eti ELECTRONICS TODAY INTERNATIONAL

$4.95*

TOP PROJECTS

COMPLIMENTARY COPY

Vol. 8

d b
r board
r receiver an
uild a LED oil temp
hicle 332: Versatile ele
oscope 329: Expanded sca
ter 333: Reversing alarm for you
01: Experimental negative ion generat
567: A portable electronic core-balance re
ance relay 599: Infrared remote control unit 729:
unit 729: Masthead amp for UHF TV 735: UHF to VHF
UHF to VHF TV converter 329: Expanded scale vehicle am
arrived! — build yourself an antenna 156: High impedance inst
6: High impedance instrument probe features 100 MHz bandwid
eatures 100 MHz bandwidth 1503: An 'intelligent' battery charge
telligent' battery charger 824/825: Two slot car controllers 25
ontrollers 259: Versatile, low-cost 'incremental' timer 57
ntal' timer 573: A universal process timer 568: Sou
ound or light-operated flash trigger has many
features 578: Simple NiCad battery ch
Switchmode charger delivers 'fas
NiCads 574 Disco strobe lig
storm this percus
rpose

Second Release

World Radio History

TOP PROJECTS
Vol. 8

Editor: Jan Vernon
Art Direction: Bill Crump
Managing Editor: Collyn Rivers
Managing Director: John Fink
Advertising: Sydney 268-9016
Melb. 662-1222

Top Projects Vol. 8 was printed by Offset Alpine Printing Pty Ltd, Cnr. Derby & Wetherill Sts, Silverwater NSW 2141. Distributed by Gordon and Gotch.

*(Recommended and maximum price only).

General purpose 150 W MOSFET power amp module

Here's a high power, general purpose power amplifier module for guitar and PA applications employing rugged, reliable MOSFETs in the output.

David Tilbrook

Geoff Nicholls

WE PUBLISHED the ETI-477 MOSFET amp in Electronics Today (Jan, Feb and Mar '81) and have received a continued demand for a general-purpose MOSFET power amp module suitable for guitar or PA applications. The ETI-477 can of course be used but is unnecessarily complex for this purpose. To fill this demand we have developed the ETI-499 module. It produces similar power levels to the ETI-477 (i.e: around 100 W RMS into an 8 ohm load or around 150 W into a 4 ohm load when used with the Ferguson PF4361/1 transformer), but has been designed with constructional simplicity as the foremost consideration. The power supply circuitry is included on the pc board so that the only connections to the board are from the power transformer, input sockets and output terminals. This greatly simplifies construction and installation and ensures that all power supply wiring is done with the necessary high current handling capability. In all transistor amplifiers, but especially with MOSFETs, the resistance between the main filter capacitors and the output devices must be kept as low as possible if low distortion and stability are to be ensured.

The circuit used in the ETI-499 is a development from one published in the Hitachi application notes for these MOSFETs. The original circuit used very high-gain bipolar driver transistors developed especially by Hitachi for use as MOSFET drivers. Unfortunately these devices are at present unavailable in Australia. Since these are an extremely fast device, replacement by more common bipolars limits the open loop bandwidth and causes the amplifier to be unstable. The main departures from the Hitachi circuit are therefore to ensure a stable design with common transistors.

We used the BF469 and BF470 as drivers. These are a complementary video output pair supplying good slew rate and V_{ceo} figures at a reasonable price. The resulting power amp module is fast and stable, with distortion figures completely adequate even for many high fidelity applications. The module is easy to construct and capable of withstanding continued clipping or full-power operation for extended periods when provided with a suitable heatsink.

SPECIFICATIONS — ETI-499

Power output
150 W RMS into 4 ohms
100 W RMS into 8 ohms
(at onset of clipping)

Frequency response
20 Hz to 20 kHz, +0 −0.5 dB
10 Hz to 60 kHz, +0 −3 dB
(measured at 1 W and 100 W levels)

Input sensitivity
1 V RMS for full output

Hum
−98 dB below full output

Noise
−114 dB below full output

Total Harmonic Distortion
0.006% at 1 kHz
0.03% at 10 kHz
(measured at 12 W level)

Stability
Unconditional — tested to full output driving 3.5 uF short circuit at 10 kHz.

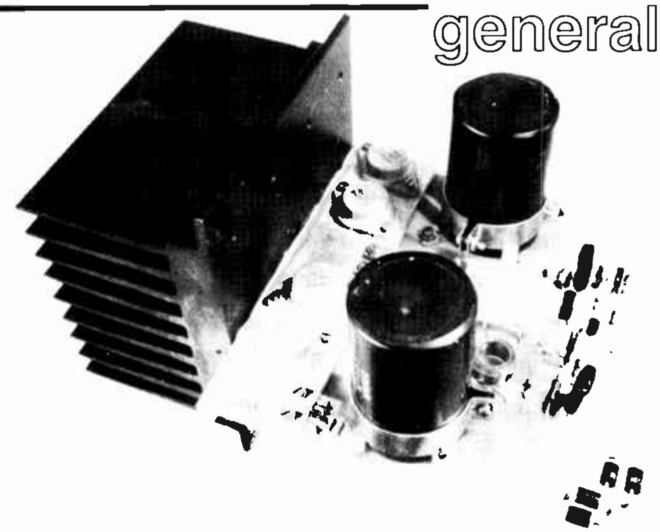
Why MOSFETs?

The power MOSFET is a relatively recent development and offers several distinct advantages over the more common bipolar transistor. To understand these differences it is helpful to look at some of the characteristics of bipolar output transistors.

Most power amplifiers employ bipolar transistors in a common-collector or emitter-follower configuration. The relationship between the output signal voltage and the input signal voltage is a function of the load impedance and the forward transfer admittance of the particular device. Forward transfer admittance is commonly given the symbol y_{fs} and its non-linear characteristic gives rise to distortion in the output stage. With bipolar transistors, the greatest non-linearity occurs for low input voltages, typically between 0 V and 0.6 V. Once outside this voltage range the forward transfer admittance is high and quite linear. So most of the distortion generated in a bipolar output stage occurs at low signal voltages and is called *crossover distortion* (for a more detailed explanation of crossover distortion refer to the article on the ETI-477 power amp module published in January 1981).

The most common method used to overcome this problem is to make use of bias current. A fixed voltage of around 0.6 V is applied to the bases of the output transistors so that the applied signal voltage does not have to operate the transistor over the most non-linear region. However, a problem arises with this technique because this voltage must be controlled extremely accurately. Even 0.5 V in excess of the correct voltage will saturate the output devices, probably destroying them. Furthermore, as the output devices heat up due to normal operation, the bias voltage must be decreased to maintain the same operating conditions. This is very difficult to do accurately enough, so the power amp is often running either with insufficient bias current or is dangerously close to destruction.

The problem occurs because the bipolar transistor has a positive temperature coefficient. This means that as the



temperature of the device is increased the collector-emitter current will increase if the base-emitter voltage is held constant. The increased current causes further heating and a further increase in current. This condition is called *thermal runaway* and results in the destruction of the output device.

Another problem with conventional bipolar output transistors is speed. The techniques used in the construction of these devices to ensure broad SOAR characteristics (SOAR stands for Safe Operating ARea) usually conflict with those to ensure high speed. Since the output transistors must handle the largest currents they are usually the slowest devices in the amplifier and determine the maximum signal slope that can be handled by the amplifier before distortion results. Distortion generated by this mechanism is called *slew-induced distortion* and *transient intermodulation distortion.* Once unnecessarily high signal slopes have been removed by a suitable filter at the input of the power amp the only solution is to increase the slew rate of the output devices.

One of the major advantages of power MOSFETs is their extremely high speed. When driven correctly the MOSFETs used in this project can switch a current of around 2 A in 30 nanoseconds! This is roughly *100 times* the speed of commonly available bipolars. Another advantage of MOSFETs is their very high input impedance. Unlike the bipolar transistor, they are a voltage-controlled device and require only enough drive current to overcome their input capacitance. Probably their most important advantage over bipolar transistors, however, is that *they have a negative temperature coefficient.* Heating causes an increase in the resistance of the device, so MOSFETs are inherently self-protecting. If one part of the device attempts to conduct more current it heats up more than the surrounding region, increasing its resistance, which distributes current over the rest of the device. Similarly if several devices are used in parallel, the negative temperature coefficient will ensure that all devices share current equally. In guitar and PA applications the negative temperature coefficient of MOSFETs provides the amplifier with unprecedented reliability, and the high speed helps to eliminate the problem of slew-induced distortion.

On the other hand a disadvantage with MOSFETs arises from their relatively low forward transconductance when compared to a good bipolar transistor. Although the transconductance of bipolars is highly non-linear when the base emitter voltage is below 0.6 V, it increases dramatically once outside this region. The MOSFET, although not as non-linear for small voltages, never achieves the forward transconductance of the bipolar transistor. The distortion generated by the power MOSFETs is therefore higher than that of bipolar transistors and must be reduced to acceptable limits through the use of negative feedback. This is not a real problem, however, since the high input impedance eliminates at least one stage of a conventional bipolar amplifier design. This allows a simpler circuit with fewer active devices and consequently improved stability margins, allowing greater levels of overall negative feedback before oscillation results.

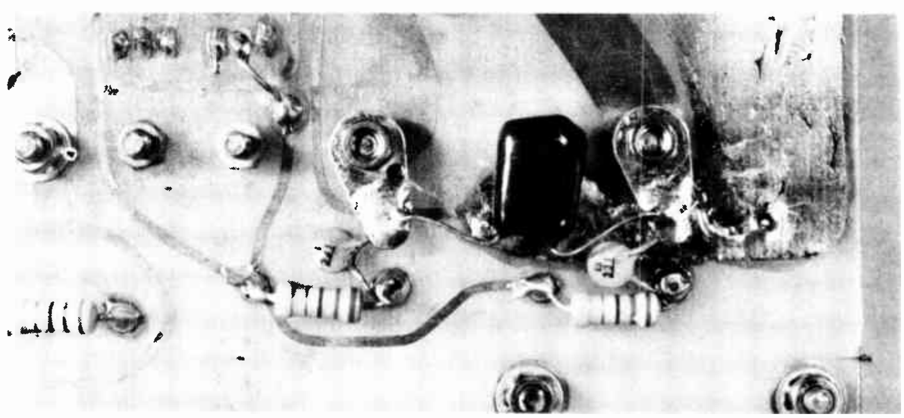
Construction

Construction of the ETI-499 is relatively simple, since all the components mount on the pc board, including the output transistors and power supply components. The design of a good pc board pattern is often as difficult as the design of the original circuit! This is especially true for power amplifiers or any circuit in which both large and small currents are involved. The problem of large currents occurs because of voltage drops across earth return paths, destroying the integrity of earth reference points for small signal currents. To overcome this problem, the pc board must be designed to ensure the ▶

HEATSINKING

The heatsink will need to dissipate around 100 W when the module is run at full output for lengthy periods. A heatsink with a thermal capacity of around 0.65°C/watt is recommended if free-air cooling is contemplated. A 152 mm length of Philips 65D6CB will do nicely (cost — around $30). Alternatively, the module may be mounted on one of the ETI-designed Series 5000 heatsink panels. In fact, two modules may be mounted on a Series 5000 heatsink panel. The panels are available from some kit and component suppliers.

If fan-forced cooling is contemplated, then a heatsink rated at 1.2 to 1.5°C/watt should be used. A 225 mm length of commonly available extruded 'fan' type heatsink will do the job. This type of heatsink is flat on one side, the other side having two sets of fins fanning out from a central channel. A suitable length will set you back about $10. A fan will set you back around $20 to $30, unless you have one lying around.



Compensation capacitors are required for the two 2SK134 output MOSFETs (Q8 and Q9) to equalise the input capacitances between the n-channel and p-channel output devices. They are mounted under the board as shown here. Solder lugs are placed on top of the mounting nuts and held with another nut each. C6 and C7 mount from these to the pads shown, while C7 mounts between them. Note the resistors mounted under the board also.

validity of the earthing arrangement. If at all possible, the pc board published should be used, as departures from this design could seriously affect amplifier performance.

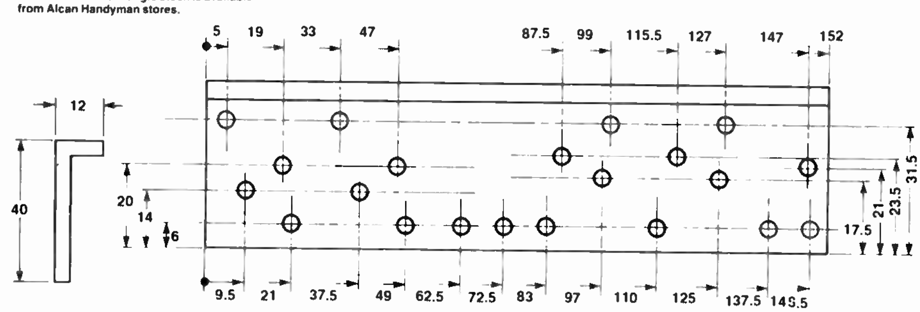
Commence construction by soldering all the resistors onto the circuit board with the exception of the four 0R22 output resistors. These effectively connect all the sources of the MOSFETs together and make it difficult to locate faults in the mounting of the MOSFETs. Solder the 1 W resistors slightly above the circuit board since these can become hot under certain conditions. The components marked with an asterisk on the circuit diagram are mounted on the rear of the pc board. They should be mounted close to the MOSFETs. Do not solder the resistors to the rear of the circuit board at this stage. These are best left until after the MOSFETs have been mounted.

Solder the capacitors onto the circuit board with the exception of those on the rear of the board and the two large electrolytics. The 100u capacitor C3 is the only other electrolytic, so be careful with the orientation of this component. The capacitor is marked to indicate which of its leads are to be connected to a positive or negative voltage. Check the correct orientation on the overlay diagram. This also applies to the diodes and zener diodes used in the circuit, which can be mounted next.

Both the driver and power transistors are mounted on a length of aluminium angle extrusion, which is bolted to the pc board by bolts through the transistor mounting holes. This is shown in the accompanying diagrams. The extrusion is used to conduct the heat generated by the output and driver transistors to the heatsink, which will also be bolted to the extrusion. If you purchase the mod-

ALL 4 mm DIA.
MATERIAL 40 x 12 x 3 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.

BRACKET DRILLING DETAILS



PARTS LIST — ETI-499

Resistors .... **all ½ W,5% unless stated**

R1,R2	100k
R3,R11	1k
R4,R5,R18-R21	220R
R6,R7	3k9
R8	22k
R9	680R
R10	10k
R12,R15,R16,R17	100R
R13	33k
R14	10k 1 W
R22-R25	0R22 W
R26	4R7 1 W
R27	1R 1 W
RV1	100R preset
RV2	250R preset

Capacitors

C1,C9	220n greencap
C2	2n2 greencap
C3	100u/25 V electrolytic
C4	33p ceramic
C5	6n8 greencap
C6,C8	330p ceramic
C7	47n greencap
C10,C11	100n greencap
C12,C13	8000u/75 V electrolytic

Semiconductors

Q1,Q2,Q3	BC546
Q4,Q5	BF470
Q6,Q7	BF469
Q8,Q9	2SK134 Hitachi MOSFET
Q10,Q11	2SJ49 Hitachi MOSFET
D1-D4	1N914
D5-D8	1N5404
ZD1,ZD2	12 V 400 mW zener

Miscellaneous

ETI-499 pc board; plastic bobbin (from P26/16 potcore or similar); 5 A fuse (speaker fuse, not mounted on pc board); fuse holder; 1 m of 0.8 mm enamel-covered copper wire; 155 mm length of aluminium extrusion, 40 mm x 12 mm, for use as the heatsink bracket; assorted nuts and bolts, hookup wire, etc; two solder lugs.

