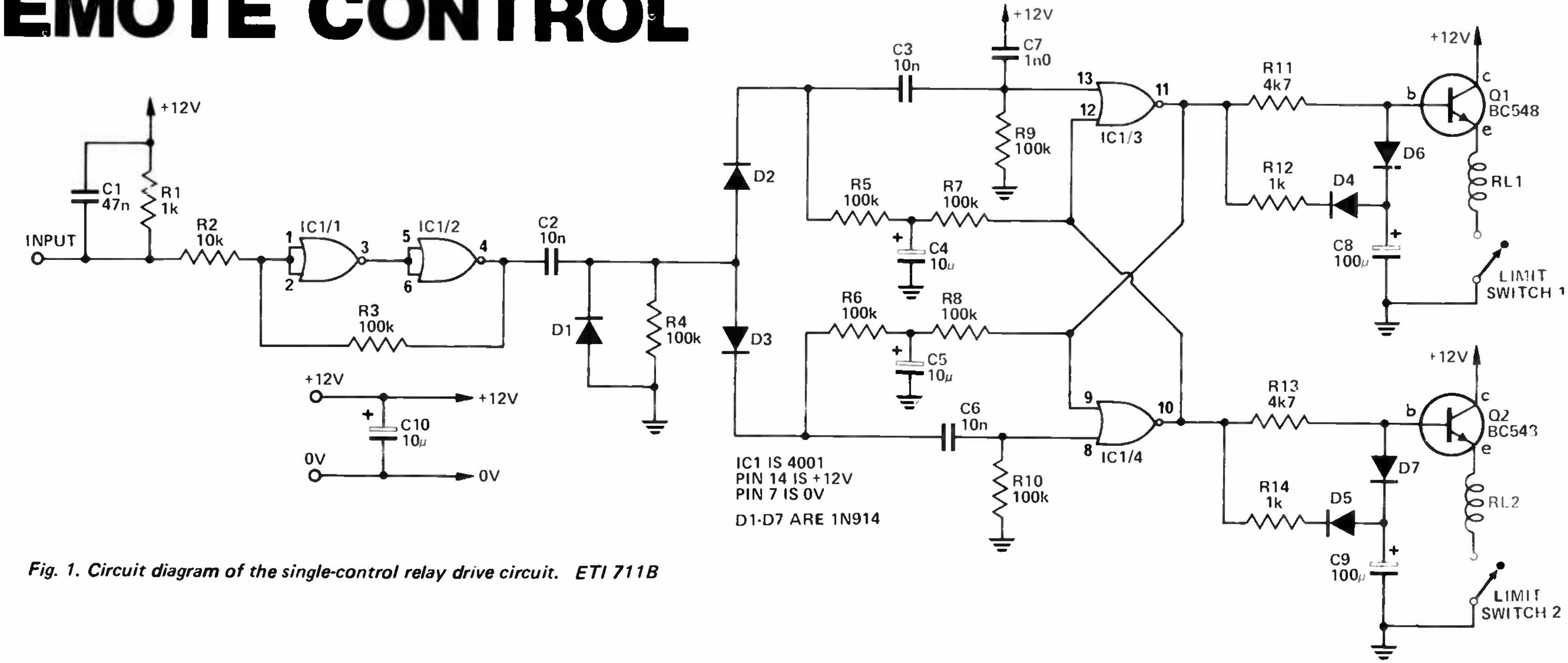


Fig. 1. Circuit diagram of the single-control relay drive circuit. ETI 711B

HOW IT WORKS – ETI 711

Single-Control Relay-drive Circuitry

By referring to the decoder circuit it may be seen that the output of the decoder is by a transistor with an open-circuit collector. The load for this transistor is resistor R1 which is bypassed by C1 to eliminate any possibility of signal pick-up which could occur with long leads. With a single press of the command button up to three pulses may appear at the input in a 100 millisecond period. These pulses are squared up by the schmitt trigger, formed by two sections of IC1, the output of which is differentiated by C2 and R4.

The other two sections of IC1 are connected as a flip-flop which has a steering network to ensure that it acts as a toggle. Capacitors C4 and C5 slow down the toggle rate so that the multiple input pulses do not trigger the flip-flop more than once in the one 100 millisecond period. Capacitor C7 is connected from plus twelve volts to pin 13 of IC1/3. This capacitor, at switch-on, feeds a pulse into IC1/3 thus ensuring that its output is always low after initial switch-on. The relays are driven by transistors Q1 and Q2 which are connected as emitter followers. An initial delay on switch-on occurs due to the action of capacitors C8 and C9. These capacitors are, however, isolated on switch-off by the action of diodes D6 and D7. After switch-off the capacitors are discharged by R12,D4 and R14,D5 to ensure that the full delay occurs when next switched on. The delay of about one second ensures that when reversing a motor some time is allowed for the motor to stop before it receives reverse drive.

If a light globe (or other device where only simple on/off operation is required) is being operated, only a single relay and its associated drive circuitry is required (Q1 and RL1). R12,D4,D6 and C8 may also be omitted.

If using motors limit-switches will invariably be required and these are simply connected in series with the relay coils.

Double-Control Relay Circuitry

This is a simpler circuit than that of the single-control unit and consists of two separate flip-flops which each drives a relay via a buffer transistor.

For the control of drive motors a stop position must be incorporated between the two different direction commands. With this circuit, when the motor is travelling in one direction and a reverse command is given before the motor has stopped, the motor will simply stop.

Another command must be given for the motor to reverse. However if the limit-switch is made, and the motor has already stopped – then only one command is required. Capacitors C3/4, resistors R3/4 and diodes D1/2 are incorporated to provide this action.

If lights or similar devices are being controlled this board may be used to control two separate units if required. This may be achieved by deleting C3, C4, R3,4 and D1,2 and by using input 1 and limit-switch 1 to control RL1 and input 2 and limit-switch 2 to control RL2.

Additional 1k resistors should be added from pins 6 and 8 to +12V to act as loads for the decoder.

Power Supply

This is simply a full-wave rectified and filtered power supply which provides 12 volts for the relays and 9 volts, via a further RC network, for the receiver and decoder boards.

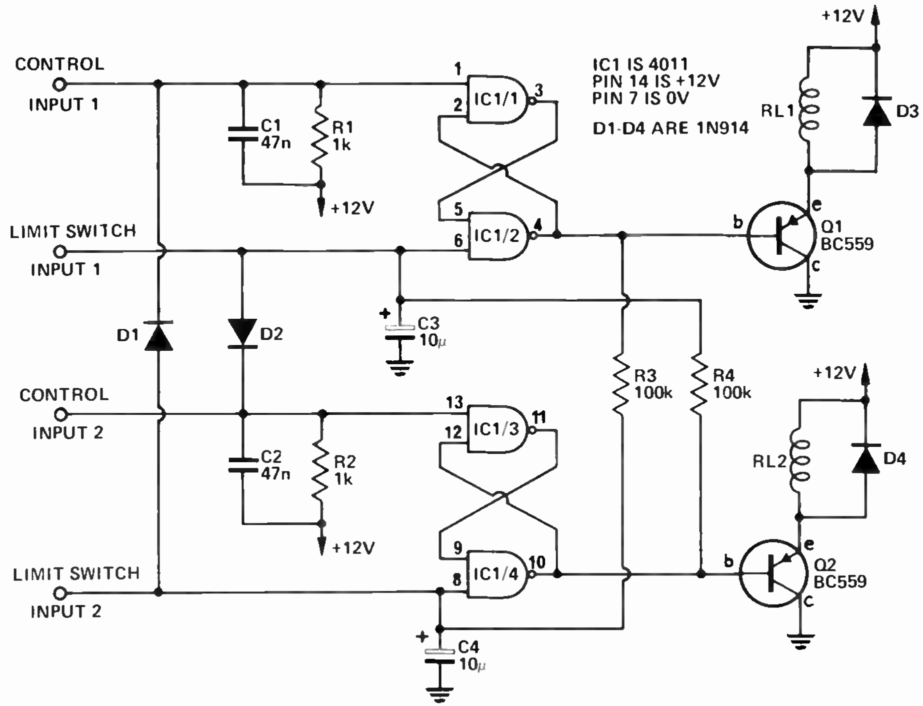


Fig. 2. Circuit diagram of the double-control relay drive circuit. ETI 711C

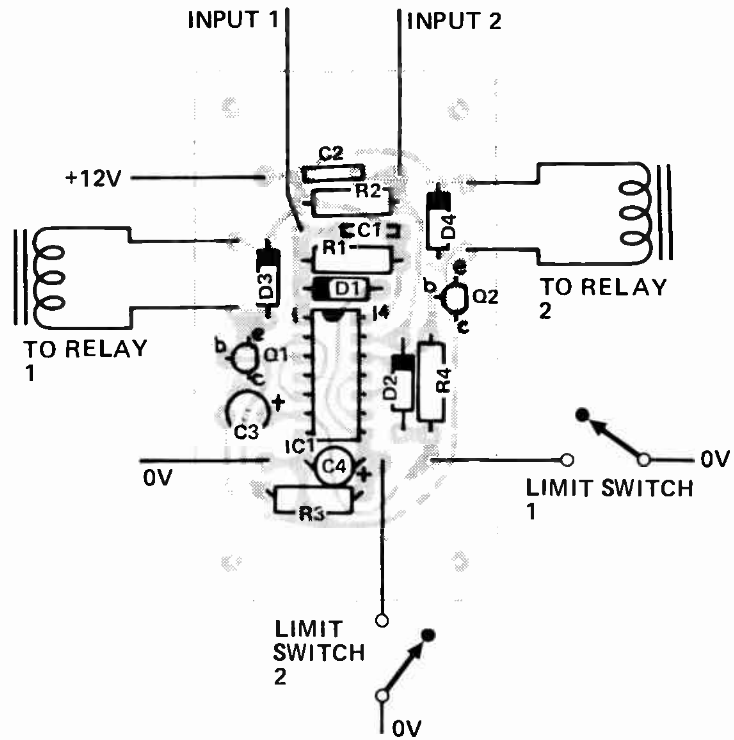


Fig. 4. Component overlay and interconnection diagram for the double-control relay driver.

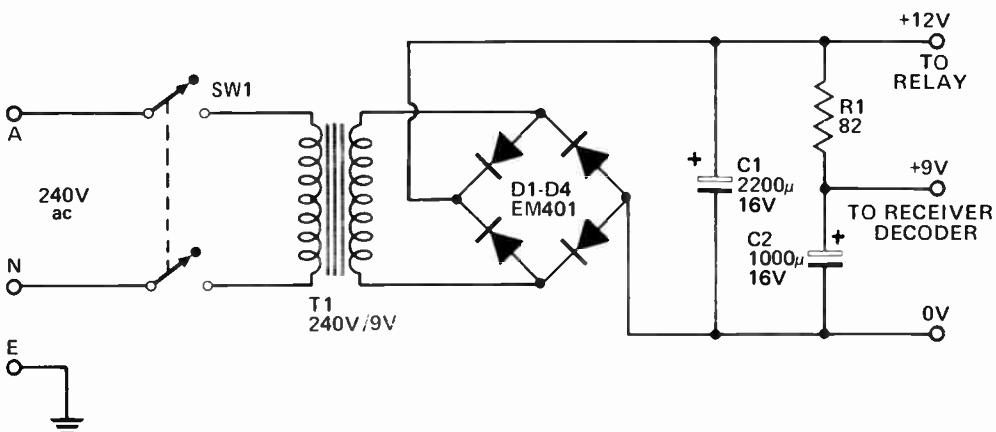


Fig. 3. Circuit diagram of the power supply for the complete receiver decoder. ETI 711P

Parts List ETI 711 B

Resistors all ½w 5%

R1	1 k
R2	10 k
R3-R10	100 k
R11	4k7
R12	1 k
R13	4k7
R14	1 k

Capacitors

C1	47 n polyester
C2,3	10 n polyester
C4,5	10 μ 16 V electro
C6	10 n polyester
C7	1n0 polyester
C8,9	100 μ 16 V electro
C10	10 μ 16 V electro

Semiconductors

D1-D7	IN914
Q1,2	BC548
IC1	4001 (CMOS)

PCB	ETI 711 B
RL1,2	Relays 12V coil 150 ohm or higher. Contacts to suit requirement.