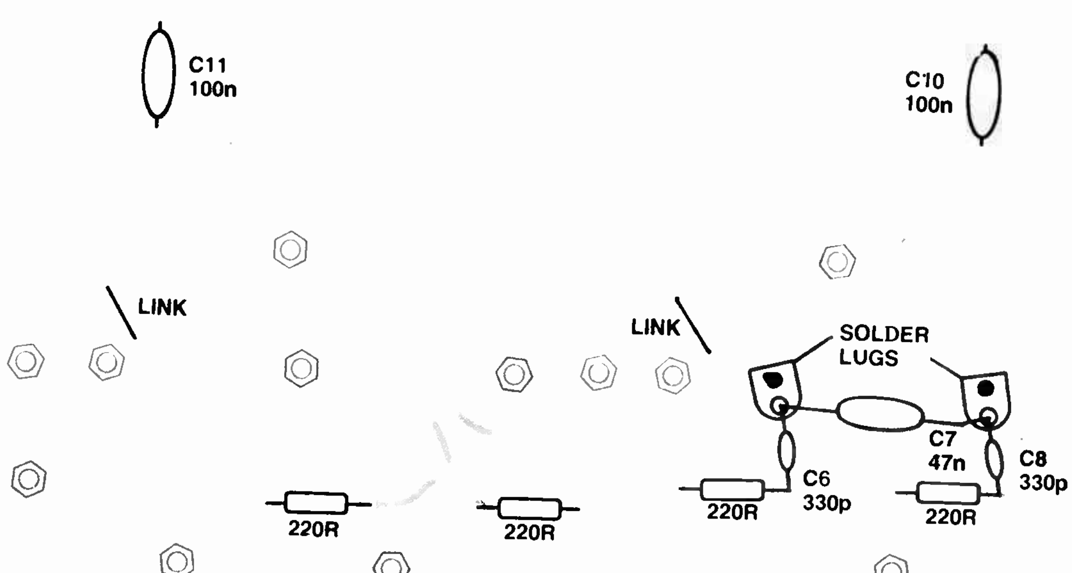
Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

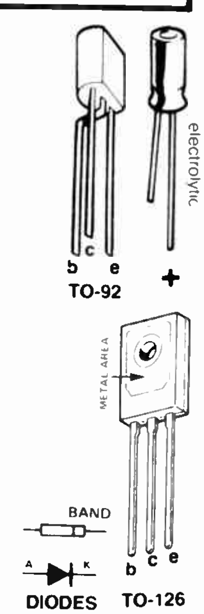
$75-$85

(heatsink & transformer extra)

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



TRACK SIDE OVERLAY DIAGRAM

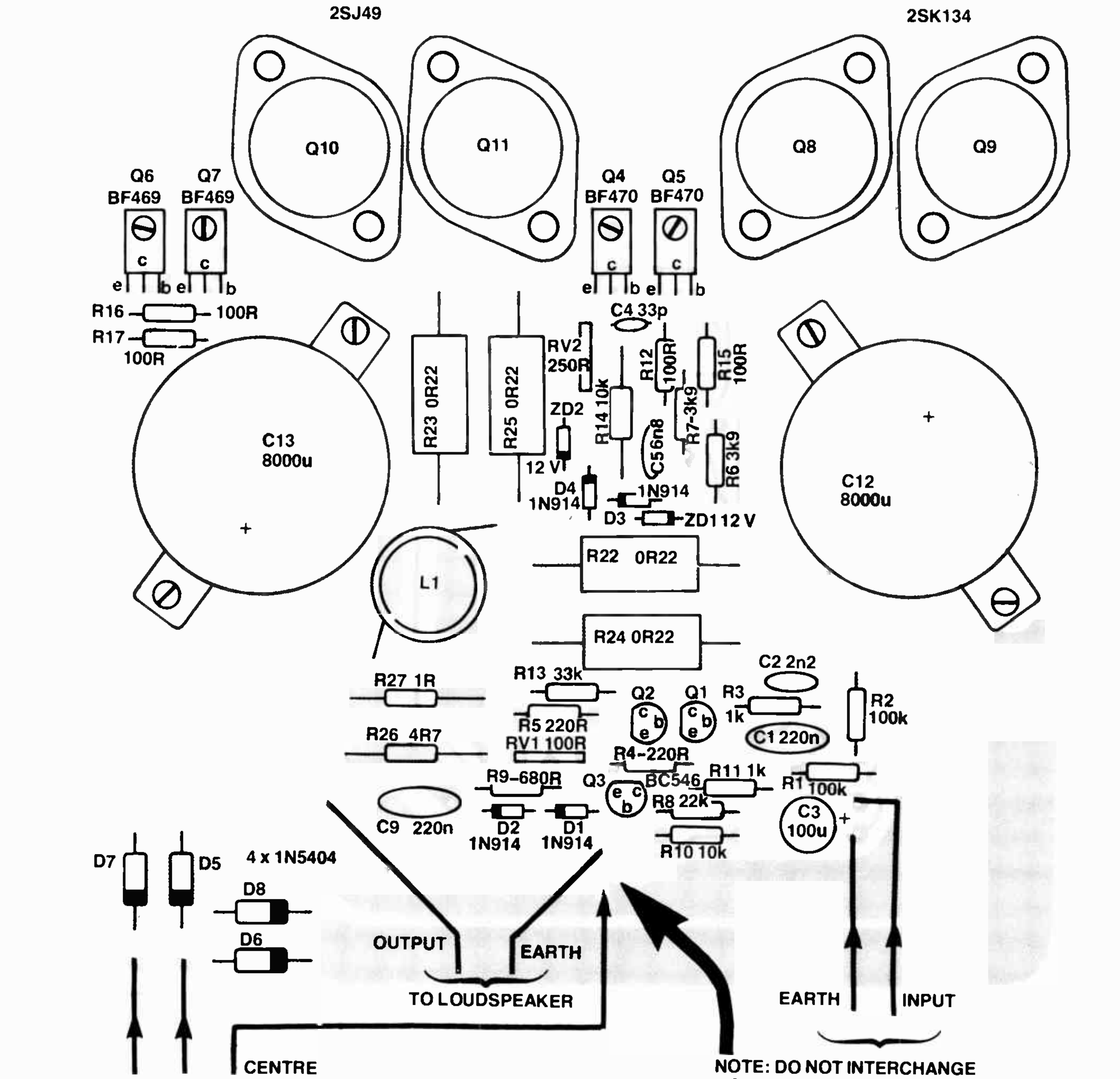


ule in kit form from one of the kit suppliers who support our projects, this bracket should be supplied drilled, ready to mount the transistors. If not, drill all the necessary holes before proceeding further. Make certain the holes are free of burrs or shavings that might otherwise cut through the transistor insulating washers. This is best done with a couple of twists of an oversize drill (i.e: around 13 mm diameter).

The bolts holding the MOSFETs in place also serve to make electrical connections to the cases of the devices. These bolts must be insulated from the heatsink bracket, which will be at earth potential. This is done with the use of short insulating sleeves cut from a length of 'spaghetti' insulation. Use a small quantity of heatsink compound on both sides of the transistor insulating washers to ensure good thermal contact. Insert the sleeves in the holes of the heatsink bracket and mount the four MOSFETs as shown in the accompanying diagram.

The four driver transistors can now be mounted. Again, use transistor insulating washers between the metal sides of the transistors and the heatsink bracket, although insulating sleeves are not necessary.

Once all the transistors have been mounted on the heatsink bracket use a multimeter to check for any short circuits to the heatsink bracket by measuring the resistance from the case of each MOSFET, and from the centre lead of each driver transistor, to the bracket. The measurements should show open circuit on all transistors. If a short does exist the transistor should be ▶

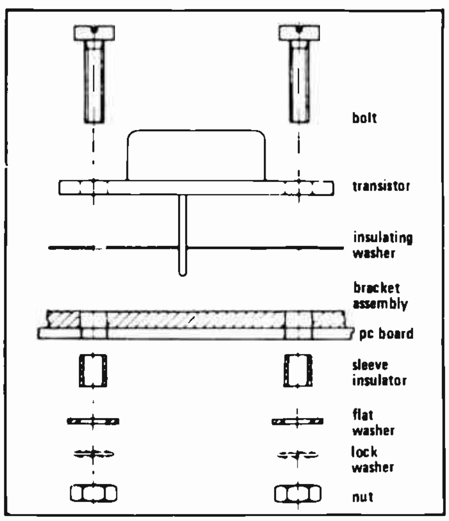


COMPONENT SIDE OVERLAY DIAGRAM

removed and remounted, possibly with a new insulating washer. Finally, solder the leads to the transistors.

Once the MOSFETs and drivers have been mounted, the remainder of the components can be mounted on the pc board, including the small signal transistors and the components on the rear of the pc board. Mount the two 8000u electrolytic capacitors last; be sure to bolt the capacitors down, however, before soldering the lugs. Mount the four 0R22 resistors now, leaving around 5 mm between the resistor and the board. Ensure that all components mounted on the rear of the pc board are mounted close to the board with their leads cut as short as possible.

The output inductor, L1, is formed by winding 20 turns of 0.8 mm enamel wire around a 14 mm former. The plastic bobbins supplied for use with the P26/16 potcores are ideal for this purpose.



Exploded view of how to mount the output devices to the bracket and pc board.

Powering up

Supply fuses have not been included on the pc board because the resulting resistance necessitates the use of a second set of electrolytic capacitors close to the output devices. To protect the loudspeakers in the case of failure of the power amp a fuse should be used in series with the loudspeaker cable. We will shortly be publishing a loudspeaker protector, with the emphasis on PA applications, for use with the ETI-499. In the meantime, however, use a fuse as specified in the parts list.

Before powering up check all stages of construction, including the orientation of all polarised components. Check that no shorts exist between the cases of the output devices and the heatsink bracket. Mount the heatsink bracket to a suitable heatsink, again using heatsink compound to ensure good thermal contact. Do not connect a loudspeaker at this time. Adjust RV1 to centre and RV2 fully counterclockwise, as viewed from the positive rail side of the pc board. If all is in order, connect the module to the power transformer and switch on. Using a multimeter on the 1 V range, adjust RV2 so that the voltage between the ends of RV2 reads 0.8 V. Now adjust RV1 so that the voltage between the output terminal and ground is as close to zero as possible. Ideally, a digital multimeter should be used for this measurement since most analogue meters do not have the necessary resolution. Adjust RV1 to achieve a dc voltage on the output of less than 10 mV, if possible. If your multimeter does not allow measurement of voltages this small, leave RV1 set at the centre position. When both of these adjustments have been made, the module is ready for operation.

Performance

We have tested the prototype into both inductive and capacitive loads and at all times *it performed impeccably*. The sound is clean and smooth with no sign of the harshness sometimes experienced with transistor power amps. The high speed of MOSFETs helps to ensure freedom from slew-induced distortions and the amp clips cleanly with no sign of instability.

In coming months we will present articles on the loudspeaker protector board and a preamplifier to form a complete PA or guitar amplifier. ●

SOME CAPACITORS AREN'T . . .

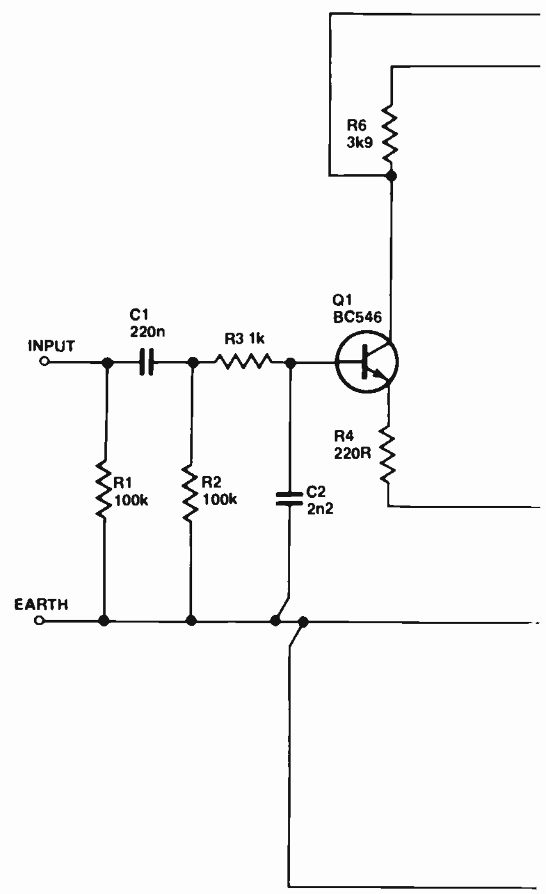
For the R26-C29 network to provide an effective high frequency load to the output stage it is imperative that C9 (220n greencap) have low self inductance. From experience, we have found Elna type greencaps and Philips polycarbonates meet this requirement. High frequency instability, if not outright oscillation, may result if this requirement is not met.

To a lesser extent, the same applies to C7, C10 and C11. Note that C7 ac-couples the sources of Q8 and Q9 together, so that the self inductance of the source ballast resistors R22 and R24 is no longer important, preventing high frequency instability in this section of the output stage brought about by the inductance of the wirewound ballast resistors.

HOW IT WORKS — ETI-499

The circuit is a development from one published in Hitachi's application notes for these MOSFETs. The original circuit uses driver transistors designed by Hitachi for use as MOSFET drivers. Unfortunately these devices are not available in Australia at the present time, so most of the differences are to ensure stability and low distortion with a more readily available driver. We have used the BF469, BF470 complementary video output pair as used in the 477 module. These transistors provide the necessary speed so as not to degrade the performance of the output transistors.

One of the most difficult stages in the development of an amplifier module of this type is the pc board design. Separation of the large currents flowing to the electrolytic capacitors from signal earth is absolutely imperative if low distortion is to be obtained. An earlier pc board using exactly the same circuit gave distortion figures as high as 1% when driven into 8 ohms at around 10 W RMS! The problem was simply interaction between charging currents to the electrolytic capacitors and the earth reference to the input differential pair. For best performance use the pc board design published with this article and pay special attention to all earth and supply connections. In particular ensure that the connections to the



centre point of the transformer and the loudspeaker earth are soldered into the correct positions on the pc board. Although these two points are immediately adjacent on the pc board they are *not* equivalent electrically due to the slight resistance of the board. If these wires are connected the wrong way around the distortion will be increased possibly by as much as 20-30 dB!

Transistors Q1 and Q2 form an input differential pair. Their function is to compare the output signal with the input signal and drive the voltage amplifier transistors in the driver stage with the necessary correction signal, sometimes called the error voltage or error signal. The base of Q1 is held at ground potential by resistor R2. Capacitor C1 in conjunction with R2, R3 and C2 forms an input filter, which defines the upper and lower 3 dB points of the amplifier. This filter therefore restricts the maximum possible signal slope capable of being driven to the input of the differential pair. This is an essential function since it eliminates slew-induced distortions such as TIM, provided that the rest of the power amp has a slew rate in excess of this limit. For a more detailed description of slew-induced distortions and their remedies see the articles on the 477 MOSFET module published in Electronics Today, January, February and March 1981.

The gain of the differential pair is around 17, so most of the open loop gain is done by the driver transistors Q4 and Q5, and their associated current mirror formed by Q6 and Q7. The series RC network C4, R12 ensures stability of the amplifier by decreasing the gain of the driver stage at very high frequencies, while keeping the phase shift produced within 90°.

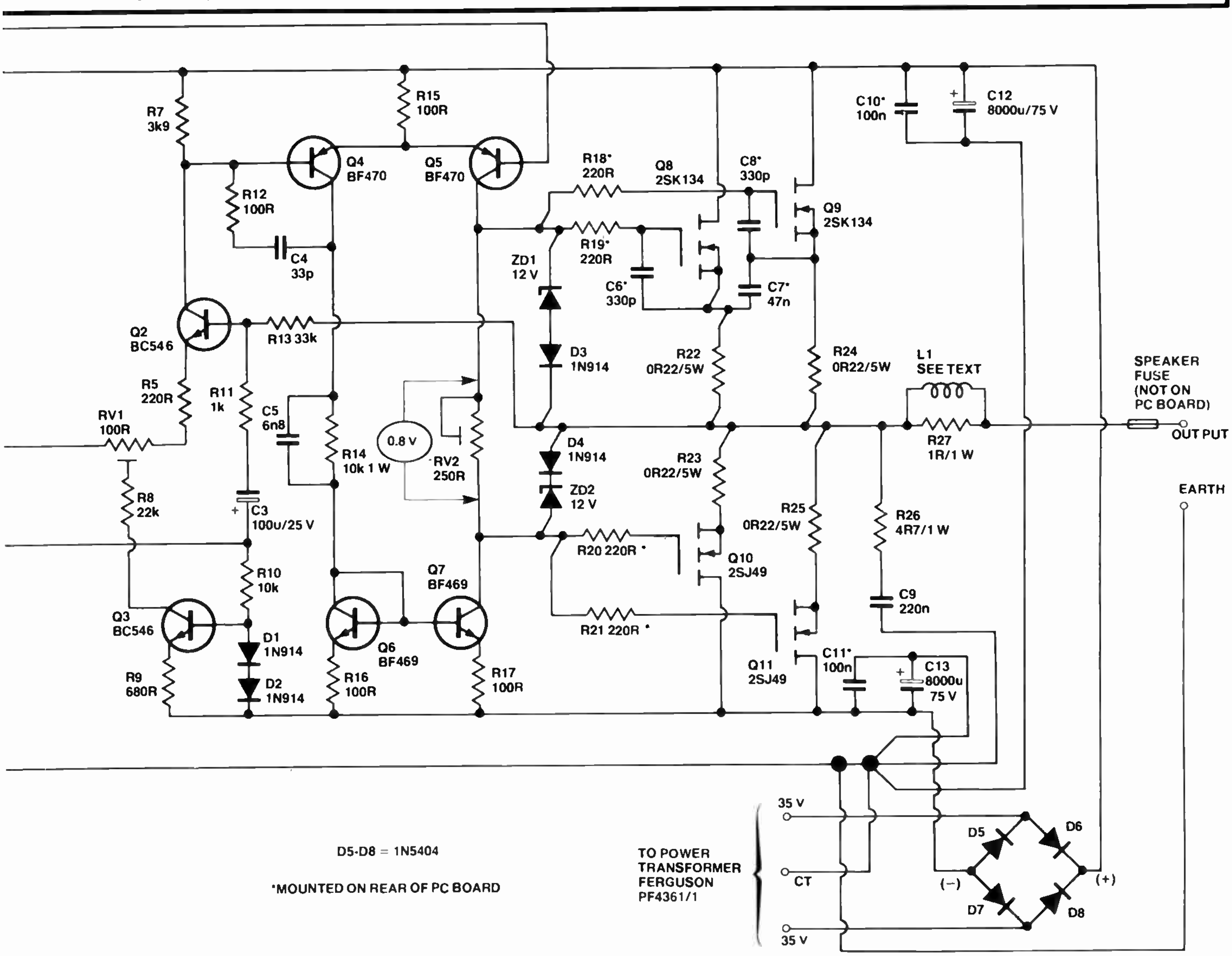
As stated above, transistors Q6 and Q7 form a current mirror. The purpose of these devices is to ensure the current through the two driver transistors remains identical. At the same time the very high impedance represented by Q7 on the collector of Q5 ensures high open loop gain, and consequently low distortion through the relatively large amount of negative feedback available. RV2 varies the voltage between the gates of the output MOSFETs and therefore the amount of bias current through the output transistors. If the voltage across this preset is set to around 0.8 V the bias current will be approximately 80 mA, which is about right. If the bias current is decreased completely by turning RV2 fully away from the MOSFET end of the board, the MOSFFTs will remain off until a signal is fed to the input. This is pure class B operation and results in the coolest operation of the power amplifier. The disadvantage, however, is that a slight increase in distortion, called crossover distortion, will result. In PA or guitar applications this is not a problem, so the amplifier can be used in this mode without hesitation.

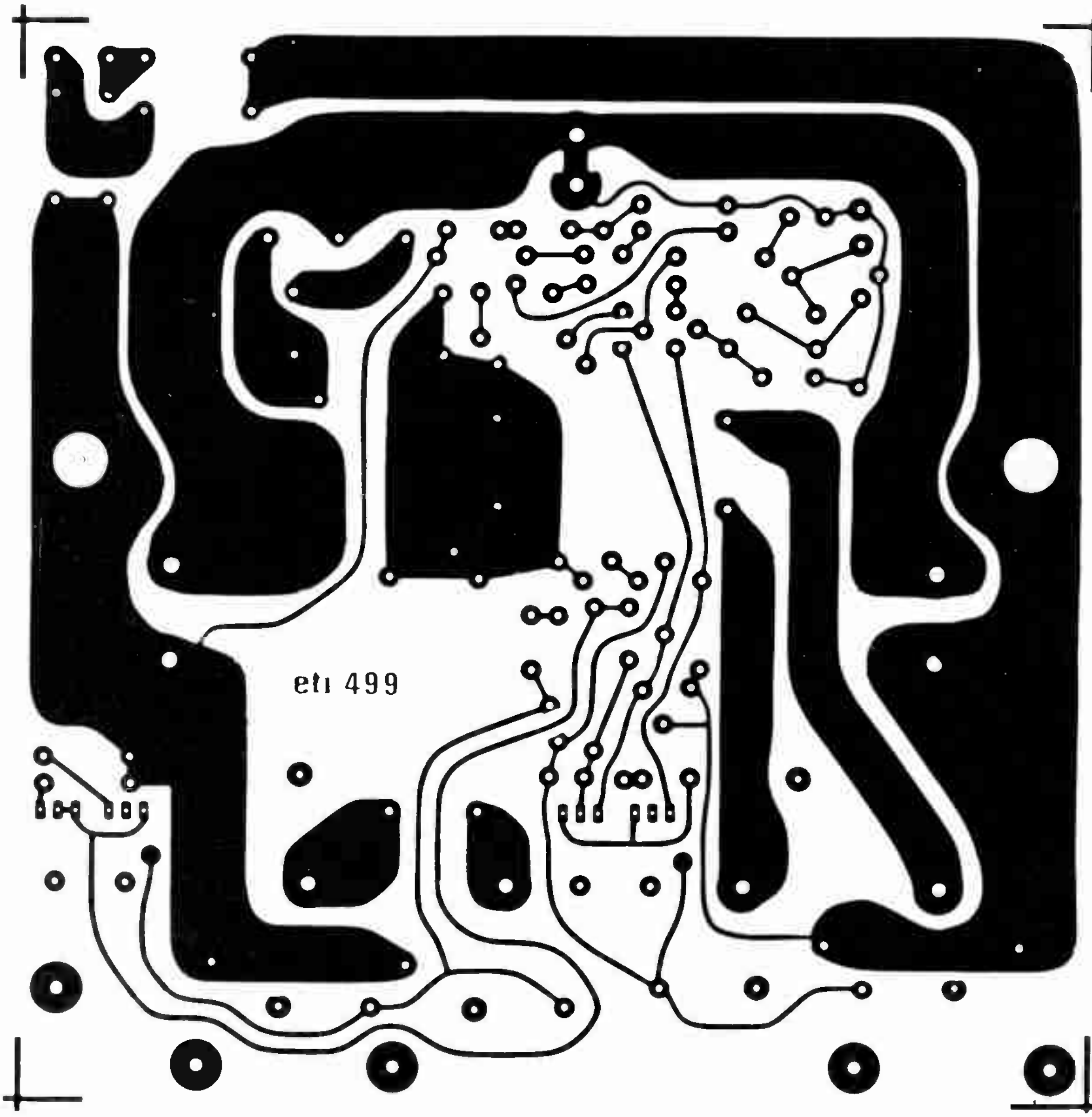
The diodes D3, D4 and the zener diodes ZD1 and ZD2 ensure that the voltage between the gates of the FETs and their sources never exceeds 12.6 V, the most common cause of MOSFET failure.

Capacitors C6 and C8 equalise the capacitive input characteristics of the MOSFETs and make it considerably easier to correctly stabilise the output stage. Capacitor C7 brings the sources of the two 2SK134 MOSFETs to the same potential at high frequencies, and overcomes possible problems that might otherwise be caused by inductance in the source resistors R22 and R24.

The four resistors R22-R25 help to match the differences between the characteristics of the different output devices.

The passive filter network formed by R26, C9 ensures that the module always has a load at high frequencies. If the amplifier is tested with large high frequency sinewaves this resistor will become extremely hot, but this does not indicate a fault condition. The inductor L1 and the resistor R27 help to ensure total stability into capacitive loads, such as when driving extremely long loudspeaker leads.




eti 499

Darth Vader to Daleks

— all from our Sound Bender!

Based on a remarkably versatile function generator IC, the XR2206, this project is capable of modifying an audio signal to produce tremolo effects on music or those peculiar, metallic robot voices so abundantly found in shows like 'Dr Who', 'Star Wars', 'Star Trek', etc.

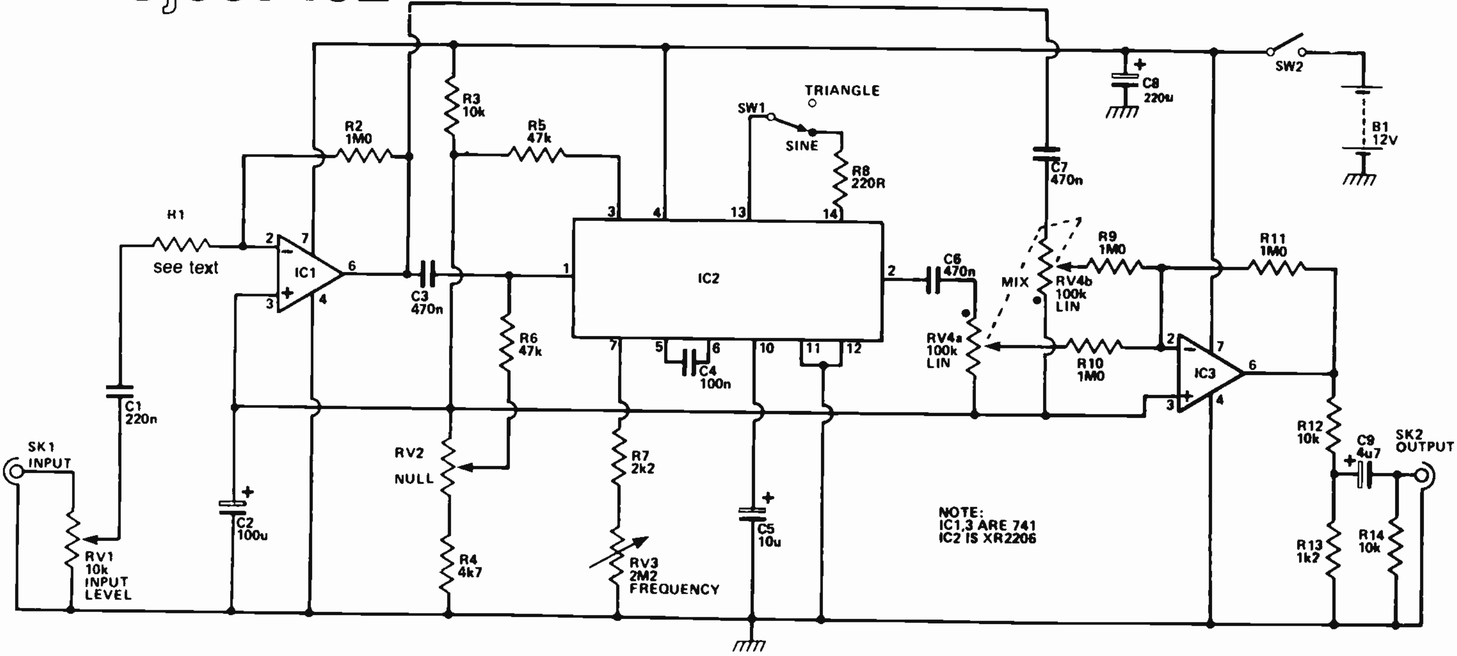
Design: **Ray Marston** Development: **Roger Harrison**

'VARIETY is the spice of life' goes a famous old saying, and when electronics entered the musical arena, engineers and musicians sought ways of extending the variety of available musical sounds, some by developing electronic 'instruments', others by developing circuits that modified the sound produced by the voice or an instrument. Deliberately introducing plain old distortion gave rise to the 'fuzz box', amplitude modulating the sound gave a 'tremolo' effect, etc.

Now, a device developed to permit more conversations per line on the telephone system was discovered to produce a range of 'intelligible', but highly modified, sounds from voice and music signals. Called variously a 'ring modulator' or 'four-quadrant multiplier', it is achieved by mixing an audio signal with an oscillator signal, and the output is the product of these two signals, containing both sum and difference frequencies. The oscillator or 'carrier' signal is reduced or suppressed. If, for example, the carrier frequency is 1 MHz and the audio signal is speech with a range of around 150 Hz to 3 kHz, the ring modulator's output would be two 'sidebands' — a 'lower' one (the difference) at 997 kHz to 999.85 kHz and an 'upper' one (the sum) at 1000.15 kHz to 1003 kHz. The 1 MHz carrier level could be 20 dB to over 40 dB lower in level than the sidebands, depending on how 'good' the ring modulator is. If the carrier is set at 1 kHz, though, the sum and difference frequencies at the output spread up and down the audio spectrum, and if speech is the input you get a jumble of voice sounds, some shifted up in frequency, some inverted and apparently shifted down in frequency. The best examples we can cite are the voices of Darth Vader from 'Star Wars', the Daleks from 'Dr Who' and the Cylons from 'Star Trek'. If the carrier is placed at a sub-audible frequency, then the result is a tremolo effect, where the audio signal is seemingly amplitude modulated at a slow rate.

The XR2206 function generator IC contains a voltage-controlled oscillator and a four-quadrant multiplier or ring modulator, so in one chip we have both the carrier oscillator and the modulator that can be combined in a circuit to produce the effects we seek. As the panel on page 14 shows, which explains the XR2206 and typical applications, the IC also includes internal control and signal shaping circuitry, making the circuit design job a whole lot simpler.

This project is designed to make full use of the functions incorporated in the XR2206 for this application, and the IC's VCO — used here as the carrier ▶



HOW IT WORKS — ETI 492

By mixing or 'multiplying' an audio signal with an oscillator or 'carrier' signal that may be varied from the sub-audible to the mid-range of the audio spectrum, the original signal may be altered in a variety of ways. Mixing an audio signal with a sub-audible carrier produces a tremolo effect — a form of amplitude modulation; mixing speech with a carrier around 1 kHz to 2 kHz produces 'robot' voices. That's just to name a few of the more familiar effects possible.

The heart of this unit is IC2, an XR2206 function generator chip that incorporates a multiplier — used to perform the modulating function — plus a voltage controlled oscillator (VCO), signal-shaping circuitry, and control circuitry that permits simple variable resistance control of the VCO. The signal-shaping circuitry permits generation of sine or triangle waveforms out of the VCO.

There are three sections to the circuit: the input amplifier (IC1), the mixer/carrier generator (IC2) and the output mixer/buffer (IC3).

The audio input signal enters via SK1 and RV1, the level control. The signal is coupled to the input op-amp IC1, which has a gain of 10 or 100 depending on the choice of value of R1. If R1 is 100k, the gain of this stage is 10, for 10k the gain is 100. The output of IC1 is coupled to the 'AM input' of IC2 and also to the input circuitry of the output buffer/mixer via C7 and RV4b.