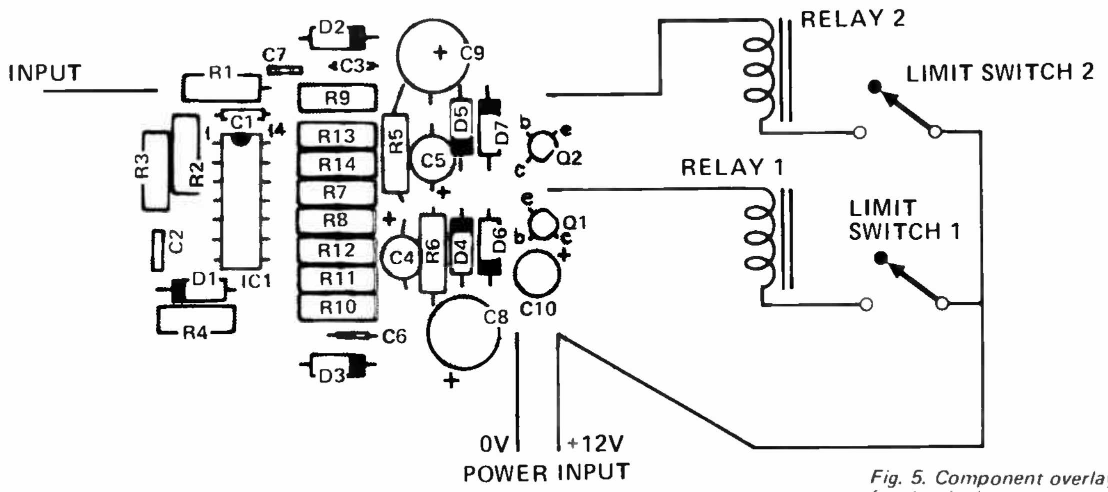


Fig. 5. Component overlay and interconnection diagram for the single-control relay driver. ETI 711B

Parts List ETI 711 C

Resistors all ½ w 5%

R1,2	1 k
R3,4	100 k

Capacitors

C1,2	47 n polyester
C3,4	10 µ 16 V electro

Semiconductors

D1-D4	IN914
Q1,2	BC559
IC1	4011 (CMOS)

PCB	ETI 711 C
RL1,2	Relays 12 V coil 150 ohm or higher. Contacts to suit requirement.

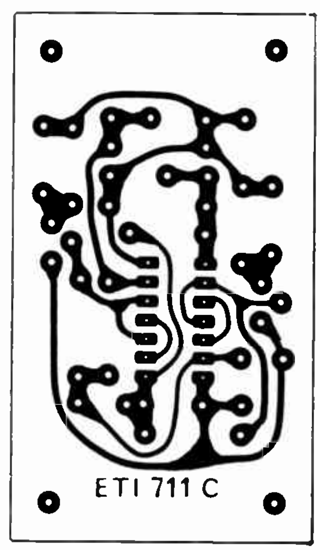


Fig. 6. Printed-circuit layout for the double-control relay driver.

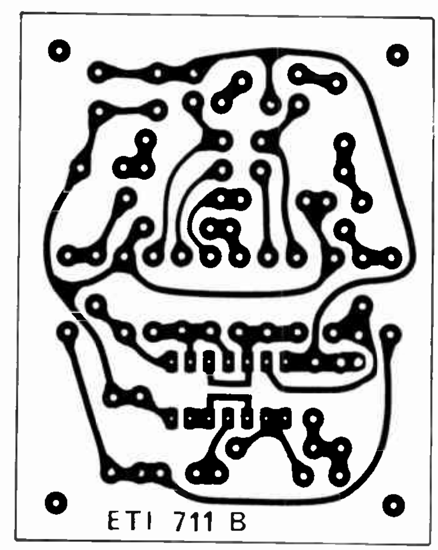


Fig. 7. Printed circuit layout for the single-control relay driver.

Parts List ETI 711 P

R1	Resistor	82 ohm 5% ½w
C1	Capacitor	2200 µF 16 V electro
C2	Capacitor	1000 µF 16 V electro
D1-D4	Diode	EM401 or similar
T1	Transformer	240 V/8.5-9.5 V DSE 2155 or similar

6 way tag strip

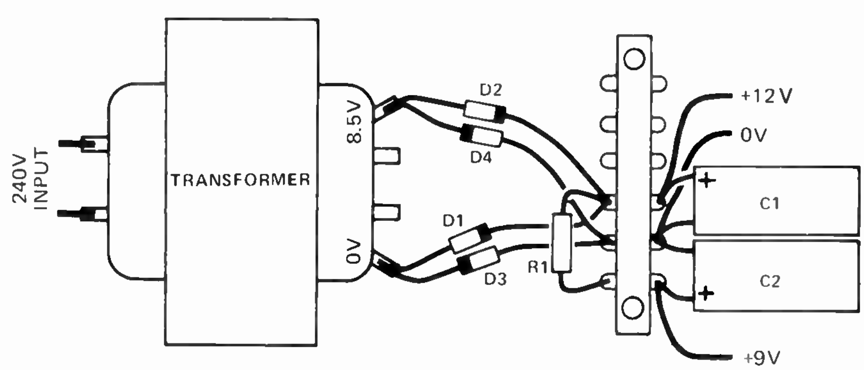


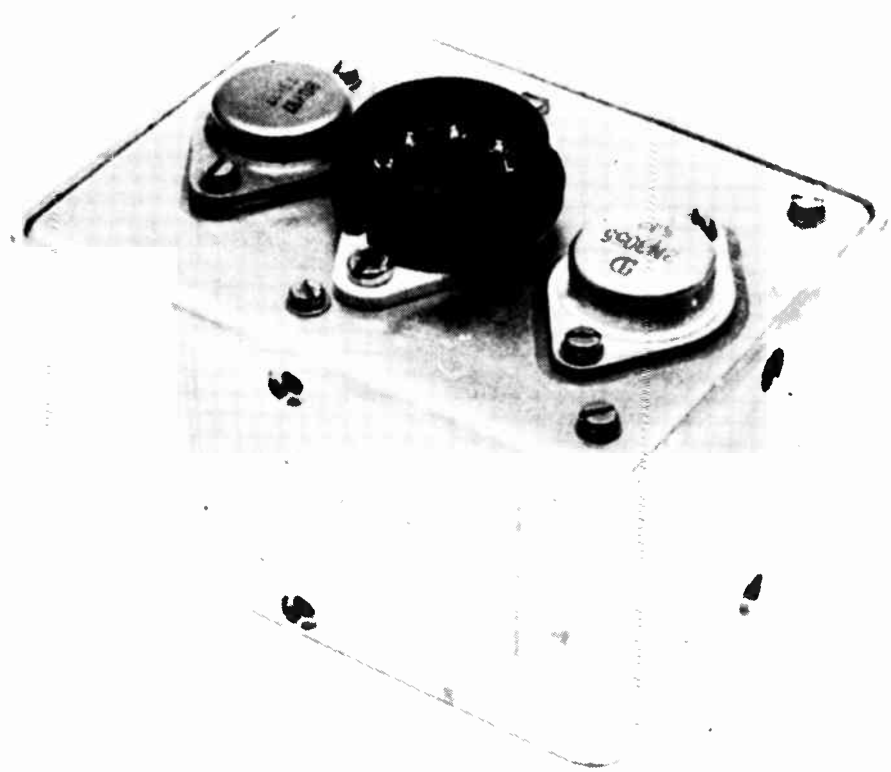
Fig. 8. Interconnection diagram for the power supply.

TRANSISTOR ASSISTED IGNITION

A reliable type of electronic ignition which uses the existing points in the distributor.

THE MOST POPULAR project for use in a car must be some type of electronic ignition. The Kettering system (the one used on most cars) is as old as the car itself and has not changed much over the years. It still works by a set of points which close, to allow the current to build up in the spark coil, and then open so that the energy in the magnetic field of the coil is used to generate the high voltage needed to fire the plugs. The system has problems at high speed in that the current does not have time to rise to a high enough level before the points open – resulting in the output voltage falling as the speed increases. At low speed (when starting) the points open too slowly and some energy is lost in arcing across the contacts. The use of a ballast resistor (usually about 1-1.5 ohm) and a lower inductance coil helps the high speed performance and shorting the ballast resistor while starting helps.

While this system has performance limitations it is reliable. The points need to be cleaned every 10,000 km or so but the system is unlikely to suddenly fail without warning.



Electronic Ignition

Electronic ignition has been around for about 15 years, but until recently no major car manufacturer has used it in production. This is due not only to the additional cost but mainly to the reliability problems (how many NRMA men carry spare transistors?).

The first electronic ignition system simply used a transistor to switch the main current – giving longer points life. Unfortunately in those days a high voltage transistor could handle a maximum of about 150 V and special transformers (ignition coils) had to be wound and a large ballast resistor was needed. These normally consumed about 10 or 15 A from the battery.

Soon afterwards dwell extenders made a brief appearance and these used an SCR to close the points about 1 ms after they opened, giving a longer time for the current to build up. This helped the high speed performance but did not help starting or points life.

The main system, which has been around for many years is CDI, where the required energy is stored in a capacitor and when required it is dumped into the spark coil which is used only as a transformer (not for energy storage). This system is economical on power, is good at both high and low speed and has been most popular with the hobbyist.

TRANSISTOR ASSISTED IGNITION

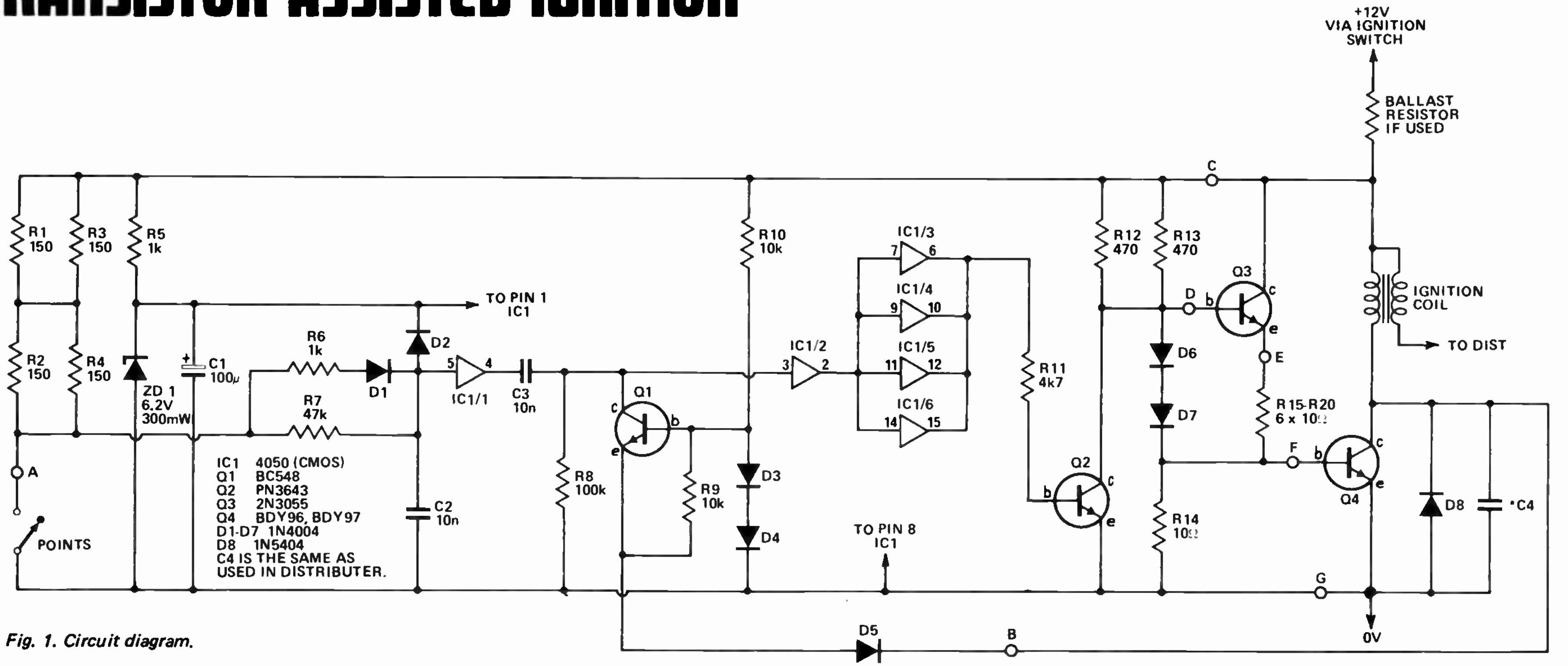


Fig. 1. Circuit diagram.

HOW IT WORKS ETI 316

The main current in the coil is switched by Q4 which is a 750 V 10 A transistor. The base current, of which about 500 mA is needed, is provided by Q3, which acts as a constant current source. We used this instead of a resistor as the supply voltage can vary from 6 to 12 volts (and the power dissipation would be too high). The current source is switched on and off by Q2 (the output transistor being off if Q2 is on). Diode D8 prevents reverse voltage damaging Q4 while C4 prevents the output voltage rising too high.

The points are supplied with a current, by R1-R4, of about 60 mA, which keep them clean, and when they open C2 is charged rapidly via R6 and D1. This is buffered by IC1/1 (IC1 is a CMOS hex buffer) which triggers the monostable made up of C3 and R8. This is then buffered by IC1/2 then by IC1/3-6 and this then controls the output stage. This will turn the output transistor off for about 1 ms (normal dwell) unless Q1 intervenes. This transistor operates if the output voltage falls to, or below, zero and resets the monostable, turning Q4 on again. This occurs after the first transient and ensures that Q4 is not turned on when there is high voltage across it.

When the points close C2 discharges more slowly via R7 and if the points open again quickly (ie, bounce) this is ignored. The supply voltage of IC1 is regulated by ZD1 and C1 to 6.2 V.

Construction

We made our prototype in a metal box — Horwood type 34/2/D. The two power transistors are mounted on the lid along with the changeover socket, capacitor C4, and the diode D8. All other components are mounted on the pc board which is mounted on 20 mm spacers.

The pc board should be assembled with the aid of the overlay in Fig 2. Ensure the transistors are oriented correctly — also check the diodes, IC1, and C1. The IC should be installed last. Mount the power transistors using insulating washers. The capacitor C4 should be the same type as used in the distributor. If desired it can be removed from the distributor and fitted on the coil itself, between earth and the negative terminal. In this place it will

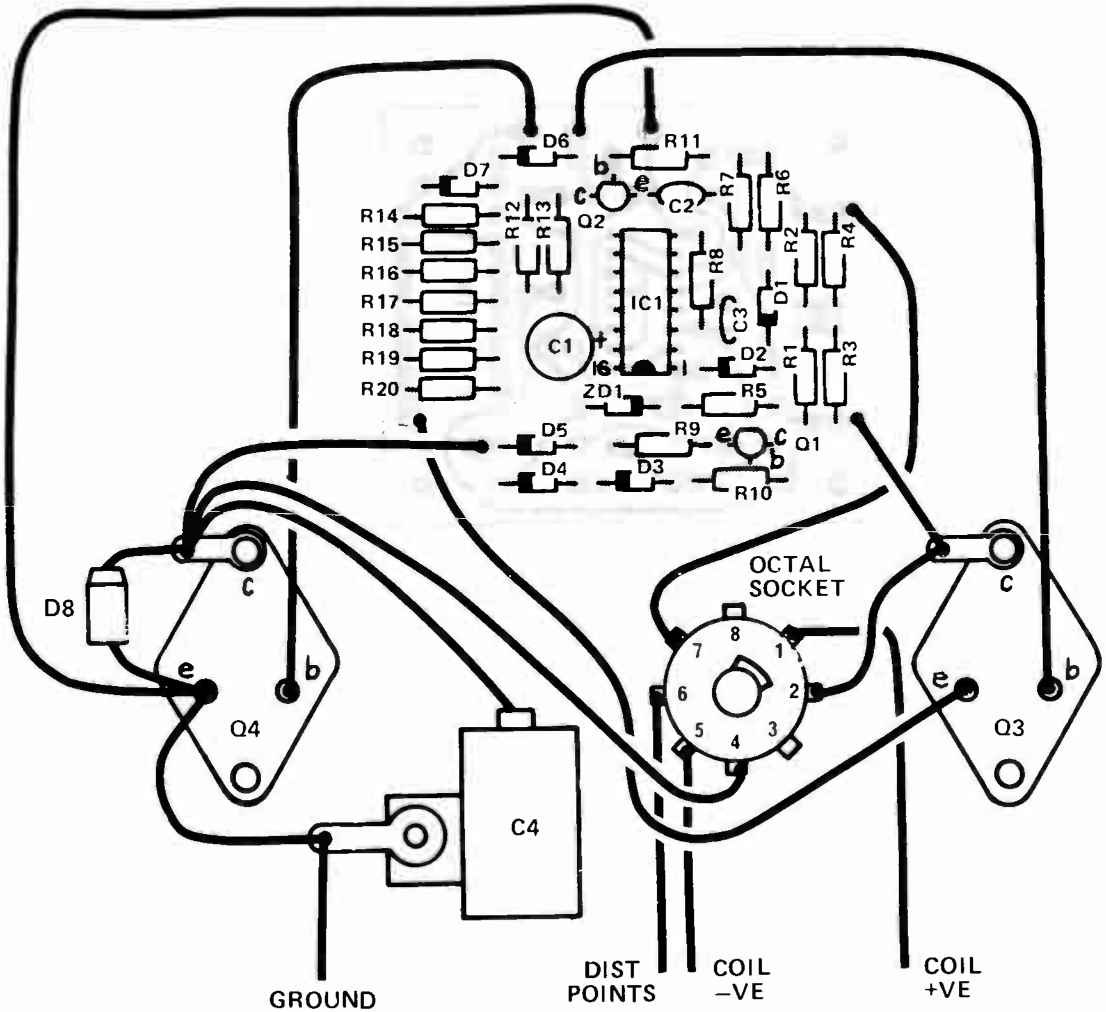


Fig. 2. Overlay and wiring diagram.

work for standard or assisted ignition.

The external wiring can now be done according to Fig 2. Ensure that the outer surface of C4 is connected to the emitter of Q4. When mounting the pc board ensure that the spacers do not touch any of the tracks if they do use a piece of insulation under the end.

As the octal plug has to be capable of plugging-in in two positions, ie, standard or assisted ignition, the socket has to be modified slightly. This entails making a new slot between pins 1 and 2 similar to the one between pins 1 and 8. This can be either a new slot or the existing slot can be widened. There are three links required in the plug, these being between pins 1&8, 3&4 and 5&6. With the plug in the normal position standard ignition is selected and in the second position transistor assisted ignition is operational.

PARTS LIST – ETI 316

Resistors all ½W 5%

R1-R4	150 ohm	
R5,6	1 k	
R7	47 k	
R8	100 k	
R9,10	10 k	
R11	4k7	
R12,13	470 ohm	
R14-R20	10 ohm	
Capacitors		
C1	100 μ 16 V electro	
C2,3	10 n polyester	
C4	see text	
Semi conductors		
Q1	Transistor	BC548
Q2	"	PN3643, 2N3643
Q3	"	2N3055
Q4	"	BDY96, BDY97

(If you have trouble locating a BDY96 or BDY97, A BUX80 may be substituted without changing any other components).

D1-D7	Diodes	1N4004
D8	"	1N5404
ZD1	Zener	6.2 V 300 mW
IC1	4050 (CMOS)	

Miscellaneous
PC board ETI 316
Case, Horwood 34/2/D or similar
Octal plug and socket
Four 20 mm long spacers

Today many of the major car manufacturers are offering electronic ignition either as standard or as an option. These however are not (generally) CDI but types similar to the earlier transistor switch type (using modern high voltage transistors). Some systems also eliminate the points – using either an optical or magnetic pickup instead.

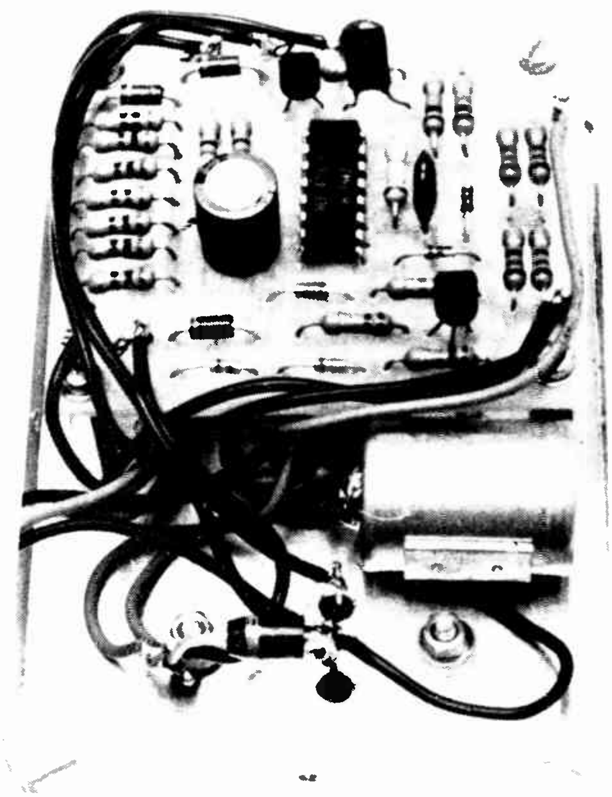
The system described here is a transistor switch type but with dwell extension built in. The unique circuit can provide a spark rate beyond that needed by most motors and will give a good spark at speeds which some CDI systems will stop. It is simple to install and we have provided a change-over plug (just in case you have problems).

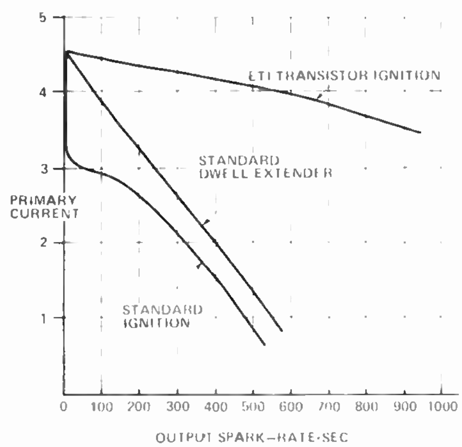
Design Features

The output transistor and the case are the major expenses and both are necessary. We therefore decided to see what other facilities we could add to make the project more worthwhile without making it much more expensive.

Adding dwell extension improves high speed performance but with the standard design method the voltage still falls somewhat at high speeds. After examining the primary waveform it was realised that when the points open a lot of energy is wasted in ringing and that the main spark energy occurs only in the first positive going transient. It was decided therefore to turn on the switching transistor (thus in effect reclosing the points) immediately after this transient. This provides a more stable spark of higher energy and allows very high speeds (over 1500 sparks per second) to be obtained. The primary current remains much more constant as the coil does not completely discharge each cycle.

Since the design was published a few readers found that this early switch-on caused misfiring. This occurs only with a very few, and generally older vehicles. If encountered it will almost certainly be cured by deleting diode D5.





Graph showing relationship between average coil current and spark rate for the different systems.

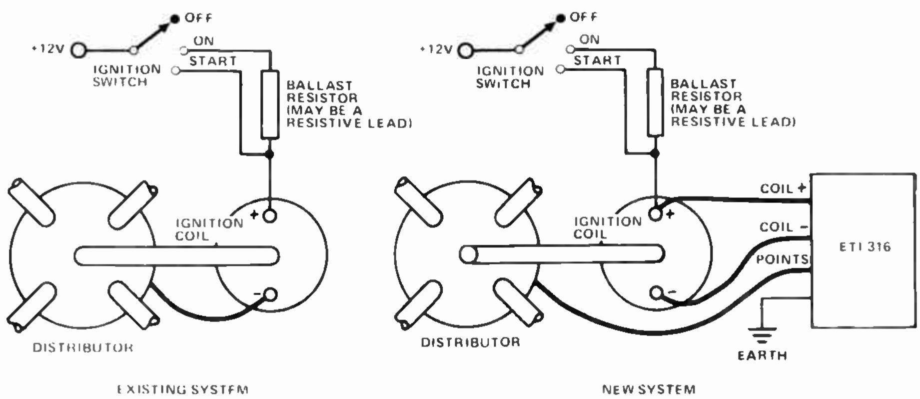


Fig. 4. Diagram showing how to connect the unit to the car.