In this application, the VCO in the XR2206 can produce either sine or triangle waveforms by means of switching a resistor in or out of circuit with SW1. A triangle waveform contains odd harmonics, which give a 'rough' or 'dirty' sound. A sinewave with little distortion has almost inaudible harmonics and thus sounds 'clean'. This is important, as we shall see shortly. The frequency of the VCO can be varied from the range from 3 Hz to about 5 kHz by means of RV3, the 'frequency' control. The frequency is determined by the values of C4, R7 and RV3. The AM input of IC2, pin 1, has a dc bias applied to it via R6, the bias voltage being determined by a divider network between the two supply rails consisting of R3, RV2 and R4. RV2 permits variation of the bias so that critical balancing of the XR2206's multiplier can be achieved to 'null out' the carrier signal (from the VCO). This 'null' control is normally adjusted to produce zero output with no audio signal input.

When an audio signal is applied, the multiplier in the XR2206 produces a *double sideband suppressed carrier* output signal. The output is taken from pin 2, via the internal buffer. Let's take a simple case to show what the multiplier does. Say the VCO is set to a frequency of 1 kHz. With the multiplier balanced there is zero output. Now, if a signal at 440 Hz ('A') is applied to pin 1 of the XR2206, the resultant output will be two frequencies: 1440 Hz and 560 Hz (the sum and the difference). Note, no trace of the carrier — this is a result of using a *balanced* mixer or multiplier. Now, say the audio input is 440 Hz (again), and the VCO is set to 5 Hz. The output will be 445 Hz and 435 Hz. Now, as every musician knows, two instruments tuned a few Hertz apart will produce a 'beat' when sounded together. The beat is perceived as an amplitude variation of the sound — if the effect is deliberately obtained, it is called 'tremolo'.

This applies for the case where the carrier is a 'pure' sinewave. If the carrier contains harmonics, then these too will produce sum and difference products when multiplied with the audio input signal and a complex output will result. Thus for a 'clean-sounding' output, switch SW1 to SINE, for a 'dirty-sounding' output, switch SW1 to TRIANGLE.

The output from the multiplier in the XR2206 is taken from pin 2 (from the internal buffer, as mentioned before). It is coupled to RV4a via C6. Now, RV4 is a dual-gang potentiometer with the 'bottom' end of RV4a connected to the 'top' end of RV4b. With RV4 at the fully anti-clockwise position, no signal from pin 2 of IC2 is coupled to the input of IC3, while the full output of IC1 is coupled to the input of IC3. With RV4 at the fully clockwise position, the full output from pin 2 of IC2 is coupled to the input of IC3, while none of the output from IC1 is coupled to the input of IC3. Thus by varying RV4 from one extreme to the other you can obtain a varying proportion of 'direct' to 'modulated' signal.

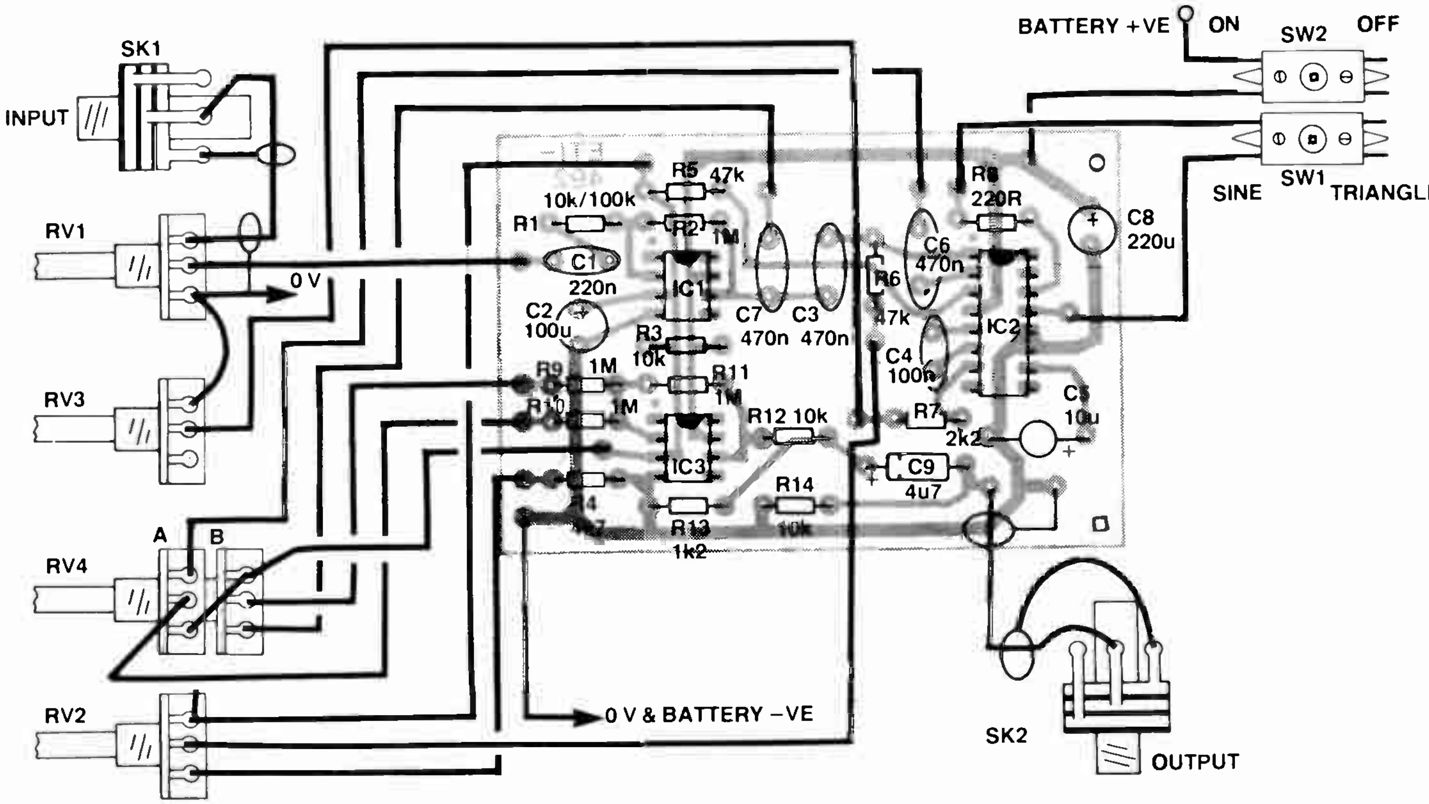
The output from IC3 is passed to SK2 first via an attenuator (R12, R13) that provides a division of 10 so that with the gain of IC1 set at 10 (R1 100k) the project has unity gain. From the attenuator the signal passes to SK2 via C9. R14 provides a dc return for the output circuit. If you wish, R13 may be omitted and R12 replaced by a link.

Capacitor C8 is a supply rail bypass, and capacitor C5 is a bypass for the internal reference of the XR2206. The non-inverting inputs of IC1 and IC3 are biased up to half the supply rail voltage by strapping them to the junction of R3 and RV2. This is done to provide a 'virtual earth' rail for these two ICs, which normally require a dual supply rail, whereas the XR2206 does not. Capacitor C2 serves as a bypass for this virtual earth rail. The multiplier direct output requires tying to the virtual earth rail also, as shown in the XR2206 application notes, and R5 does this. Note that the supply voltage can be anywhere between 9 V and 15 V. The circuit only draws a few milliamps (roughly, between 10 mA and 15 mA or so) and may be readily battery operated.

oscillator — spans a frequency range from 3 Hz to 5 kHz using a single control pot. To 'harden' or 'soften' the effect produced a 'triangle' or 'sine' oscillator waveform can be selected by a switch, and a two-channel mixer with a 'pan' control pot is incorporated on the output so that you can blend the 'direct' to 'modified' sounds to provide some control over the effect. In addition, a 'null' control has been provided as it is necessary to reduce the level of the carrier signal fed through to the output from the IC's modulator or multiplier.

The project can be operated from input levels as low as a few millivolts (e.g: microphone) or line levels of 100 mV or greater (e.g: preamp output, such as the 'effects send' on a mixer).

The Sound Bender may be powered from a supply ranging from 9 Vdc to 15 Vdc and draws typically between 10 mA and 15 mA current. A small dc plugpack would make an ideal power supply.



Alternatively, it may be battery operated.

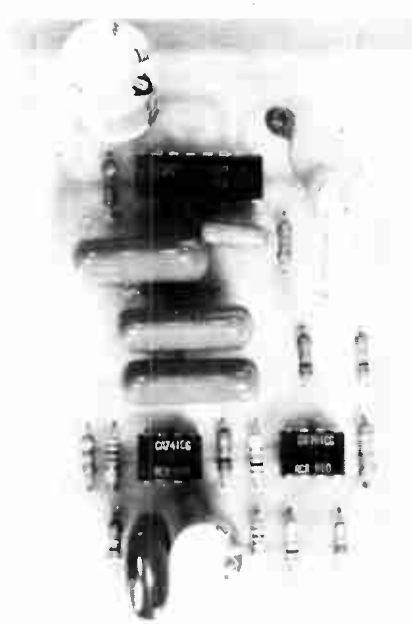
Construction

We have not described details of a case, front panel, etc, as this project will undoubtedly find a wide variety of uses and we leave it to individual contructors to arrange their own housing. Fortunately, housing is not critical, providing the controls are not mounted too far from the pc board. Leads from the board to the controls should be kept as short as possible, less than 300 mm preferably, as this avoids possible feedback and hum pick-up problems. If the unit is to be mounted in other equipment, keep it away from transformers and mains leads, or thoroughly shield it, again to avoid hum pick-up.

Construction should commence with the pc board. Solder IC1 and IC3 (the two 741s) in place first, taking care that you get them the right way round. They both face in the same direction. Next, insert all the resistors and solder them in place. You'll have to decide at this stage whether you use a 10k or a 100k resistor for R1, as noted with the circuit. The XR2206, IC2, may be inserted next. As it is a CMOS IC, remove it from its packing carefully, taking care only to handle the ends of the pack, not touching the pins. Carefully insert it in the board and solder pin 4 and then 11 and 12. Then solder all the other pins. Take care not to overheat any of the ICs when soldering them in place. Now all the capacitors may be inserted and soldered in place. Watch that you get the orientation of C2, C5, C8 and C9 correct.

Now you're ready to wire up all the external major components. These can be mounted in any order, to suit yourself, but keep the wiring to RV1 (input level) and RV4 (mix) separated to avoid possible feedback. Use shielded cable where indicated (input and output).

Our overlay and wiring diagram gives an overall guide as to assembly and wiring of the unit.



PARTS LIST ETI-492

Resistors	all ½W, 5%
R1	100k
R2,9,10,11	1M
R3,12,14	10k
R4	4k7
R5,6	47k
R7	2k2
R8	220R
R13	1k2
RV1	10k lin.
RV2	5k lin.
RV3	2M2 lin.
RV4	100k dual lin.
Capacitors	
C1	220n greencap
C2	100u/16 V electro.
C3,6,7	470n greencap
C4	100n ceramic
C5	10u/25 V electro or tant.
C8	220u/16 V electro.
C9	4u7/16 V axial electro.
Semiconductors	
IC1,IC3	741
IC2	XR2206

Miscellaneous
ETI-492 pc board; two SPDT miniature toggle switches, two phono sockets; case to suit; wire; knobs; nuts and bolts, etc.

Price estimate $28 — $35

Using it

To try out the Sound Bender, connect a supply (battery, plugpack or bench supply — what-have-you) and connect the output to the input of an audio amplifier. We used the ETI-453 General Purpose Amp Module (ETI April '80). As we wanted to use a microphone, a 10k resistor was used for R1. Set the Sound Bender's input level to zero, set the mix control fully clockwise, and turn up the audio amp's input gain. SW1 may be set to sine or triangle, it doesn't matter. If you don't hear a whistle, rotate the frequency control until you do. Then vary the null control until you obtain minimum output. This null will be quite sharp so take it slowly. A big knob on the pot shaft or a small vernier would assist. A 10-turn pot here might seem extravagant, but some users may find it useful. ▶

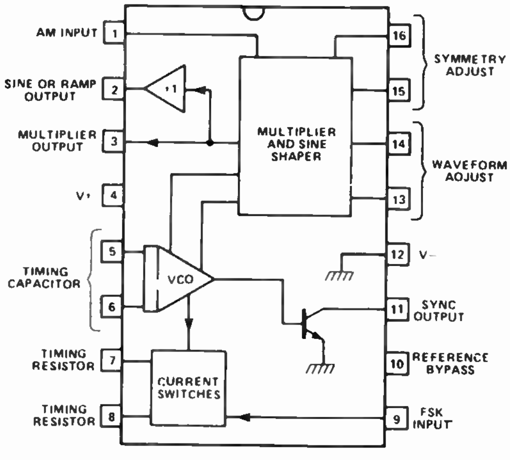


Figure 1. **Internal block diagram and pinout for the XR2206 function generator IC.**

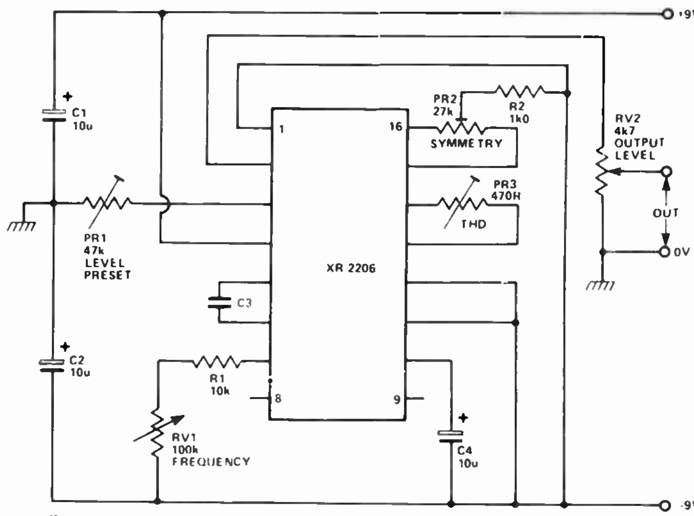


Figure 2. **High-performance sinewave generator. See Table 1 for values of C3.**

A BRIEF LOOK AT THE XR2206

The XR2206 integrated circuit is undoubtedly one of the most useful function generator or waveform generator chips available. It can generate sine, square, triangle, ramp and pulse waveforms at frequencies ranging from a fraction of a Hertz to several hundred kiloHertz, using a minimum of external circuitry. The frequency can be swept over a 2000:1 range using a single control voltage or resistance, and sinewave distortion can typically be as low as 0.5%. The chip incorporates special built-in modulation facilities that enable the generated waveforms to be subjected to AM or FM control, or to phase-shift or frequency-shift keying.

The XR2206 chip is housed in a standard 16-pin DIL package and can be powered from either single or split supplies in the range 10 to 26 V. The sinewave output of the device has maximum amplitude of about $2V_{RMS}$ and output impedance of 600R. The frequency stability of the IC is excellent, being about 20 ppm/°C for thermal changes and 0.01% V for supply voltage changes.

Figure 1 shows the pinout and internal block diagram.

WAVEFORM GENERATION

The XR2206 is a reasonably easy IC to use for basic waveform generation. A high-performance sinewave generator is shown in Figure 2. It requires a split supply rail, but total harmonic distortion at the output is typically less than 0.5%. Adjustment of trimpots PR2 and PR3 with a distortion meter connected to the output is necessary, but the THD holds over the frequency range. Trimpot PR1 requires setting for correct operation first, however. Disconnect PR3 (to obtain triangle output), then adjust PR1 until no clipping of the output waveform is visible on a 'scope hung on the output.