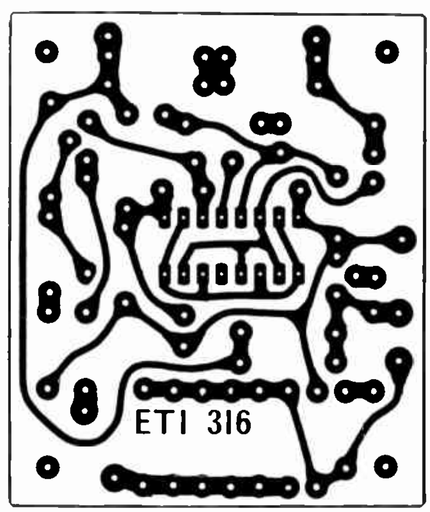
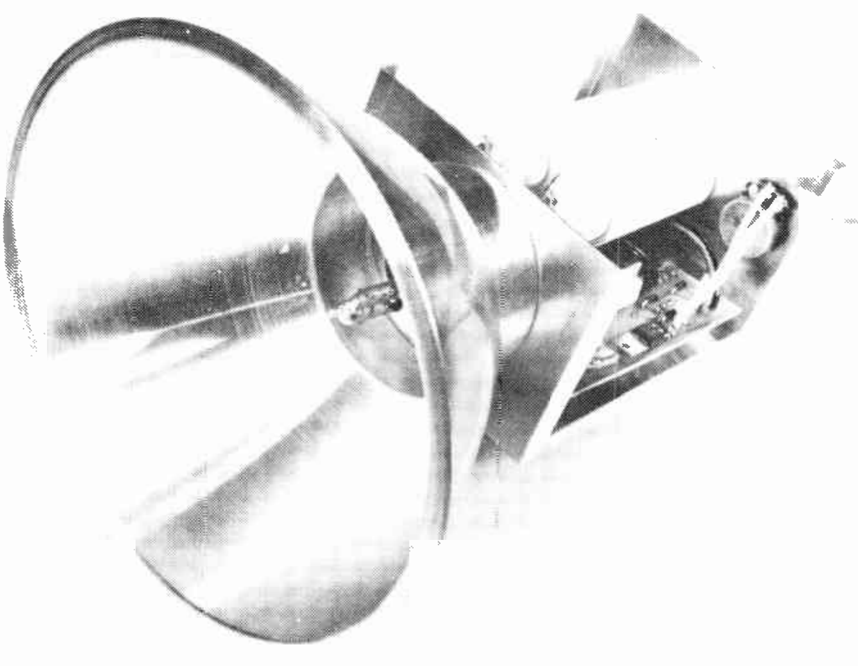


Fig. 3. Printed circuit board. Full size 65 x 55 mm.

Disco strobe light

We published our first strobe unit way back in August 1971. It has been one of our all-time popular projects. This unit is an up-dated version featuring a number of improvements.

Phil Wait



STROBE LIGHTS are very popular as lighting effects devices at parties and discos. Emitting a series of bright flashes of light several times per second, the movement of dancers takes on a jerky 'stop-motion' effect. Used in conjunction with coloured 'light show' effects units that vary the colour and intensity of a bank of lights, the overall effect achieved can be quite stunning.

We first published a strobe unit for this application back in August 1971. That was the ETI 505 High Power Strobe. It has been by far the most popular project we have ever described. The ETI 505 was still available as a kit – and a steady seller by all accounts – quite recently.

When the demand for a new strobe became apparent earlier this year, we sat down and took a long hard look at the original design. But despite all the revolutionary technology that has appeared since then, there was no way we could see of significantly altering the device to any advantage. That original design was just about the simplest, least expensive and most effective for a strobe that could be devised. However, experience over the years showed up a number of minor shortcomings and we have modified the circuit to eliminate these – and this Disco Strobe is the result.

The effect

How does a strobe produce the 'stop-motion' effect? Quite simply, really. At each flash of light, in a darkened room, you will see everybody in the position they are in at the instant of the flash. During the short interval before the next flash, they will have moved and you will see them in a slightly different position, and so on.

Thus, it seems they 'jump' from position to position and anything or anybody that moves does so in the characteristic jerky fashion. If the flash rate of the strobe is fairly close to the rhythmic movements of the dancers, the effect is quite dramatic.

Improvements

There were a couple of points on which we though the old strobe could be improved. Firstly, some constructors reported intermittent false triggering of the strobe tube, resulting in a disturbing 'flutter' in the flash rate. In the original circuit, the gate of the SCR pulsing the strobe tube was connected directly to the two neon trigger tubes with no resistor from the SCR gate to ground. Without being 'clamped' to ground by a resistor, the sensitive SCR gate is prone to being triggered by mains-borne noise 'spikes' capacitively coupled to it via the neon tube or adjacent circuitry. This has been corrected in the current project.

The second point was more of a construction problem. The capacitor charging circuit and the flash timing circuit on the original strobe were each powered by separate half-wave rectifiers. Now that appears like a full-wave bridge rectifier with the bridge not completed. Many constructors saw this and immediately took it to be a mistake – so they 'put it right' by connecting the cathodes of D3 and D4 in that circuit. The result was always disastrous! Our sympathies to those who were caught.

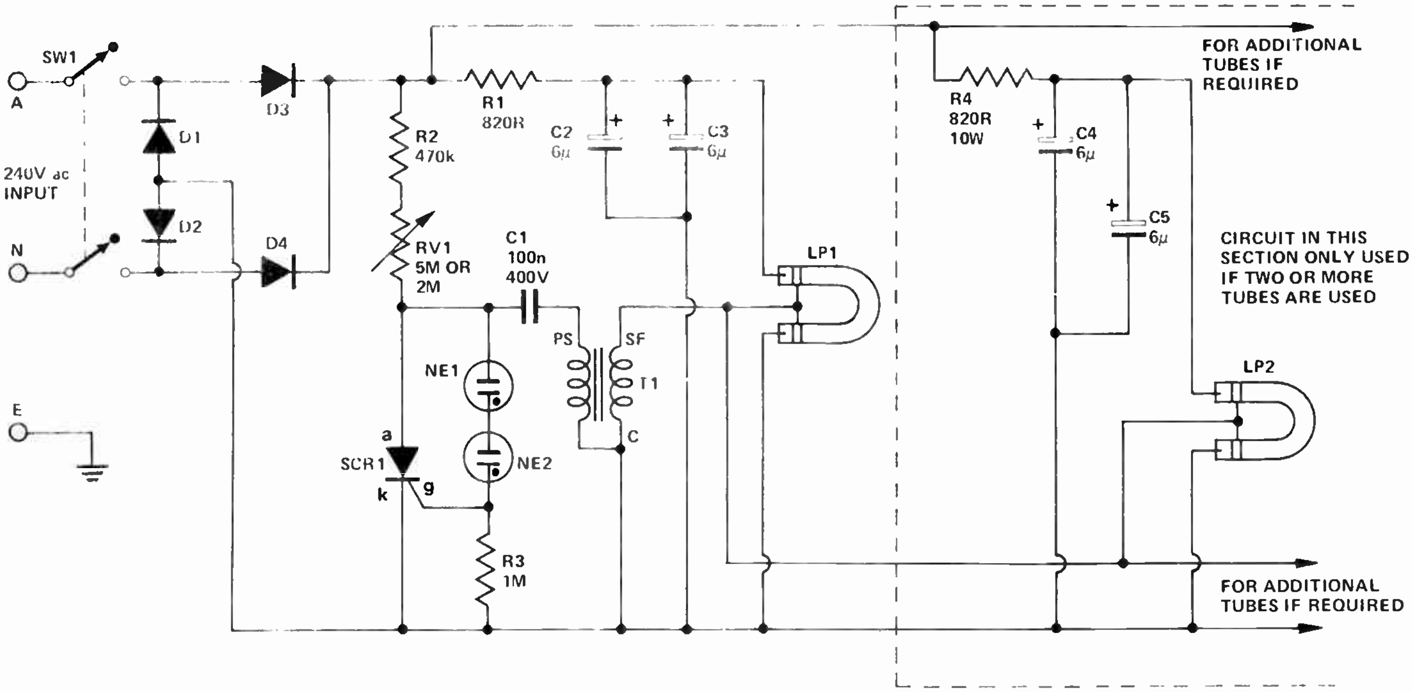
To avoid this occurring again we decided to use a conventional bridge rectifier to power the complete circuitry.

Construction

Carefully examine the photographs and the construction diagrams. Assembly is quite straightforward and little difficulty should be experienced. Care must be taken with the wiring though, as the unit operates directly from the mains.

The electronics is all mounted in a 145 x 115 x 90 mm aluminium box. A 180 mm diameter spun aluminium reflector is mounted on one end, the strobe tube(s) being mounted inside this by a plug and socket arrangement. An octal valve socket is used, its mounting screws being used to secure the reflector to the box.

At the opposite end of the box, the discharge capacitors are mounted, two or four being used depending on whether one or two strobe tubes are



HOW IT WORKS – ETI 574

The principle of operation of the strobe tube is discussed in the general text, so here we'll concentrate on the overall circuit.

The mains voltage is rectified by a diode bridge circuit formed by D1, D2, D3 and D4. Since there is no capacitor directly across the dc output of the bridge rectifier, the output consists of a series of half-wave pulses at a frequency of 100 Hz (i.e.: twice the mains frequency). The storage capacitors, C2 and C3 (plus C4, C5 etc if extra tubes are added) are charged from the bridge rectifier output via R1 (R3 etc for extra tubes). They will charge to the peak value of the rectifier output, about 340-350 volts. (That is, 1.414 times the mains voltage: 240 x 1.414 = 339 volts).

The resistor in series with the storage capacitors (R1, R3) limits the peak charging current to prevent damage to the rectifier diodes and also serves to isolate the strobe tube from the mains.

The two neon 'trigger' lamps, NE1 and NE2, each have a 'striking potential' of around 120 volts. That is, the neon gas inside will ionise, ('break down') and the lamp 'fires', conducting current very suddenly when this striking voltage is reached or exceeded.

Now, C1 is charged from the bridge rectifier output via R2 and RV1. As the voltage across C1 rises it will eventually reach the striking voltage of the two neons. As these are in series, the voltage across C1 must reach about 240 volts before they strike. When this occurs, a pulse of current will flow into the gate of SCR1, causing it to conduct. This effectively places C1 across the primary of T1 as the anode of SCR1 is then connected to earth for all intents and purposes. C1 will then rapidly discharge, the resulting pulse in the primary of T1 being transformed to about 4 kV at the secondary.

As the secondary of T1 is connected to the trigger electrode of the strobe tube, this will 'break down' and emit a bright flash of light when the trigger electrode receives the 4 kV pulse from T1.

After C1 has discharged, NE1 and NE2 will extinguish, SCR1 will turn off and C1 will commence to charge again. The whole cycle will then be repeated.

Varying the rate at which C1 charges, and thus the amount of time it takes to charge C1 to about 240 volts, will vary the time between flashes. Thus RV1, a 2 M or 5 M potentiometer, serves as a 'flash speed' control. Increasing the resistance of RV1, increases the time it takes C1 to charge to 240 volts, increasing the time between flashes – which decreases the flash rate.

The storage capacitors, C2 and C3 (with one tube), discharge when the strobe tube fires, recharging between successive flashes.

When two (or more) tubes are used, each must have a separate storage capacitor (made up of two capacitors here, for convenience) and limiting resistor, otherwise – as explained in the text – the first tube to fire in a parallel-connected arrangement would prohibit the other tube(s) from firing.

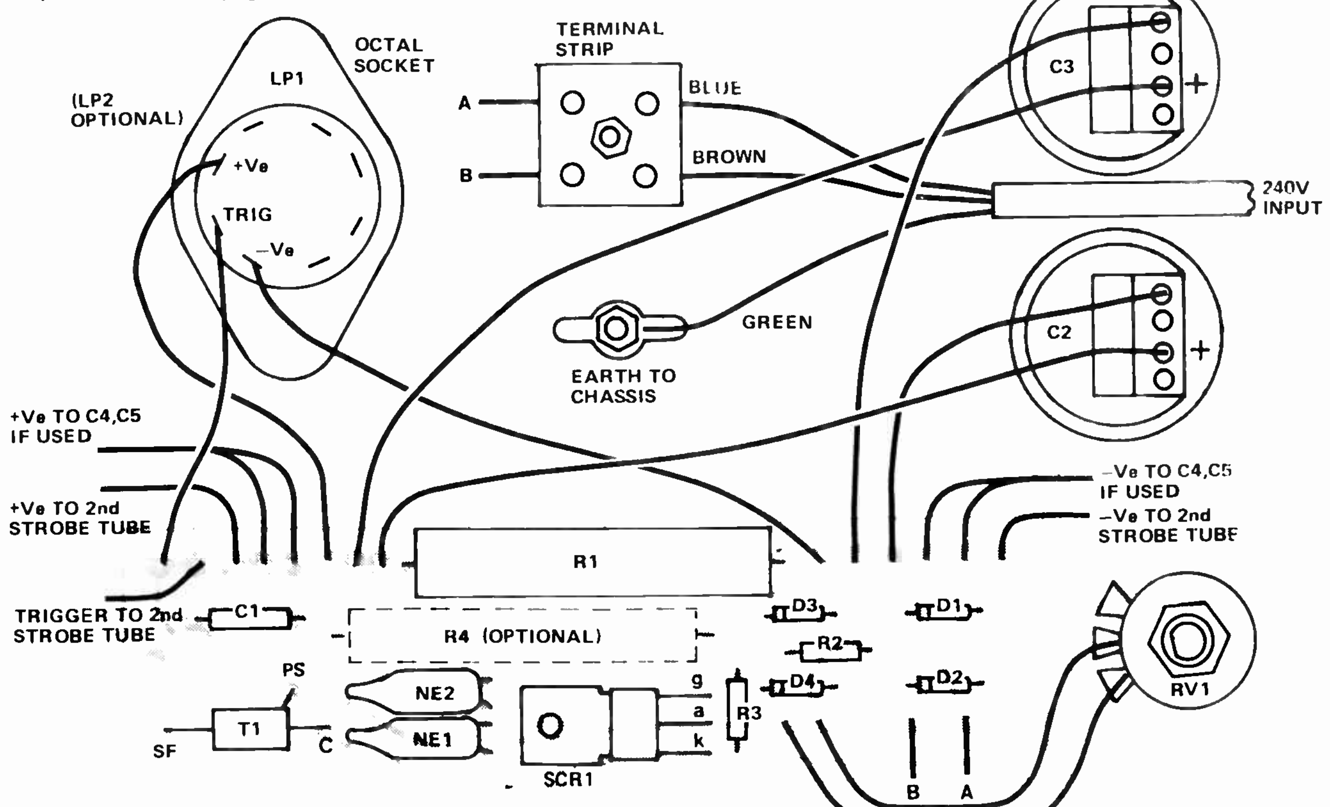
The resistor between the gate of SCR1 and ground, R4, prevents spurious triggering of SCR1.

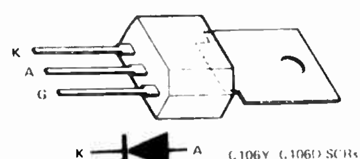
used. The capacitors specified have a threaded mounting bolt protruding from the base, making mounting a simple matter. Also mounted on this end of the box are the flash speed potentiometer and the power switch. The power cord passes through the panel also, being secured by a clamp-type grommet. A two-pole mains switch must be used and can be either a separate switch or integral with the flash speed potentiometer. Note that a switch-pot. has been specified in the parts list.

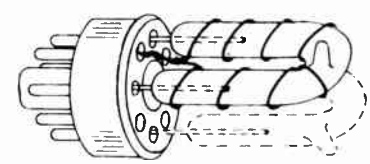
If one strobe tube is used, only two capacitors will be required. These should be mounted, so that two more may be mounted at a later stage if another strobe tube is added. The potentiometer may have a value of either 5M or 2M, depending on which is the more readily available. The 5M pot. will give a speed from about one flash per second to about 20 flashes per second. The slowest speed is somewhat too slow for most applications, but this matters little as the desired flash rate will be within the general speed range in any case. The 2M pot. gives a range of about two or three flashes per second up to about 20 flashes, as before.

Whatever you do, do not omit the plastic cover over the front of the reflector. This is to prevent accidental contact with the flash tube and the lethal voltages present.

The pc artwork is on page 83.







PARTS LIST – ETI 574

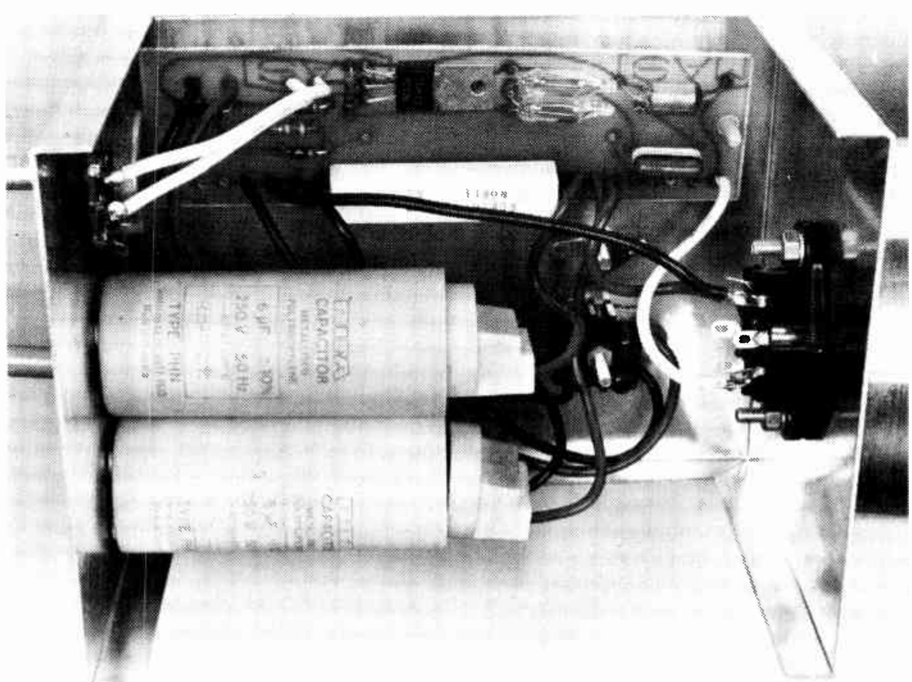
Resistors
R1 . . . . .820R 10W
R2 . . . . . . .470k ½W
R3 . . . . . . .1 meg
R4* 820R 10W
RV1 . . . . . .2M or 5M linear potentiometer with double pole switch (see text)

Capacitors
C1. . . . . .100n 400Volt polycarbonite
C2,C3,C4*, C5* . . . . . 6μF 240Vac capacitor (RIFA type PHN)

Semiconductors
D1-D4 . . . . . IN4004,EM404,A14A or sim.
SCR1 . . . . . .C106D,BT100A 500R, or sim.

Miscellaneous
NE1,NE2. . . .neon indicator tube GE - NE2
LP1,LP2* . . .Strobe tube, Circuit Components type MFT 1210 or Dick Smith type.
T1. . . . . . . .pulse transformer to suit tube type TR4KN or sim.
Octal Plug . . .McMurdo L8USR1
Octal Socket McMurdo type RT8, reflector, metal box 145 mm x 115 mm x 90 mm, perspex cover, hinge, magnetic catch, power cable, ETI 574 pc board.

*Components marked with an asterisk are only used for two tubes.



Caution!

The entire circuit is at mains potential (including the tube) and, if you don't want to fry yourself — or be responsible for somebody else accidentally doing likewise — it is essential that the case be securely earthed. The power cord must be arranged and secured strictly as shown in the diagrams. Use proper 240 Vac rated wiring (23-0076 PVC insulated) for all connections. For safety's sake, a perspex cover is bolted over the open end of the reflector.

Assemble the printed circuit board according to the overlay, noting the polarity of the diodes. If two strobe tubes are to be used, include the additional 820 ohm, 10 watt resistor as shown.

Plastic standoffs must be used to mount the pc board. These standoffs decrease the chance of a short to the metal case. They are necessary secondly because the trigger transformer develops 4 kV pulses which could possibly develop arcs across the pc board should metal standoffs be used.

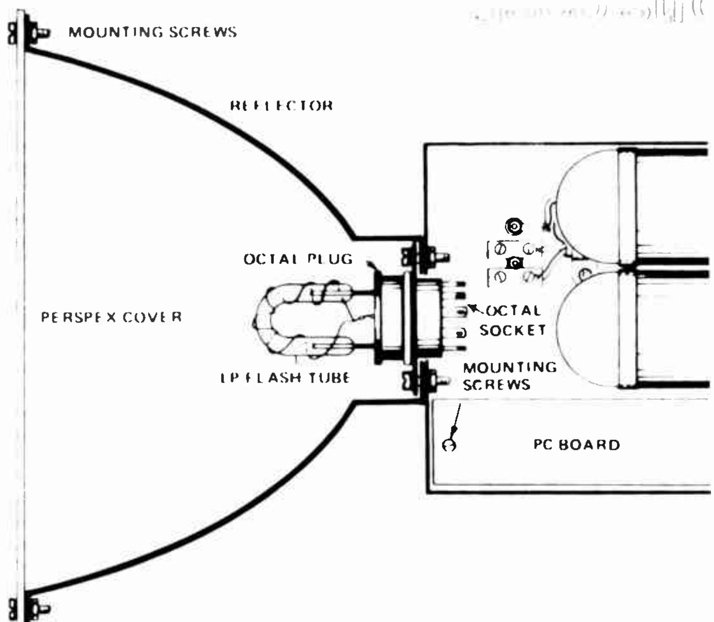
The strobe tube itself is not a critical component. Two types are commonly available. The type MFT1210 from Circuit Components of Bexley NSW is one such unit. Another is that advertised by Dick Smith, (catalogue No. S-3882).

Neither of these tubes includes a trigger electrode, so one must be attached. This is simply made by winding a length of 22 gauge (or some gauge thereabouts) tinned copper wire around the glass and taking it down to a spare pin in the octal base on which the strobe tube is mounted. The diagram shows how one or two tubes, together with their trigger electrodes, are mounted in the octal plug.

When you have the assembly complete make sure all components are securely mounted and there are no short circuits or any possible — and RE-CHECK THE EARTH CONNECTION.

The smoke test

Perhaps that's a little too strong! Nevertheless, once you have the unit assembled and carefully checked, set the speed potentiometer to minimum flash rate (fully anticlockwise), plug in and switch on. If all is well, the strobe should flash about once per second or a little faster, depending on which value pot. is installed. Advancing the control should increase the flash rate.



How the strobe tube works

For those not familiar with a strobe tube and the way it works, the following explanation should, er . . . throw some light on the subject.

A strobe tube is a simple tube of glass, sealed at the ends and bent into a convenient shape, evacuated and then filled with a tiny amount of one of the rare gasses — in this case Xenon. Small metal electrodes are sealed in the ends of the tube, projecting into the interior. A third, 'trigger' electrode is attached in some manner around the outside of the tube, though not completely covering it. Some 300 to 500 volts dc is applied between the two end electrodes, generally from a storage capacitor, but the resistance of the gas is very high at this stage and negligible current will flow. When a very high voltage pulse, about 4 kV, is applied to the trigger electrode, the gas inside the tube ionises ('Breaks down'), its resistance falling quickly to a very low value. The storage capacitor discharges through the tube and an enormous current flows — amps of it! — the voltage across the electrodes falling in about 100 microseconds to a value below that necessary to maintain the gas ionised. When the gas ionises it emits an intense burst of light, extinguishing when the discharge ceases.

The amount of light produced during each flash is dependent on the value of the discharge capacitor and the voltage across it. For those interested, the formula for the energy of the discharge is:

$$E = \frac{1}{2}CV^2$$

where E is the discharge energy, in joules
C is the capacitance in Farads
V is the voltage

Increasing either the capacitance or the voltage will increase the energy of the discharge, and hence the light output. However, as the output is increased, tube life falls off dramatically.

A better way to obtain more light output is to use two tubes. Separate storage capacitors are necessary as each tube varies with regard to discharge characteristics. If two tubes are simply connected in parallel, whichever commences to discharge first — even though it may only be microseconds earlier — will prevent the other tube from firing.

In the circuit used for this strobe unit, two 6 uF capacitors are used in parallel for the storage capacitor. For two tubes, another two capacitors are used. The same trigger transformer may be used to trigger both tubes in a twin-tube model.