Note that the signal appearing on pin 3 of the IC is similar to that on pin 2, but has lower distortion and higher output impedance. Also, the signal on pin 3 is very nearly symmetrical about 0 V but that on pin 2 has an offset of several hundred millivolts. If desired, a slight dc offset may be applied to pin 3 to reduce the offset on the output signal from pin 2 — as shown in Figure 3.

The XR2206 will generate linear triangle waveforms by deleting PR3. A sine/triangle/square wave function generator is shown in Figure 4. Rise and fall times of the square wave output are typically 250 ns and 50 ns respeetively, with pin 11 loaded by 10 pF.

C3	FREQUENCY RANGE
1u0	10 Hz TO 100 Hz
100n	100 Hz TO 1 kHz
10n	1 kHz TO 10 kHz
1n0	10 kHz TO 100 kHz

Table 1. Values of C3 for different frequency ranges

MODULATION

The amplitude of the pin 2 output signal of the XR2206 can be modulated by applying a dc bias and a modulating signal to pin 1 as shown in Figure 5. The amplitude of the pin 2 signal varies linearly with the applied voltage on pin 1 when this voltage is within 4 V of the half-supply value of the circuit; in split-supply circuits, of course, the half-supply value equals 0 V. When the pin 1 voltage is reduced below the half-supply value the pin 2 signal again rises in direct proportion, but the phase of the output signal is reversed. This last-mentioned phenomenon can be used for phase-shift keyed (PSK) and suppressed carrier AM generation.

The pin 1 terminal of the IC can also be used to facilitate gate-keying or pulsing of the pin 2 output signal. This can be achieved by biasing pin 1 to near half-supply volts to give zero output at pin 2, and then imposing the gate or pulse signal on pin 1 to raise the pin 2 signal to the desired turn-on amplitude. The total dynamic range of amplitude modulation is 55 dB.

The frequency of oscillation of the XR2206 is proportional to the total timing current (I_T) drawn from pin 7 or 8, and is given by:

$$f = \frac{320 \times I_T}{C} \text{ Hz}$$

where I_T is in milliamps and C is in microfarads.

The timing terminals (pins 7 and 8) are low-impedance points and are internally biased at 3 V with respect to pin 12. The frequency varies linearly with I_T over the current range 1 uA to 3 mA. Consequently, the frequency can be voltage-controlled by applying a voltage in the range 0 to +3 V between pin 12 and the timing terminal via a suitable resistor, so that the timing current is determined by the resistor value and the *difference* between the internal (+3 V) and external (0 to 3 V) voltages. This simple technique can be used to either frequency sweep the generated signals using an externally applied sawtooth waveform, or to frequency-modulate the waveforms with an external signal.

Figure 6 shows the basic method of applying FM to the standard XR2206 circuit. Here, the external modulation signal is applied to the junction of R1-RV1 via blocking capacitor C1.

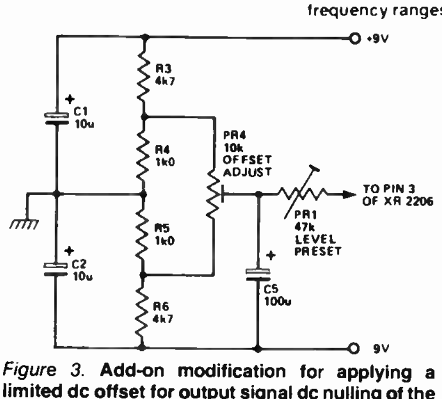


Figure 3. **Add-on modification for applying a limited dc offset for output signal dc nulling of the circuit in Figure 2.**

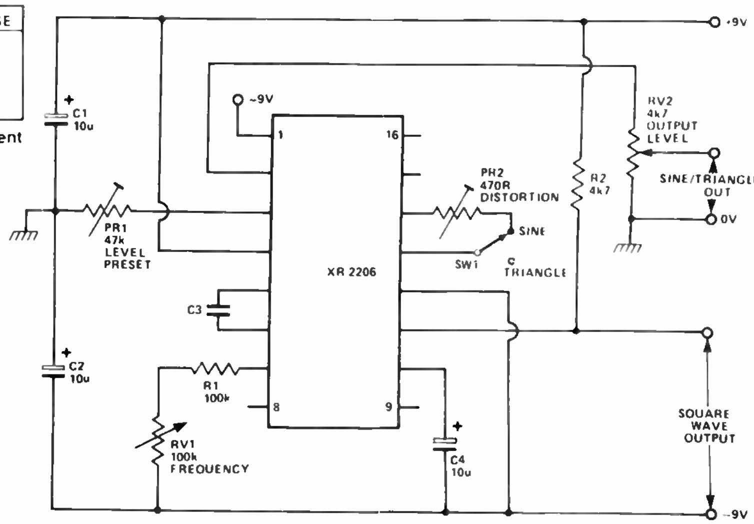


Figure 4. **Simple sine/triangle/square wave generator. See Table 1 for values of C3.**

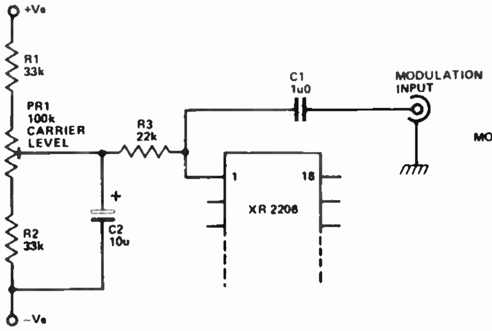


Figure 5. **How to add an amplitude modulation (AM) facility (split-supply circuit, as per Figure 2).**

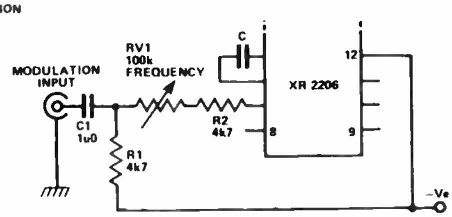
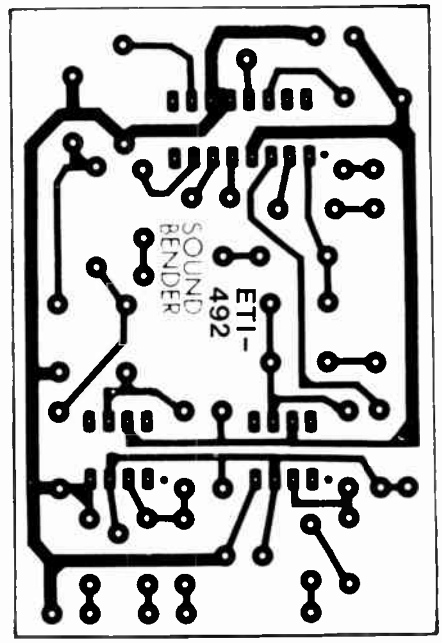


Figure 6. **How to add a frequency modulation (FM) facility (split-supply circuit, as per Figure 2).**



Note that the null is not perfect and there is some carrier feedthrough. However, this can be reduced and the effect-to-carrier leakage ratio improved by judicious adjustment of the mix and input level controls. Keeping the mix control somewhat back from the all-modulated end and the input level up does the trick.

Having nulled the multiplier, plug in a mike or signal source and advance the input level. Set SW1 to triangle for a 'dirty' sound. If the frequency is set to minimum (fully anti-clockwise), you will hear a tremolo effect. Setting the frequency control about two-thirds advanced you will be able to obtain 'Daleks', 'Darth Vaders', etc, with speech input. With the mix control you can 'fine tune' the effect quite well — we rarely used it fully clockwise (all modulated).

The unit performs best with a 'single signal' input — such as voice or one instrument (such as a guitar). Complex signals, such as from a band or orchestra, end up a confused jumble.

With SW1 set for a sinewave modulating signal, the effect produced is 'soft', while the effect produced when SW1 is set for a triangle wave modulating signal is 'hard'.

We noted that there seems to be some slight delay in the signal through the IC — or the modulator produces a similar effect — and the output sounds a bit 'echoey', especially when the frequency is very low, as on the tremolo effect.

Have fun with your Sound Bender! ●

Project 257

'Universal' relay driver board

Operating a relay to switch heavy current or mains voltages is a common requirement in electronic control applications. This project permits a relay to be switched in a variety of ways and from a variety of inputs.

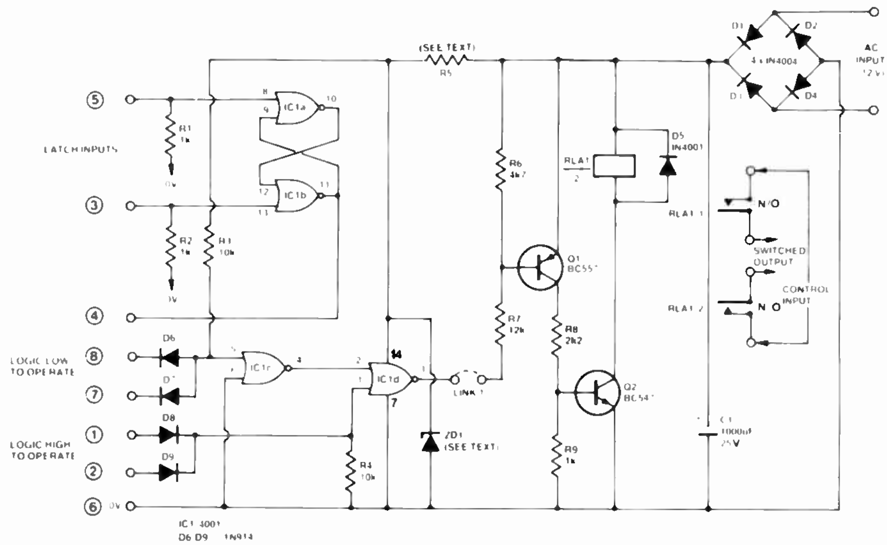
Graeme Teesdale

THIS VERSATILE relay driver unit is intended to be used with projects or devices not normally providing a switched relay output. In addition, power for external circuitry can be obtained from the board.

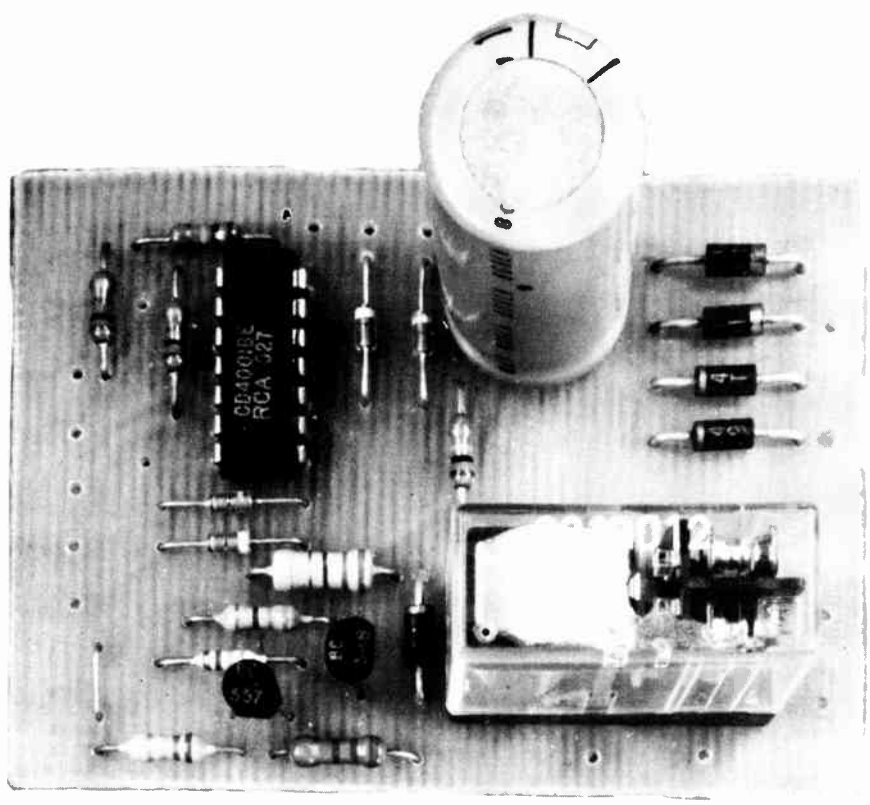
The unit has three groups of 'logic' inputs and a direct input. The relay itself is driven by two transistors, Q1 and Q2, and the direct input goes to the base of Q1 via a resistor (R7). Linking this input to the unit's 0 V rails — via a switch, a transistor which is turned on by a signal (open-collector logic) or a logic gate output — will operate the relay.

The logic circuitry on the board can be implemented by installing Link 1, which connects the output of the logic circuitry to the direct input. There are two "logic high to operate" inputs (pins 1 and 2). A logic high level — i.e: voltage level above about 2 V — on either of these inputs will operate the relay. There are also two "logic low to operate" inputs (pins 7 and 8). Pulling either of these inputs below logic low — about 0.5 V — will operate the relay. Note that these input pairs are ORed with diodes and can be linked so that one input inhibits the other. In addition there are two "latch" inputs, pins 3 and 5. Pin 4 is the output of the latch circuitry and latch operation is implemented by linking this pin to one of the other inputs. All the logic inputs are high impedance and can be driven from CMOS circuitry.

This unit is powered from a 12 to 15 Vac source such as a plugpack or 5 VA transformer. Supply for IC1 (and perhaps any off-board circuitry) is ob-



Circuit diagram of the relay driver board. Note that the rectifier diodes may be any of a range of types, such as 1N4001-2-4, etc, or EM401, EM402, etc. A variety of common relays will fit the pc board.



The relay driver board is simple, yet versatile. The external input/output pins are located around the edges of the board.

HOW IT WORKS — ETI 257

The best place to start is right in the middle of the circuit — because that's the 'business' end!

Transistor Q2 has relay RLA1 as its collector load. Diode D5 provides protection for Q2 when the coil current is cut off whenever Q2 is turned off. The base of Q2 is driven by the collector of Q1 via R8 and R9. Base bias for Q1 is obtained from the resistor network of R6 and R7. The 'free' end of R7 can be linked to on-board logic circuitry (IC1) or driven by an external source.

If the free end of R7 is connected to 0 V then base current will flow in Q1, which will turn on. This will turn on Q2 and the relay will operate. In fact, all that is required to turn Q1 on is to 'pull' the free end of R7 about 1 V below the positive supply rail to overcome the 0.6 V base-emitter turn-on voltage of Q1.

Effectively, a 'low' level on the free end of R7 will operate the relay.

Two groups of logic circuitry built around IC1 are included to provide a variety of operating 'modes'. IC1 is a quad NOR gate package. One gate, IC1d, is arranged to provide a 'logic high to operate' mode. Two diodes connected as a simple OR gate have their cathodes connected to pin 1 of IC1d. The output of another gate, IC1c, drives the other input, pin 2, of IC1d. IC1c has one input (pin 6) connected to 0 V, which is thus held at logic low. Pin 5 IC1c is held at logic high by R3 and thus its output, pin 4, will be high. As this drives pin 2 IC1d its output, pin 3, will be high. With Link 1 fitted, Q1 will normally be off and the relay not operated.

When a high logic level is applied to either input pin 1 or 2, or both, the diode(s) will conduct driving pin 1 IC1d high. The output, pin 3, will go low and the relay will operate. The relay will remain operated only while the input remains high.

Two diodes (D6, D7) are connected as a simple OR gate with their anodes connected to pin 5 IC1c. A logic low on either input pin 7 or 8 ('logic low to operate') or both will pull pin 5 IC1c low and its output, pin 4, will go low. Pin 2 IC1d will go low and thus pin 3 IC1d will go low and the relay will operate. The relay will remain operated only while the input remains low.