For small rooms or total darkness, the light output of a single tube unit will be more than adequate. For larger rooms, halls etc, two tubes will be necessary. ●

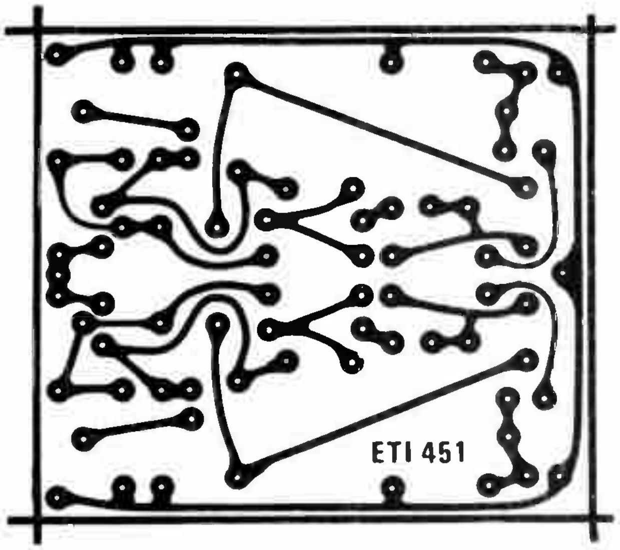
WARNING

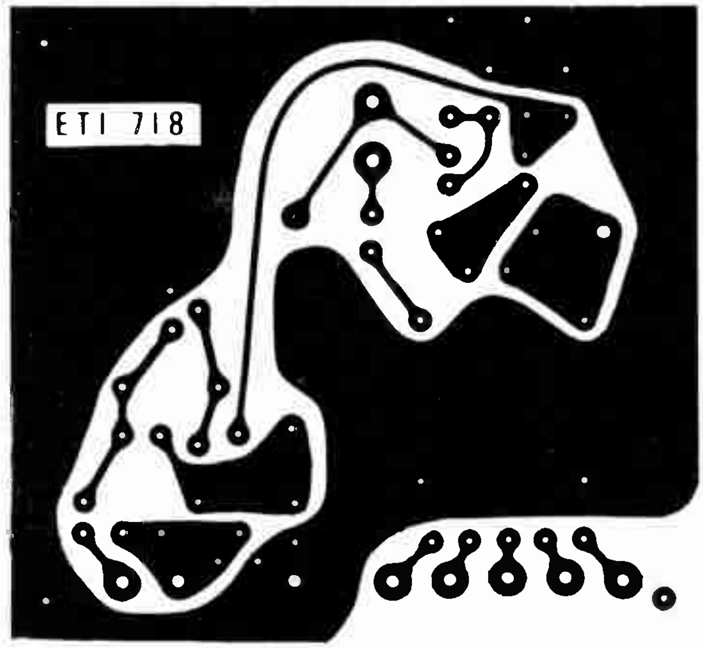
Repetitive pulses of light — especially around nine flashes per second — can cause epileptics to have convulsive seizures.

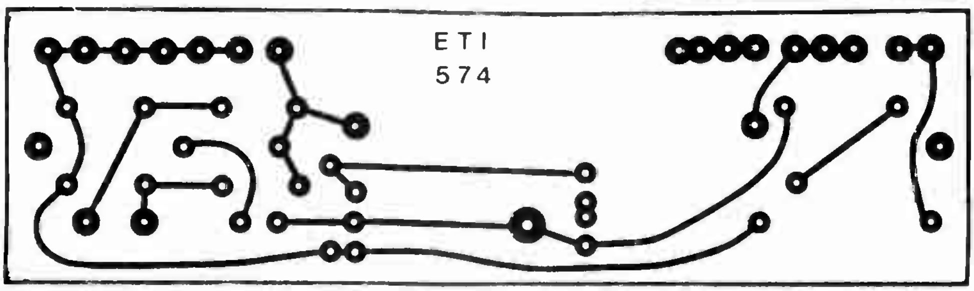
Those prone to grand mal, or psychomotor attacks should avoid areas where strobe lights are operating. In fact, most people will suffer nausea or headaches after long exposure to a strobe.

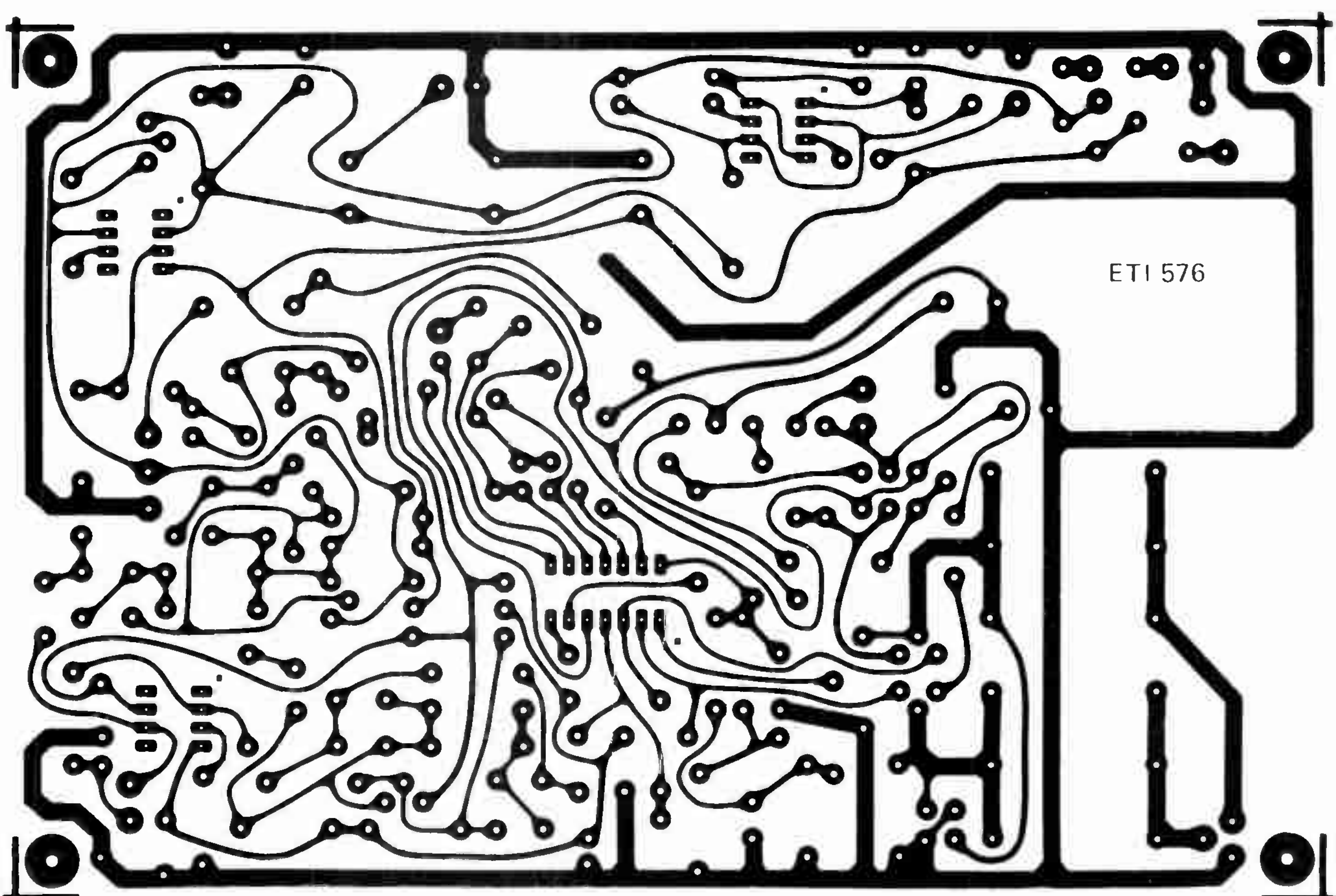
In the event of an attack whilst the strobe light is operating, it must be turned off immediately.

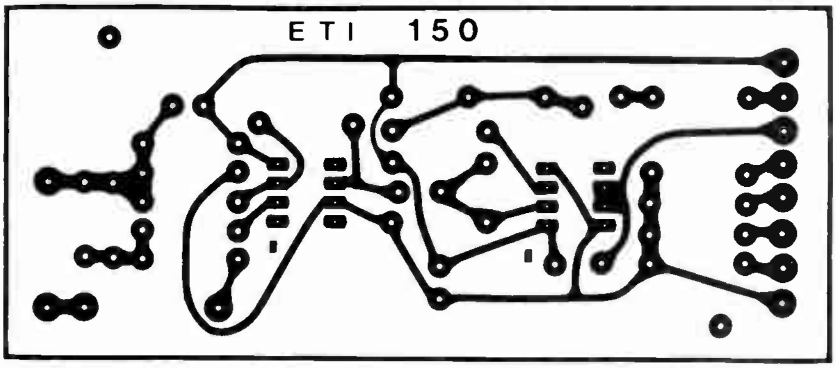
PCB's







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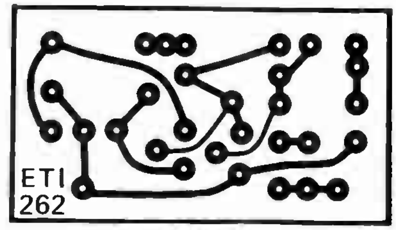
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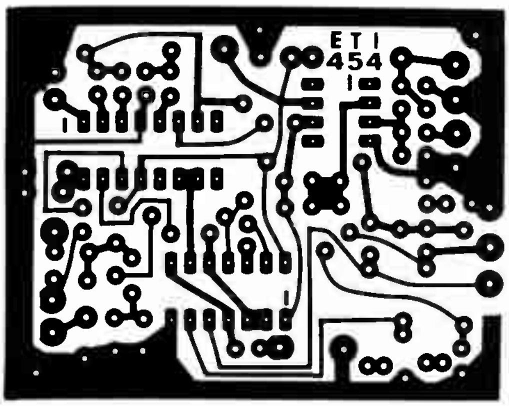
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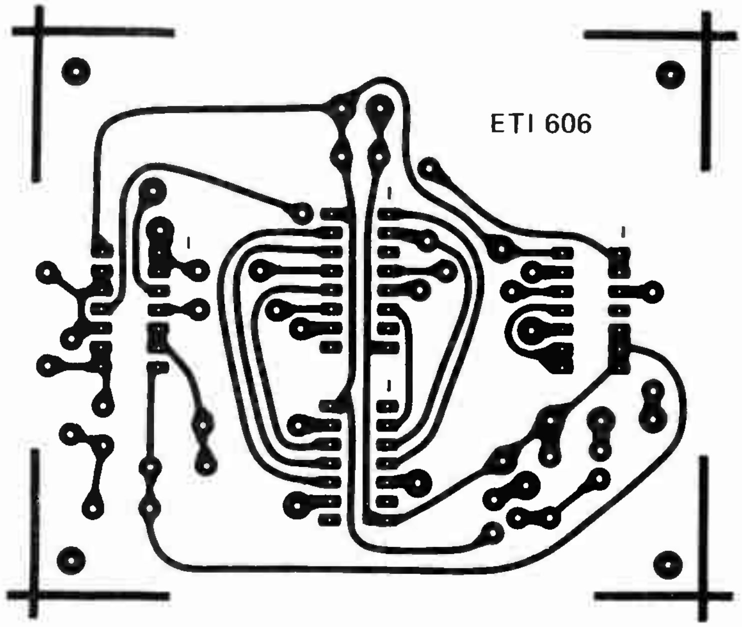
454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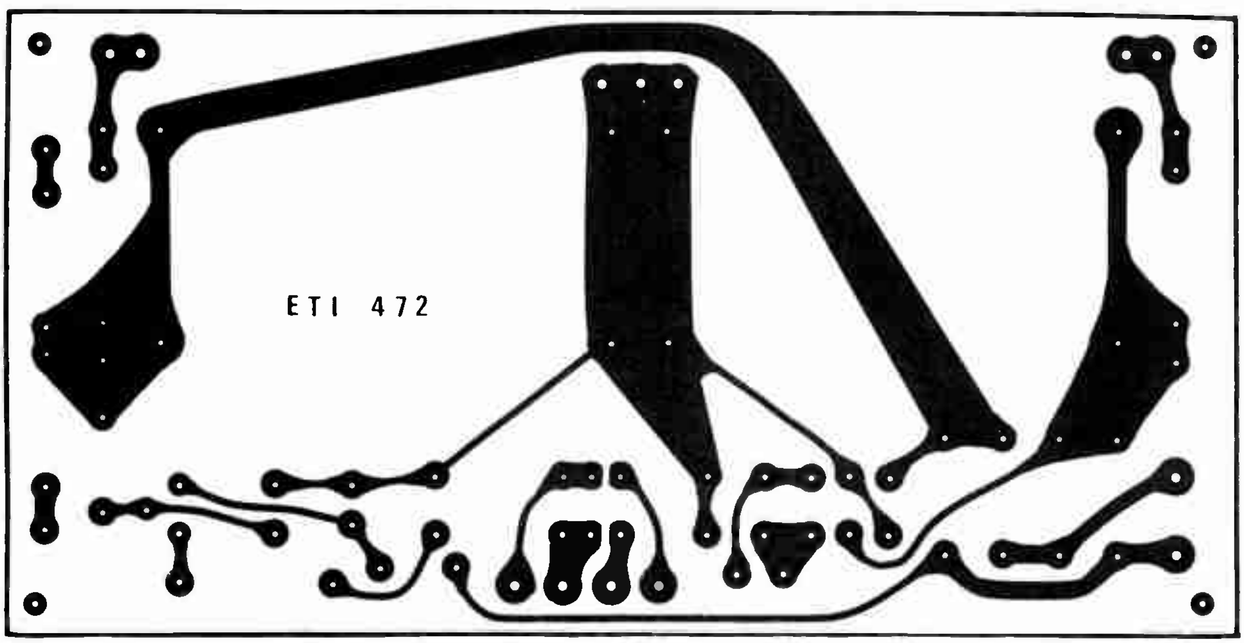
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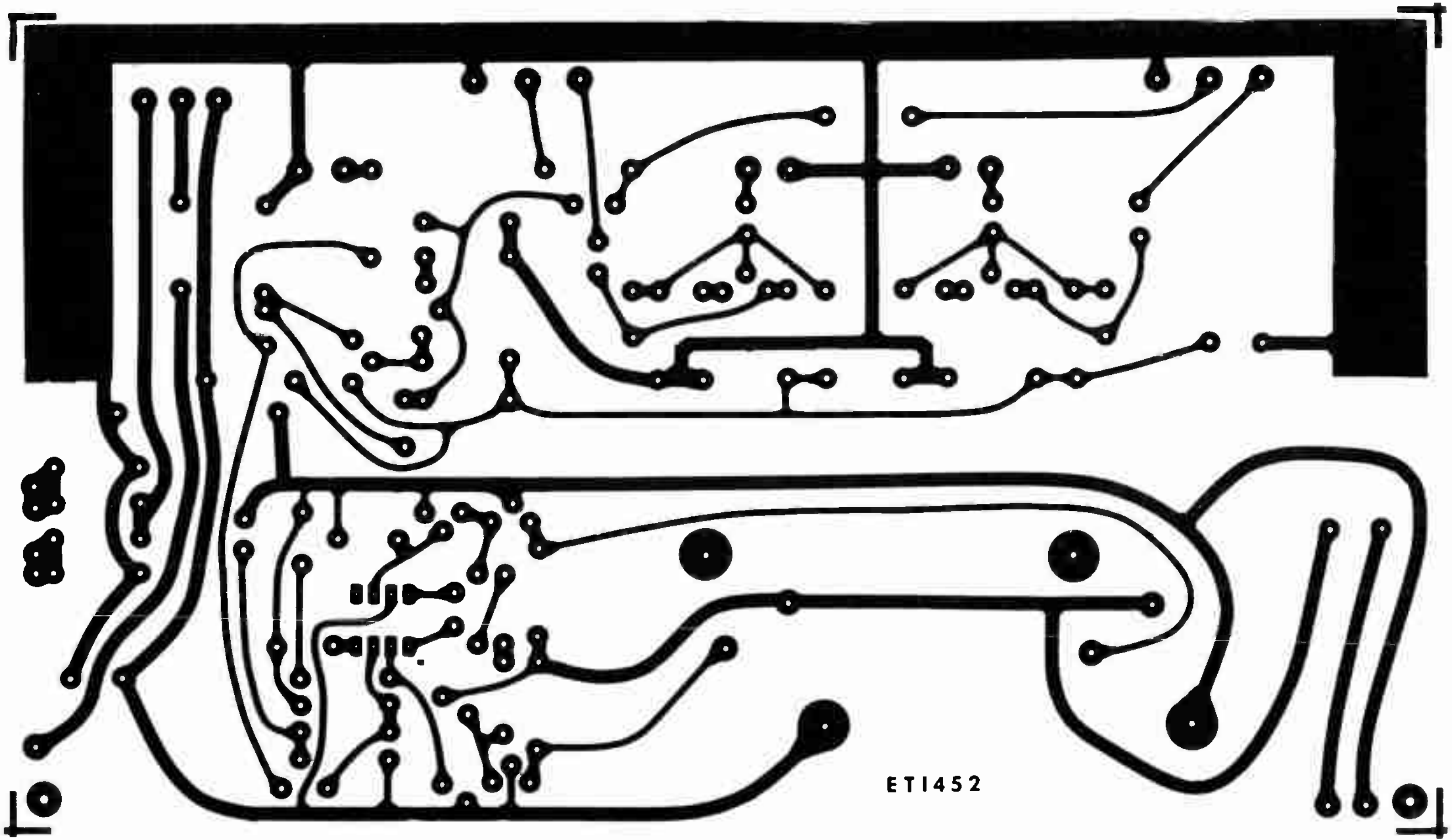
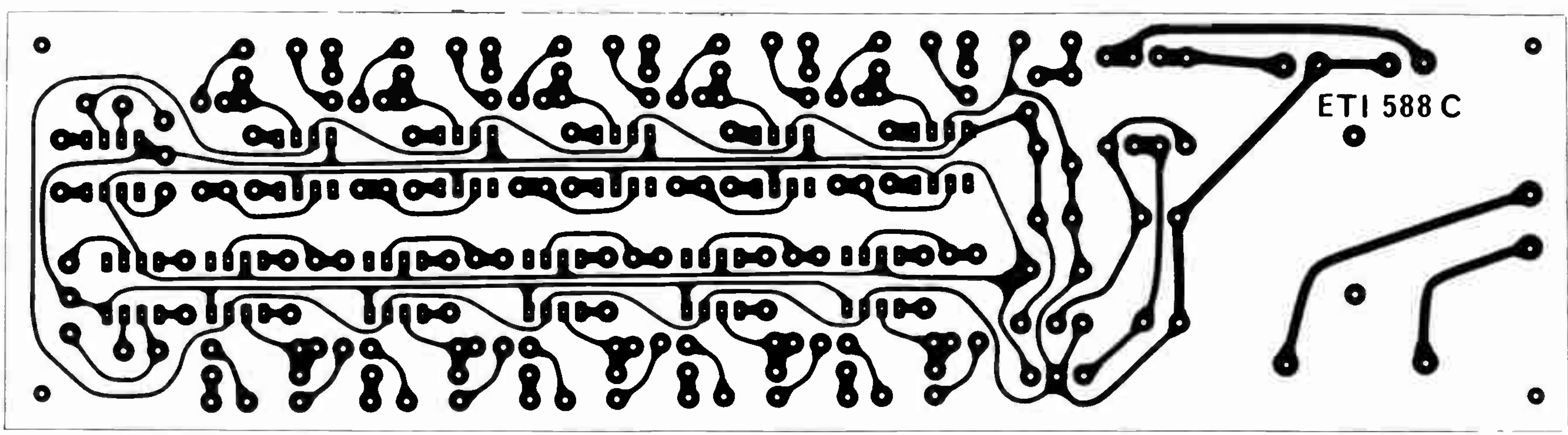

ETI452


ETI 588 C

Shoparound

THIS PAGE is to assist you in finding parts and kits for the projects featured in this book. So far as we have been able to ascertain at the time of going to press, the information contained here is accurate. However, for a variety of reasons, the situation may change and suppliers may discontinue a project, or line of components, for one reason or another and it is always wise to check that what you want is available.

Printed circuit boards

First of all, the printed circuit boards for all of these projects may be obtained from the following firms. If they don't have them in stock when you enquire, they will obtain them to order within a very short time. Here they are:

RCS Radio
651 Forest Road, Bexley NSW.

Radio Despatch Service,
869 George Street, Broadway NSW.

All Electronic Components
118 Lonsdale Street, Melbourne Vic.

In addition, the particular suppliers mentioned later, in conjunction with individual projects, can supply pc boards and components too.

The projects have been ranked in numerical order here, along with the information about suppliers relevant to each, as this makes it easy to dig out the information you require.

Kits of components for many of the projects in this book are available from various component suppliers. Listed below are some of the companies we suggest you contact.

Applied Technology Pty Ltd, 1A Pattison Avenue, Waitara, NSW 2077. Ph. (02) 487-2711.

Bill Edge Electronic Agencies, 115 Parramatta Road, Concord (PO Box 1005, Burwood North 2134). Ph. (02) 747-6472.

J.R. Components, PO Box 128, Eastwood, NSW 2122. Ph. (02) 85-3976.

Dick Smith Electronics P/L, Cnr Waterloo & Lane Cove Roads, North Ryde, 2113. Ph. (02) 888-3200.

All Electronic Components, 118 Lonsdale Street, Melbourne, Vic 3000. Ph. (03) 662-3506.

Tasman Electronics, 12 Victoria Street, Coburg, Vic 3058. Ph. (03) 354-5062.

Jaycar Pty Ltd, PO Box K39, Haymarket, NSW 2000. Ph. (02) 211-5077.

S M Electronics, 10 Stafford Court, Doncaster East, Vic3109. Ph. (03) 842-3950.

Ellistronics, 289 Latrobe Street, Melbourne, Vic 3000. Ph. (03) 602-3282.

Mode Electronics, PO Box 365, Mascot, NSW 2020. Ph. (02) 666-6324.

Orbit Electronics, PO Box 7176, Auckland, New Zealand.

Pre-Pak Electronics, 718 Parramatta Road, Croydon, NSW 2132. Ph. (02) 797-6144.

Rod Irving, PO Box 135, Northcote, Vic 3070. Ph. (03) 489-8131.

Silicon Valley, 23 Chandos Street, St. Leonards, NSW 2065. Ph. (02) 439-4655.

Willis Electronics, 993 Hay Street, Perth, WA 6000. Ph. (09) 321-7609.

Trilogy, 40 Princes Highway, Fairy Meadow, NSW 2519.

150, 200 and 300 series projects

The three test instruments, ETI-150 – ETI-151 – ETI-152, generally include readily available components. Although we have specified C & K brand switches, sold by Silicon Valley stores around Australia and in New Zealand, most miniature switches of the same number of poles/positions will suffice. The 100 µA University meter specified in the **Analogue Frequency Meter (ETI-150)** is stocked by Radio Despatch Service in Sydney and All Electronic Components in Melbourne, and probably quite a number of other suppliers. The same two firms stock the close tolerance 1 n capacitors for the **ETI-152 Capacitance Meter**. The close tolerance resistors used in the **ETI-151 Linear Scale Ohmmeter** aren't common, but you could try Radio Despatch Service in Sydney; or, in Melbourne, try All Electronic Components or Stewart Electronics (33 Sunhill Rd, Mt Waverley 3149 277-0622). The cases for these three projects are distributed by A & R Soanar and are available from most electronic suppliers.

The components for the **ETI-262 Simple Intercom** are all very common. We are not aware of any supplier carrying a kit for this project, but the pc board (you'll need two, remember) and components are all available from Radio Despatch Service in Sydney plus All Electronic Components and Rod Irving Electronics in Melbourne.

The **Transistor Assisted Ignition (ETI-316)** uses some unusual components, but you should not have too much difficulty locating suppliers. So far as we are aware, kits are stocked by All Electronic Components and SM Electronics in Melbourne, Willis Electronics in Perth and Orbit Electronics in Auckland, New Zealand.

400 series projects

In general, pc boards and parts for all the audio projects featured in this book are widely available, quite a number of suppliers offer complete kits, right down to metalwork and snazzy front panels.

The **ETI-451 Hum Filter** is available as a kit from Dick Smith stores, everywhere and also from All Electronic Components and Tasman Electronics in Melbourne. Printed circuit boards are available individually from the suppliers mentioned earlier.

We understand the **Guitar Practice Amp (ETI-452)** should be available as a kit from All Electronic Components in Melbourne and pc boards will be available from the usual suppliers. No special components are used.