The remaining two gates from IC1 are connected as a set-reset (SR) flip-flop. Pin 4 on the pc board provides an output which may be coupled to the other inputs. Assume the SR flip output is initially low. A pulse applied to input pin 3 or 5 will cause pin 4 (pins 9, 11 of IC1a, b) to 'latch' high. A pulse then applied to the opposite input pin will cause the output to go low again, and remain low.

This part of the circuit can be used as a 'switch debouncer' as illustrated.

Power is derived from an off-board 9 Vac or 12 Vac source. This drives a bridge rectifier, diodes D1 to D4, smoothing being provided by C1. A zener diode, ZD1, is used to provide a regulated supply to the logic circuitry (IC1).

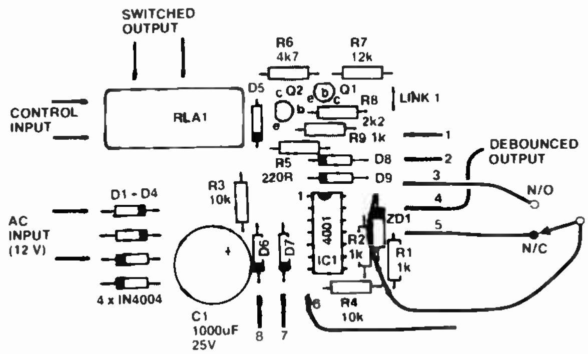
tained from a simple zener regulator circuit. This can be chosen to suit individual requirements. We used a BZY96/8V2 zener (1N4738) to provide an 8.2 V rail for IC1. We used a 220 ohm, 1 W resistor for R5. You can use any convenient zener from 5.1 V to 15 V — but no higher, and we recommend 1 W types run at around 50-60 mA current. You will have to work out the value of R5 according to your choice of zener. For a 15 V zener, R5 could be 47 ohms, for a 5.1 V zener, 270 ohms, or for a 12 V zener, say 100 ohms. There's plenty of latitude and these values are only given as a guide.

The logic circuitry (i.e: IC1) can be supplied from an off-board source if you wish. To do so, remove R5 and use a 15 V zener for ZD1 to prevent spikes on the external supply line causing damage to IC1. Note also that the logic levels on inputs 1, 2, 3 and 5 should also be no higher than 15 V.

The accompanying drawings illustrate how the unit is used in its four basic modes of operation.

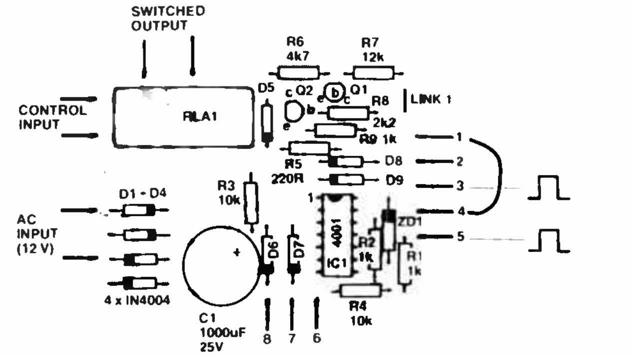
Construction

Construction is very straightforward. The components may be mounted in any order but you will probably find it easiest to leave the relay and C1 until last. Watch the polarity of all the diodes, the transistors and the IC. However, leave out link 1 at this stage.



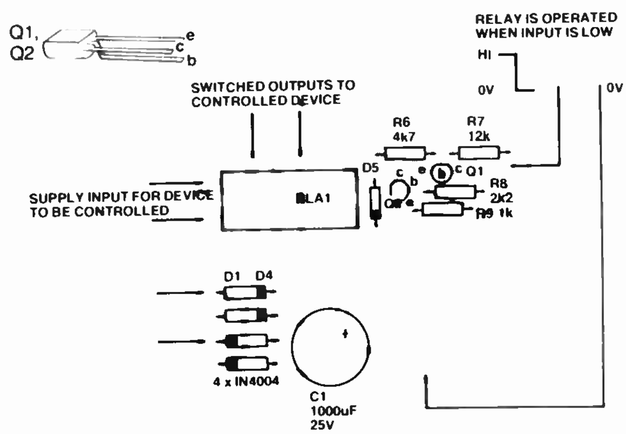
SWITCH DEBOUNCING

The SR flip-flop (IC1a and b) is not electrically connected to the rest of the circuit and may be used in external circuitry — for example, as a switch debouncing circuit.



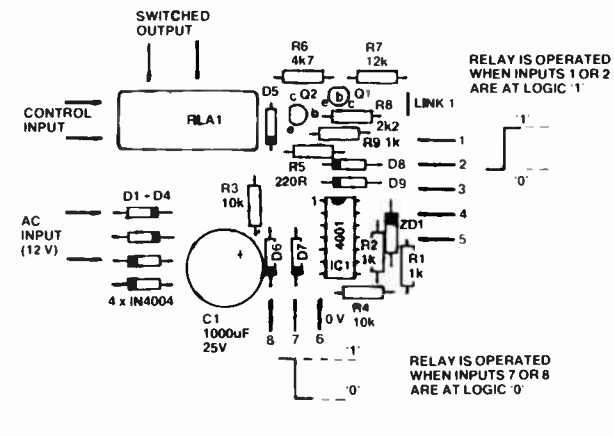
LATCH OPERATION

Pin 4, the output of the set-reset (SR) flip-flop, must be linked to either pin 1 or pin 2, or pins 7 or 8. A positive-going pulse on pin 3 or pin 5 will cause the relay to latch. A positive-going pulse on the opposite latch input will then cause the relay to unlatch.



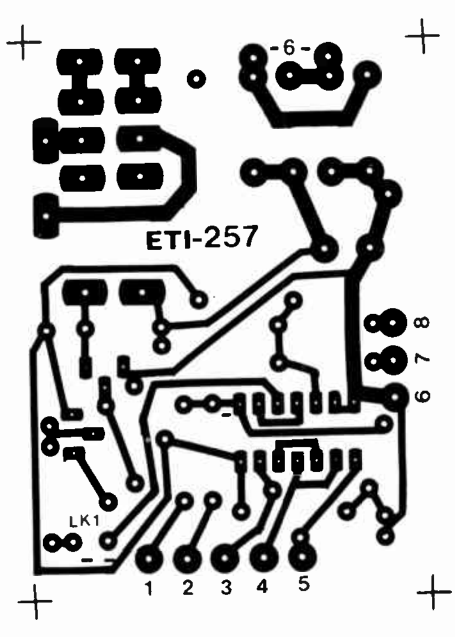
DIRECT INPUT

The relay will operate when the input is low (i.e: 0 V) or 'pulled' about 1 V lower than the positive supply rail. Only those components shown are necessary for this mode of operation.



LOW OR HIGH TO OPERATE

The relay will be operated when pins 1 or 2 are held at logic high. To operate the relay from a logic low, pins 7 or 8 must be held at logic low. The inputs are ORed so that up to two input signals can be employed to operate the relay in each mode.



Once you've got it together and have checked everything, apply 12 V ac to the ac input and check various modes of operation as follows:

(1) Bridge the free end of R7 to ground. The relay should operate.

(2) Install link 1, then bridge pin 7 to ground. The relay should operate. Likewise for pin 8.

(3) Bridge pin 1 to the cathode of the zener. The relay should operate. Likewise for pin 2.

(4) Connect pin 4 to pin 1 or 2. The relay may operate. Apply a pulse to pin 3 or 5 and see that it latches on. A pulse on the other input will drop it out again.

If all is well, your unit is ready for installation! ●

PARTS LIST — ETI 257

Resistors — all ½W, 5% unless noted

R1, R2, R9	1k
R3, R4	10k
R5	220R, 1W (see text)
R6	4k7
R7	12k
R8	2k2

Capacitors

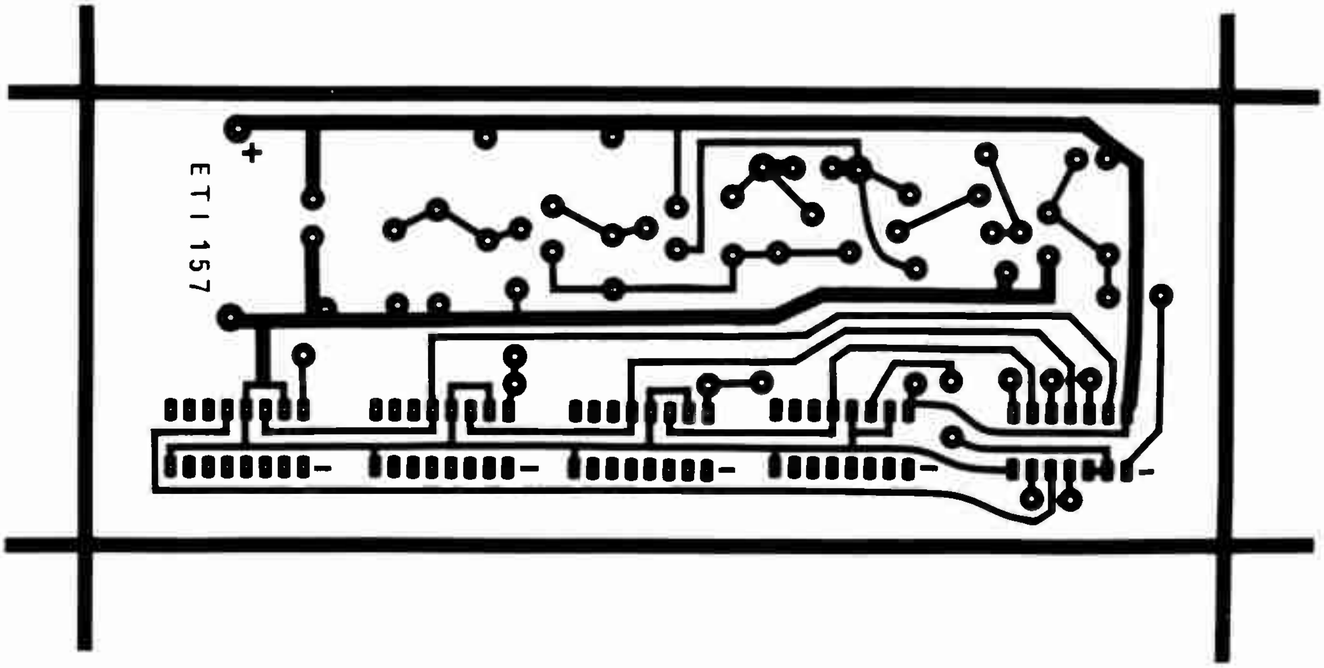
C1	1000 u/25 V electrolytic

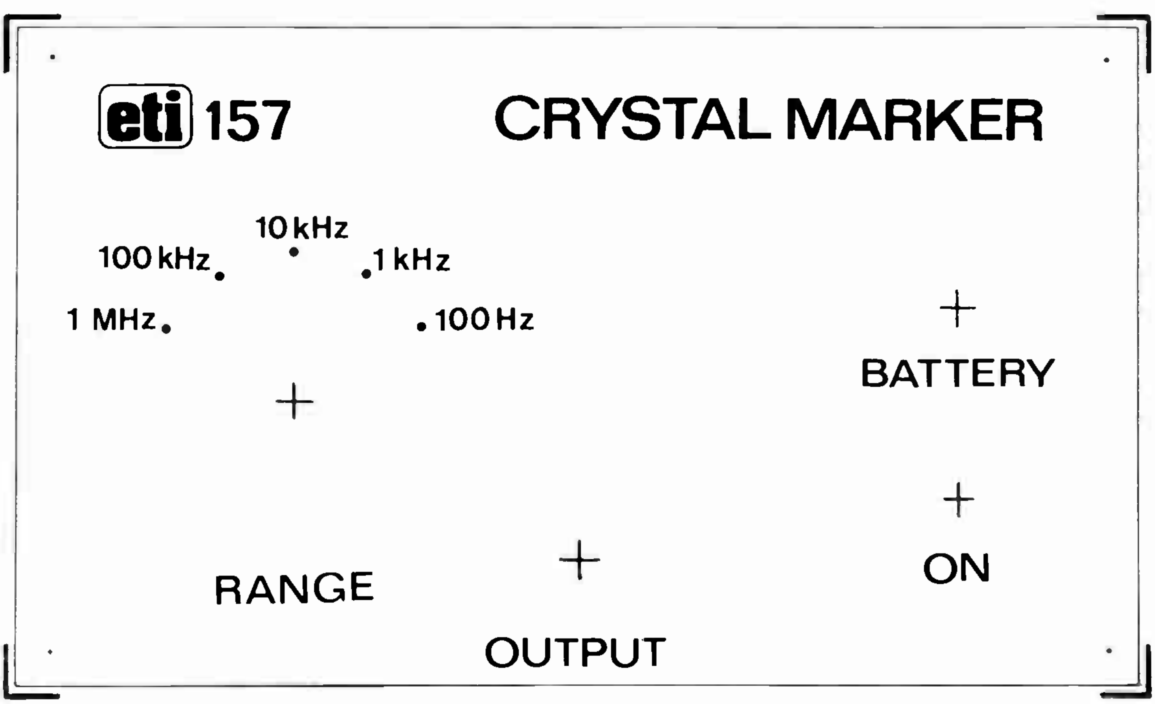
Semiconductors

IC1	4001B
Q1	BC557
Q2	BC547
D1-D5	1N4001, 1N4002 etc
D6-D9	1N914, 1N4148 etc
ZD1	400 mW or 1 W zener, see text

Miscellaneous

ETI-257 pc board; RLA1 — relay, Fujitsu FRL-621D012 or Takamisawa VB 12STAN or Pye 265/12/G2V.


ETI 157


eti 157
CRYSTAL MARKER
10 kHz
100 kHz
1 kHz
1 MHz
100 Hz
BATTERY
RANGE
ON
OUTPUT

Crystal marker generator for receiver and CRO calibration

A simple but very useful piece of test equipment for calibrating and aligning receivers, transceivers and oscilloscopes. It is portable, battery operated and inexpensive to build.

Design: **Ray Marston**
Development: **Simon Campbell**

THIS SIMPLE piece of test gear will help you calibrate receivers or transceivers which don't incorporate a crystal calibrator, set up and calibrate low-cost oscilloscopes, and even provide an accurate calibration source for frequency/period counters (especially if you've made it yourself).

Many of the older 'budget' shortwave receivers do not have dial calibrations which are sufficiently accurate to read out to even 10 kHz, and few ever had a crystal calibrator of any sort (see 'Receivers for the Budget-Minded Shortwave Enthusiast', by Bob Padula, ETI June '80, p.26). In addition, their calibration drifts with time. This project not only allows you to set a receiver's dial calibration from time to time but you can dial up a particular frequency to an accuracy of 1 kHz.

If you're keen on VHF and operate suitable converters in front of your HF receiver then this project will be useful there too, as it provides harmonics to over 150 Mhz. (See 'Modern Solid-State Converters', by Roger Harrison, ETI Feb. '76, p.63 and 'Aircraft Band Converter', ETI March 1979, p.39).

A variety of low-cost solid-state oscilloscopes, aimed at the hobbyist, has become available recently, and while useful in a general way, suffer somewhat because they do not have a calibrated timebase. You can use this project to overcome this problem and this application was one of the reasons the 100 Hz output facility was included.