The **ETI-454 Fuzz/Sustain Unit** is not as straightforward as the Guitar Practice Amp, but pc boards and components may be obtained from Radio Despatch Service and Jaycar in Sydney, or All Electronic Components and Ellistronics in Melbourne.

The **ETI-466 300 W Amp Module** is quite a special project. Nevertheless, kits may be obtained from Electronic Agencies, Jaycar and Dick Smith Electronics in Sydney or Rod Irving Electronics and All Electronic Components in Melbourne. The 'special' components (MJ15003/4 transistors, filter capacitors, pc board, transformer) may be obtained individually from Ellistronics and Rod Irving Electronics in Melbourne, if you have the other components on hand. In addition, Electronics (distributors) of Shops 2-3, 7/10 Joyce St, Pendle Hill NSW and Silicon Valley stores should stock the MJ15003/4 output transistors and the filter capacitors.

The Series 4000 Stereo Amplifier consists of four modules – two ETI-470 60 W Low Distortion Amplifiers, one ETI-471 Stereo Preamp and one ETI-472 Power Supply. It would be easier to list who *doesn't* stock these kits. However, complete kits, with all metalwork, front panel etc, can be obtained from Electronics Agencies in Sydney, or in Melbourne – All Electronic Components, Rod Irving Electronics and Tasman Electronics.

As the ETI-470 60 W Amp modules are popular and useful in their own right, here is a list of suppliers who carry kits and/or components: In Sydney – Applied Technology, Electronic Agencies and Pre-Pak Electronics; in Melbourne – All Electronic Components, Tasman Electronics, Rod Irving Electronics and Ellistronics: plus Willis Electronics in Perth and Silicon Valley Stores.

The **Moving-Coil Cartridge Preamp, ETI-473** is available as a kit from All Electronic Components in Melbourne; printed circuit boards from the usual sources. Kits etc for the power supply for the preamp (ETI-577) are available from the same sources.

The **High-to-Low Impedance Interface** for the 60 W Amp module is a fairly simple device, nothing special here, and components are widely available. Printed circuit boards may be obtained from the pc board suppliers mentioned earlier.

The **Series 4000/1 Four-Way Loudspeaker** is a top-line project for the serious do-it-yourself audiophile. Electronic Agencies in Sydney stock complete kits as do Philips dealers and agents around Australia. More information can be obtained by writing to Philips at PO Box 50, Lane Cove NSW 2066.

500 and 600 series projects

First in numerical order in this category is the **ETI-573 Universal Process Timer.** As no special components are used, you should have little difficulty obtaining parts. Printed circuit boards are obtainable from the usual suppliers, plus Rod Irving Electronics and Ellistronics, both in Melbourne.

The **ETI-574 Disco Strobe** is another kettle of fish! You'll find Dick Smith stores and All Electronic Components stock kits, while the pc boards are available from the usual suppliers (plus Rod Irving Electronics and Ellistronics). For the resourceful constructor, not starting from scratch, the strobe tube (type MFT1210) and trigger transformer (type TR4KN) are available from Circuit Components in Sydney (383 Forest Road, Bexley NSW 2207, 59-6550, 59-3720) and All Electronic Components in Melbourne. Dick Smith stock a suitable strobe tube (Cat. No. S-3882) and trigger transformer (M-0104) also. The 6 μF, 240 Vac rated capacitors used in this project are a common electrical item used in fluorescent light installations. They are available from electrical wholesalers such as George Brown and Martin de Launay in Sydney, plus Dick Smith and All Electronic Components, if you only want them as separate items. The reflector for this project is a common photographic item, but the kit suppliers will have them specially made to suit the project.

The **Electromyogram (ETI-576)** is available as a complete project from All Electronic Components, while the pc board and all the components are available as separate items from Radio Despatch Service in Sydney.

The **ETI-577 Power Supply** was designed expressly for the ETI-473 MC Cartridge Preamp, but is suitable for many other applications – kits from All Electronic Components, pc boards from the usual sources.

The **Ultrasonic Switch (ETI-585)** is available in kit form or as separate components, from Rod Irving Electronics and All Electronic Components in Melbourne and Dick Smith stores.

The **ETI-588 Theatrical Lighting Controller** is quite a specialised project. Module kits and complete kits, including all metalwork, are available from Nebula Electronics in Sydney. Meanwhile the **Electronic Tuning Fork (ETI-606)** has only one special component – the 3.579545 MHz crystal (often marked just 3.579). Dick Smith stocks them (Cat. No. K-6031), as do All Electronic Components.

700 series projects

The **Remote Control Unit (ETI-711)** is not stocked as a kit by any suppliers, so far as we are aware, but the pc boards are available from the usual suppliers and there are no special components – so, all you have to do is shop around for the best prices! The crystals may be ordered to frequency from a number of sources, but check your usual supplier first.

The simple **Shortwave Receiver, ETI-718**, is a little gem to get going. All Electronic Components stock a kit, but parts are obtainable from just about every supplier while the pc board is available from the sources mentioned earlier.

Similarly, the **ETI-721 Aircraft Band Converter** is stocked by Dick Smith and All Electronic Components, but parts and pc boards are readily available. Suppliers of parts for the antenna to suit this project (ETI-722) are listed in the article, on page 81.

● Test Gear 1

Your confidence to tackle more complex projects will increase dramatically if you have the right test equipment to troubleshoot, fault-find and generally understand the operation of the circuits you build. Why not build your own test equipment, saving money and learning as you go?

Contents include: Audio Level Meter, Impedance Meter, Audio Millivoltmeter, Simple Frequency Counter, Phase Meter, Temperature Meter, Audio Signal Generator, Audio Noise Generator, and many more.

Price: $3.00 plus 45 cents post and packing.

● ETI Circuits No. 2

This giant compendium of circuits has been assembled from the 'Ideas for Experimenters' section of Electronics Today and is packed full of ideas and suggestions for the experimenter. The chapter headings cover Alarms, Amplifiers, Automobile, Batteries, Comparators, Conversion Tables, Crossovers, Crystal Oscillators, Detectors, Digital, Filters and so on. Whenever you're looking for a circuit, this is the book to turn to.

Price: $2.95 plus 45 cents post and packing.

● 30 Audio Projects

For the Audiophile who wants good sound at a good price plus the satisfaction of having built it himself, 30 Audio Projects is required reading. The contents include our most popular audio projects: 25 watt Amp, General Purpose Preamp, Bucket Brigade Delay Line, Active Crossover, Compressor Expander, Tape Noise Limiter, Transmission Line Speaker System, Master Mixer, Graphic Equalizer and the 50/100 Watt Amp Modules.

Price: $3.95 plus 70 cents postage and packing in NSW (80 cents in other states).

● Project Electronics

Specially designed to meet the needs of newcomers to electronics, and in particular school students following the three-segment Industrial Arts syllabus in electronics, this book has been a runaway success! Twenty-six projects (many easily available in kit form) are completely described along with hints on troubleshooting, components, how to solder, etc. None of the projects is expensive and all are satisfying to build.

Available in newsagents, component stores or directly from ETI.

Price: $4.75 plus 45 cents post and packing.

● International 3600 and 4600 Synthesizers

A completely revised and updated reprint of ETI's phenomenally successful music synthesizer designs.

This book has been beautifully printed on heavy art paper and has a sturdy cover varnished for protection.

Available from some kit suppliers.

Price: $12.50 including post and packing.

● Top Projects Vol. 4

Available from newsagents or directly from Electronics Today International this book, published in June 1977, contains the following projects: Audio Expander/Compressor, 50/100 Watt Amp Modules, Stereo Amplifier, Dynamic Noise Filter, Audio Phaser, Audio Limiter, TV Game, Swimming Pool Alarm, Temperature Alarm, Active Antenna, GSR Monitor, Universal Timer, Mini-Organ, GP Power Supply, Temperature Meter, Train Controller, Car 'Scope Testing.

Price: $3.00 plus 45 cents postage and packing.

● Top Projects Vol. 5

Once again, this 'Best of ETI' publication is available from many newsagents or directly from ETI. Published in 1978 it is crammed with projects: Shutter Speed Timer, Ultrasonic Switch, Accentuated Beat Metronome, Marine Gas Alarm, House Alarm, White Line Follower, Induction Balance Metal Detector, Photographic Strobe, Simple Compressor/expander and CB Power Supply.

Price: $3.00 plus 45 cents post and packing.

DOESN'T WORK? TEST IT WITH THESE . . .

If you build electronic projects, you'll want to test them. Dick Smith has a full range of test gear – for the hobbyist or the professional. Make sure it's working correctly: it's easy with test gear from Dick Smith!

MULTI-WAY TEST LEAD SET

If you can clip onto it, plug into it, get under it or touch it this handy test lead set will help you. 16 pieces, inc. colour coded leads. Handy!

$4.95 W-4526

DICK'S OWN HOBBYIST TEST CENTRE

What's better than a 100,000 ohm per volt multimeter? How about one that also checks transistors AND capacitors! Yes, this must be one of the most uesful devices a hobbyist could own. High accuracy with minimal circuit loading (thanks to the 100k/V sensitivity), with extrmely useful ranges including 10A AC & DC. Plus, of course, the transistor checker giving both h_{FE} & I_{CO} readings. And capacitor values from 50pF through to 50uF. It's a bargain!

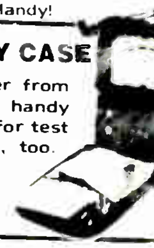
ONLY $69.50

Cat Q-1140

SPECIFICATIONS:
DCV 250mV 2.5V 10V 50V 250V & 1kV @ 100k/V
ACV 5 10 50 250 & 1kV
DCA 10uA 2.5mA 25mA 500mA 10A Plus 10A AC
RES 20 200 20k 200k ohms centre scale (x1 x10 x1k & x10k ranges)
dB -10 +16 -62dB
TRANS h_{FE} 0 - 1000 I_{CO} 0 - 50uA
CAP 50pF - 3uF & 0.01uF - 50uF accuracy 6

Q-1140 ACCESSORIES

HANDY CARRY CASE

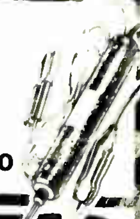


Protect your meter from damage with this handy carry case. Room for test leads plus manual, too.

$14.50

Cat Q-1137

RF PROBE



Extend the range of your Q-1140 meter to cover the RF spectrum, too. Makes it even more useful! Frequency range 150kHz to 30MHz.

$14.50

Cat Q-1138

RF GENERATOR

Quality Trio brand, with range from 100kHz to 30MHz. All solid state construction, mains operated. Great value!

$128.80

Cat Q-1250

AF GENERATOR

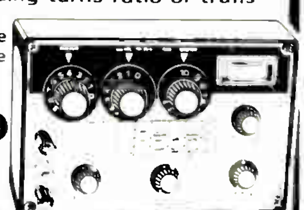
Matches above unit, 20Hz to 200kHz in 4 ranges. Wien bridge circuit with sine and square wave output.

$169.50

Cat Q-1260

AC BRIDGE

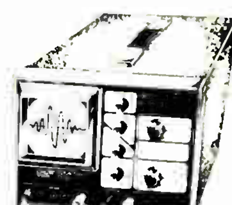
Another hobbyist and service aid you'll wonder how you got along without! Great for working out component values, R, I or C including turns ratio of transformers, etc. Extremely wide range: far more than a multimeter.



$79.50

Cat Q-1420

NEW: A CRO JUST FOR THE HOBBYIST



You'll wonder how you ever got along without a CRO in your workshop! This CRO is designed with the hobbyist and serviceman in mind: 5MHz response, easy to use and it won't break the bank. It's exclusive to Dick Smith and comes with a comprehensive instruction manual.

$199.00

Cat Q-1280

SIGNAL INJECTOR

How's this for value: signal injector for service work has harmonics right up through HF bands, great for the hobbyist or service technician.

$6.75

Cat Q-1270

CHECK THAT BATTERY!

Batteries: friend or foe? If they're suspect, you don't know! Find out with this handy checker and save hours of searching for non-existent faults. Checks all sizes & types; also fuses & globes. Go/no go meter reading.

$9.95

Cat Q-1525

LOGIC PROBE

Working with digital circuits? You'll appreciate this one: a logic probe which is CMOS/TTL compatible, shows high/low states with pulse stretching facility for fast pulses that you would otherwise miss. Low circuit loading; operates to over 12MHz.

$27.50

Cat Q-1272

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