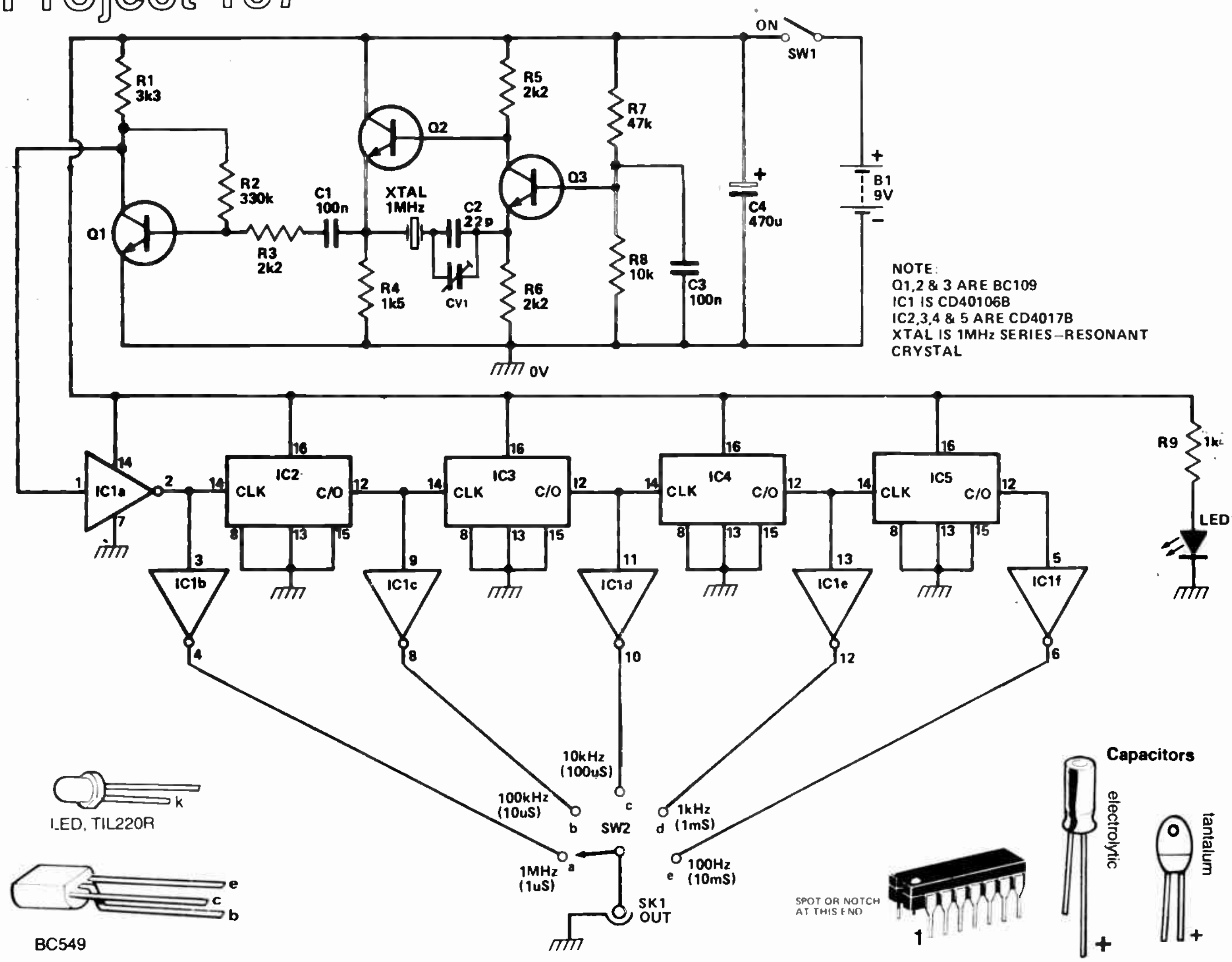
This marker generator can also be used to calibrate the timebase oscillators of frequency counters and period timers simply by plugging the marker output into the counter's input and setting the timebase frequency to obtain the correct display!

Design

The circuit design is fairly straightforward, but quite different to our earlier crystal marker generator, the ETI-706 (Feb. '76, p.53). The latter used a 4 MHz crystal and provided fundamental outputs of 4 MHz, 2 MHz, 1 MHz, 100 kHz and 10 kHz. It had useful harmonics to 30 MHz or so.

The microprocessor industry has provided a range of components that were not common a few years ago, among them 1 MHz quartz crystals. We've used one of these as the basis of this project because they're cheap and common. As they are generally meant for series-mode operation, we've used an aperiodic Butler oscillator (for more details on crystals and crystal oscillators, see 'Modern Crystal Oscillators', by Roger Harrison, ETI Jan. '76, p.46, or ETI Circuit Techniques Vol.1).

The output of the crystal oscillator is buffered by Q1, which drives one stage from a hex Schmitt inverter (40106). This 'squares up' the signal and drives the four cascaded decade dividers (all ▶



4017s). The first Schmitt inverter provides 1 MHz output, which is buffered by another Schmitt inverter to provide the 1 MHz output to the output selector switch. The output of each decade divider stage is also buffered by a Schmitt inverter to provide, respectively, the 100 kHz, 10 kHz, 1 kHz and 100 Hz outputs to SW2.

Construction

We constructed the project on a pc board and housed it in a conveniently sized jiffy box. The two switches, the LED and the RCA output socket we mounted on the metal front panel of the jiffy box. Layout of the panel is not important, and if you aren't going to use a Scotchcal of our panel, you can place these components to suit yourself. Note that, whilst we used an RCA socket for the output, you could use any suitable coaxial output socket or just a pair of banana sockets, if you wished. If you are using a Scotchcal of our front panel, it can be used as a drilling template. An all-metal box, such as the K&W C642, could be used if you wish.

HOW IT WORKS ETI-157

The crystal marker generator consists of a 1 MHz crystal oscillator driving a series of four decade dividers connected in cascade. Outputs are provided at 1 MHz, 100 kHz, 10 kHz, 1 kHz and 100 Hz. As each output is essentially a square wave (but not a perfect square wave), harmonics extending into the VHF region are generated. A switch is used to select the desired output.

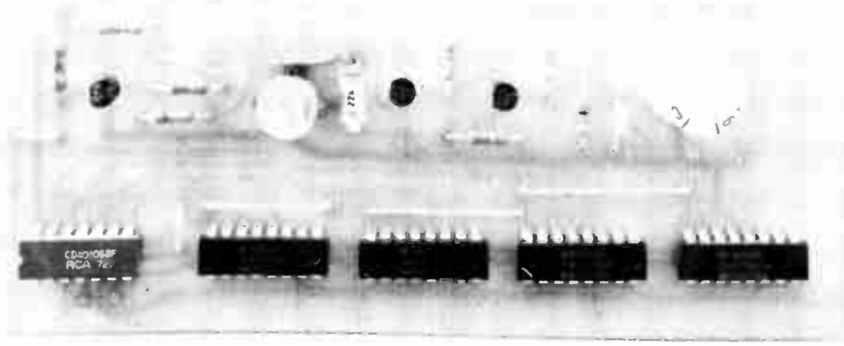
The crystal oscillator comprises Q2, Q3, R4 to R8 and C3. The circuit is an aperiodic Butler oscillator. Q2 and Q3 form an amplifier with the output linked to the input via the crystal. Positive feedback only occurs at the series resonant frequency of the crystal where the phase shift of the crystal is zero. Q3 is configured as a common-base amplifier. Its collector is direct-coupled to the base of Q2, an emitter follower (common-collector). The crystal is connected from the emitter of Q2 to the emitter of Q3, via a series capacitance comprising C2 and CV1. Thus the output of the non-inverting amplifier formed by Q2 and Q3 is connected to the input via the crystal. When the phase shift from input to output is zero, there is positive feedback, and thus oscillation occurs. CV1 is effectively in series with the equivalent series capacitance of the crystal. Varying CV1 varies the effective phase shift between the emitters of Q2 and Q3 and thus varies the frequency of oscillation.

The output of the crystal oscillator is coupled to a buffer amplifier comprising Q1, via C1 and R3. The buffer avoids loading effects on the oscillator 'pulling' the frequency. Q1 is a common emitter amplifier. R1 is the collector load and R2 provides bias to the base. As R2 is connected between collector and base, any dc drift in the collector current changes the base current in the same direction, which then opposes the drift in collector current, affecting compensation of any drift (dc negative feedback).

Q1 raises the oscillator output level sufficiently to provide the required drive to the input of IC1a, one stage from the 40106 hex inverting Schmitt trigger IC. This 'squares up' the signal. The output of IC1a drives the input to the first divider in the decade divider chain and the input of another stage from IC1, IC1b. This provides a buffered 1 MHz output to SW2.

The divider chain consists of IC2, IC3, IC4 and IC5. Each is a 4017 decade divider, the carry output of the preceding stage driving the clock input of the next. The carry output of each stage also drives the input of a Schmitt buffer. Thus the output of IC1c provides a buffered 100 kHz output to SW2, IC1d provides the 10 kHz output, IC1e the 1 kHz output and IC1f the 100 Hz output.

Capacitor C4 provides a low frequency bypass for the supply rail, while LED1 serves as an on indicator.



The finished pc board for the crystal marker generator. Note that all the ICs face the same way. Artwork for the ETI-157 pc board is reproduced on page 18 along with the full-size artwork for the front panel.

Assemble the components to the pc board, resistors first, then the capacitors followed by the transistors and ICs. Leave the crystal till last. The board has been laid out to take either of the two common crystal sizes. The HC18/U style holder has a pin spacing of 12.5 mm, while the smaller HC36/U holder has a pin spacing of 5 mm. They can be obtained with pins, meant for socket mounting, or flying leads, for soldering in place. Whilst a suitable socket could be mounted on the board we soldered the crystal in place. Do it quickly to avoid possible damage to the crystal. Make sure the base of the crystal sits flat on the board, to prevent movement.

There are five links to be installed, which can now be soldered in place, along with hookup wire to go to the switches, LED and battery. Follow the overlay/wiring diagram to complete this.

The pc board and battery we mounted in the box with double-sided sticky pads. It's simple, effective and saves drilling.

Having got it all together, connect the battery and try it out.

You can check that it's working with an ordinary broadcast band receiver, such as a transistor portable radio. Place the marker generator near the receiver and turn it on. Tune the receiver to around 10 on the dial and you should be able to hear a strong 'carrier' signal. You may hear a loud, high-pitched whistle if a broadcast station operates near this frequency in your vicinity. ▶

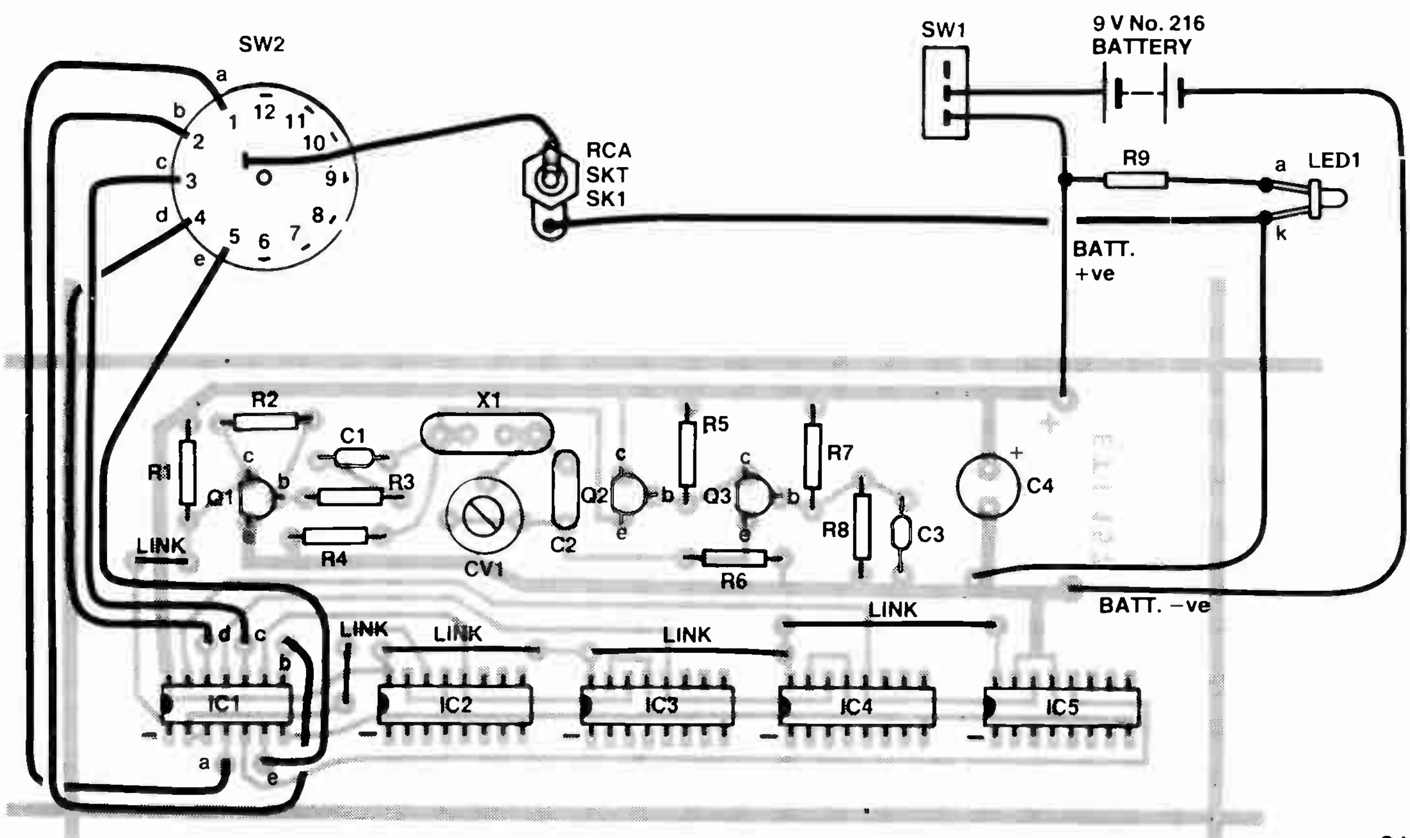
PARTS LIST — ETI 157

Resistors	all ½W, 5%
R1	3k3
R2	330k
R3,5,6,	2k2
R4	1k5
R7	47k
R8	10k
R9	1k
Capacitors	
C1, C3	100n ceramic
C2	22p ceramic
C4	470u/16 V electro.
CV1	5-40p film or ceramic trimmer
Semiconductors	
IC1	40106B
IC2,3,4,5	4017B
Q1,2,3	BC549, BC109 etc.
LED1	TIL220R or sim. red LED
Miscellaneous	
XTAL	1 MHz crystal
SW1	SPST miniature toggle switch.
SW2	single pole, five position rotary switch
SK1	RCA coax socket

ETI-157 pc board; jiffy box 160 x 95 x 50 mm (or similar); knob to suit; nuts, bolts, wire etc.

Price estimate **$18 - $25**

Note that this is an estimate only and not a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



Setting it up

To set the oscillator as accurately as possible to 1 MHz, a trimmer capacitor, CV1, in series with the crystal has been provided. Adjusting this will 'pull' the crystal frequency slightly. To set the oscillator you will need to have, or obtain access to, a shortwave receiver that covers the frequency range from 7 MHz to 15 MHz. A number of 'standard' time and frequency broadcasts can be received in this range. VNG Australia broadcasts on 7.5 MHz and 12 MHz within this range, while the US stations WWV and WWVH broadcast on 10 MHz and 15 MHz. The transmission frequencies are maintained to an incredible accuracy and you can use them to set your marker accurately on frequency.

Tune in one of the stations on 10, 12 or 15 MHz on the receiver. Plug a length of hookup wire into the marker's output socket and drape it near the antenna input of the receiver. Set SW2 to 1 MHz, turn the marker on and you should hear a strong whistle or 'beat' note. Using a non-metallic adjusting tool, adjust CV1 to decrease the pitch of the beat note until the frequency is so low you can't hear it. Doing this with heaphones plugged in helps. As you approach 'zero beat', the receiver's signal strength meter will begin to oscillate, rapidly at first and then slowly. Carefully adjust CV1 until the S-meter stops wavering or beats as slowly as possible.

This calibration method is independent of the receiver accuracy. Switch to the 10 kHz output and you should hear frequency 'pips' every 10 kHz. The 100 Hz output sounds like a 'burr' all over the dial.

If you have access to a six or, preferably, an eight-digit readout frequency counter, it is a simple matter to set the oscillator on frequency. Connect the marker's output to the counter's input, set SW2 to 1 MHz and adjust CV1 so that the display reads 1 000 000.0! Use a non-metallic adjusting tool, as before. Switch through the other outputs to check that the divider is working. You can further trim the oscillator accuracy on the lower frequency output.

Say for example that you want to tune your receiver to 14 150 kHz. First select 1 MHz on SW2 and loosely couple the marker's output to the input of the receiver. Tune the receiver to the marker, which will be found at 14 MHz. If your receiver is *grossly* off calibration (or has no dial markings!), tune in one of the standard frequency broadcasts at 10 MHz or 12 MHz, and count the required number of 1 MHz markers as you tune up in frequency until you reach 14 MHz. Once located, confirm that it is indeed coming from the marker generator by switching it on and off. Now switch to the 100 kHz markers and tune the receiver upwards to locate the first marker past 14 MHz (14 100 kHz). Now select the 10 kHz markers and tune upwards through five markers to locate 14 150 kHz. Note that if this tuning procedure is carefully carried out it is quite simple to locate any position on the dial with great accuracy.

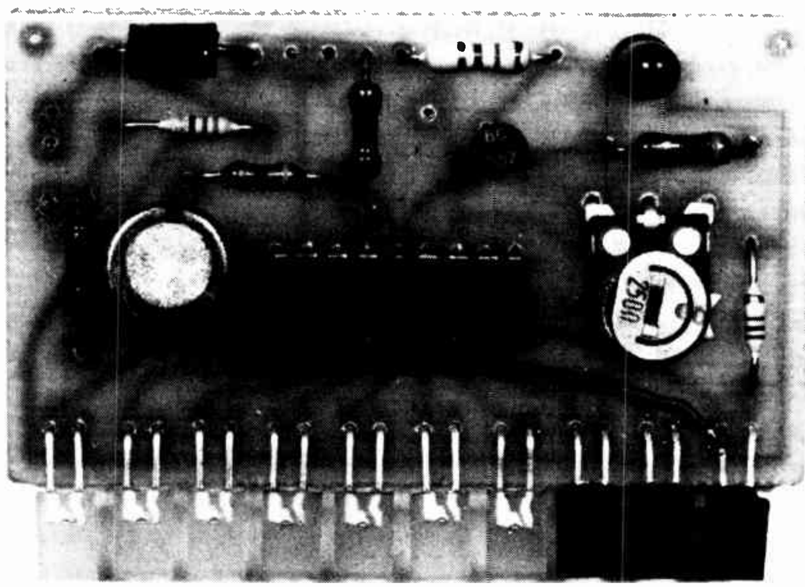
Note that the output square wave has an amplitude of 8 V peak-to-peak and should not be directly coupled to the input socket of a receiver. Some solid-state receivers may suffer front-end damage at the lower frequencies if directly connected to the marker output. Use a coupling capacitance of several pF or loosely couple a wire from the marker output near the receiver antenna input.

To calibrate a CRO timebase, set the marker to the appropriate output range and plug the output into the Y input. Set the input attenuator to obtain a display of a convenient height. Set the CRO timebase range switch to obtain one complete cycle on the screen. One cycle of a square wave is the time between two successive rising edges or two successive falling edges. Adjust the 'fine' variable control on the CRO timebase so that the two rising (or falling) edges of the cycle are aligned on the left and right extremes of the graticule. And there you have it! ●

Build a LED oil temperature meter for your vehicle

Knowing your engine oil temperature can be very valuable, this instrument employs a readily available dipstick probe with a thermistor mounted in it as a sensor and displays temperature on a row of LEDs.

Phil Wait
Simon Campbell



JUST AFTER WWII, one of General Motors' vice-presidents located a virtually brand-new Bugatti Royale — one of Europe's most sought after collector's vehicles and of which a mere thirteen had been made. This example had run less than a hundred kilometres since new and had been stored throughout the war.

When the engine was subsequently stripped down *it looked totally worn out*. Every single bearing surface was damaged beyond belief.

Ten years later, GM's Bedford truck division began an extended study into similar phenomena. A striking example was two truck fleets running similar vehicles but in dissimilar service. Fleet 1 was in long distance haulage (London-Edinburgh) and averaged 500 000 km. Fleet 2's business was house-to-house coal deliveries in London's suburbs. Their record was *less than 20 000 km* between major overhauls!

In the case of the Bugatti and Fleet 2, the mechanical carnage was caused by acid build up in the vehicles' sumps. The wear was *chemical* not mechanical.

How it's caused

When a petrol engine is switched off, a quantity of unburnt and partially burnt fuel remains in the combustion chambers. This condenses on the cylinder walls and drops down into the oil in the sump. This condensed fluid consists mainly of water and sulphuric acid.

The acid content is boiled off when the oil exceeds 80°C (176°F). But if that temperature is not reached and maintained for at least some minutes (or if acid-diluted oil is left in the engine for extended periods) engine longevity will be massively reduced.

For most commuters the problem tends to be oil that's running too cool rather than too hot. Only too often an engine that appears to use no oil is simply having a regular top-up with acid!

If your vehicle usage is limited to short runs there's not a great deal you can do about it except be aware of the problem. If you care about it sufficiently, take the car for a good long run (at least 40 km) at least once a fortnight — or at least change the oil every second month regardless of distance driven. At least you now know why cabs regularly exceed 300 000 km between engine changes!

Too hot

Apart from its lubricating function, engine oil 'washes' heat from engine components. Its ability to do this decreases rapidly beyond 135°C (275°F). There is also evidence that some multi-viscosity oils revert permanently toward the lower end (i.e: thinner) of their range of viscosity if overheated.

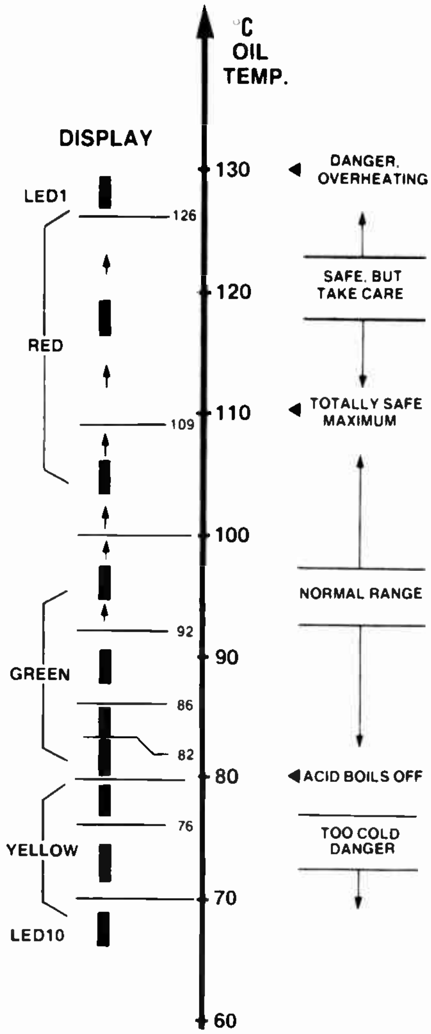
The *totally safe* oil temperature for continuous running is 110°C (230°F). Some oil companies quote 132°C (270°F) as an absolute maximum. Our Managing Editor's own experience (whilst with GM) is that, with the exception of air-cooled engines, 125°C is safe for continuous operation.

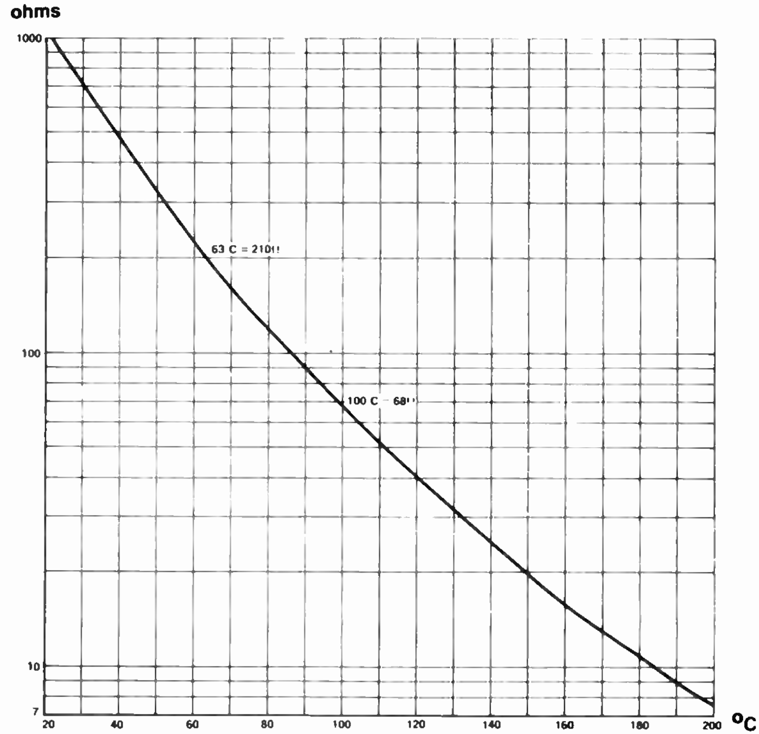
Few modern vehicles suffer from overheated engine oil (transmission fluid is something else again though!) A notable exception is some VWs (particularly Kombi versions) — few can be driven hard in an Australian summer without severe oil overheating and the risk of consequent severe engine damage.

Overheating engine oil is simpler to cure than oil that's insufficiently warm. Simply add an oil-cooler; obtainable from most specialist parts suppliers.

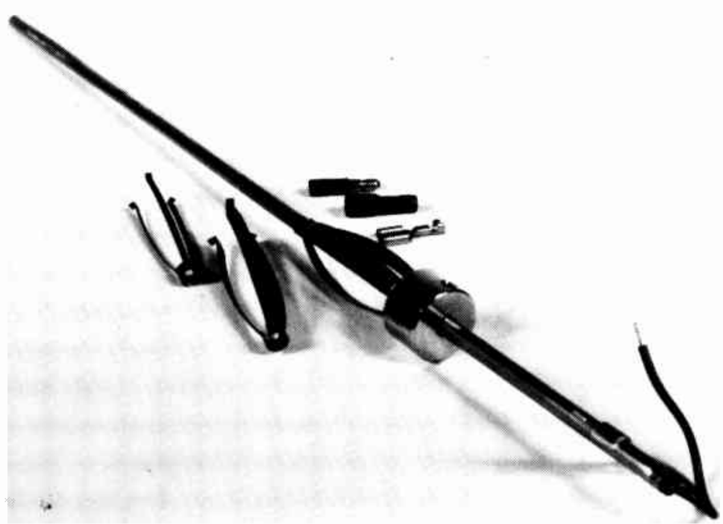
A monitor

Most cars these days, with the exception of Volkswagens, are fitted with some sort of water temperature indicator. Often this is no more than a warning light which hopefully never comes on during the life of the vehicle, and if it ▶





Calibration curve for the NTC thermistor in the dipstick probe.



The V.D.O. dipstick probe with its associated parts. Full assembly details are given on page 27.

does it's probably too late to avoid some engine damage.

Since the coolant temperature is controlled by the car's thermostat and radiator it is not a good indication of oil temperature, or true engine temperature.

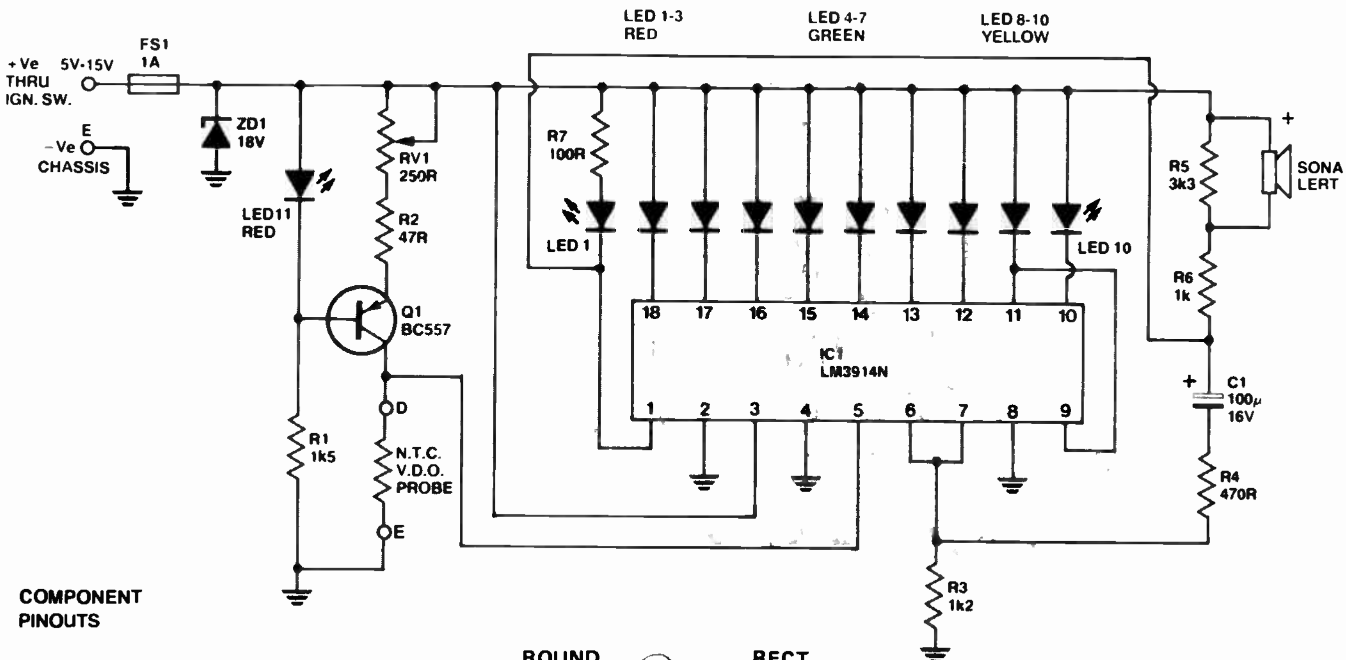
Monitoring the oil temperature is a much better indication of the engine's operating temperature but the problem is how to measure it. Any temperature probe will have to be inserted deep inside the engine or through the sump. Accidental loss of oil caused by the sensor falling out would be *catastrophic*, not to mention very expensive. The most practical way to insert a probe into the engine is through existing holes, such as the sump plug or the dip stick hole. In fact, VDO instruments make thermistor sump plugs and dip stick probes for use with their oil temperature meters.

We have chosen the VDO dipstick probe for our project as it is easy to install without having to drain the sump, and the wiring to the probe is well protected in the engine compartment. The last thing you want is a heavy-fisted mechanic tampering with wires to the sump plug every time the coil is changed.

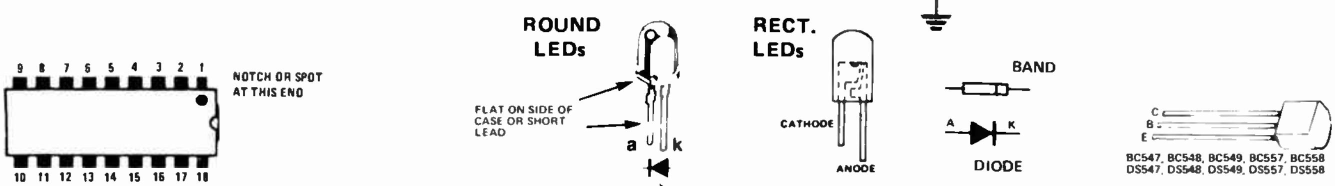
By the way, we *strongly suggest* you don't try to make your own dipstick probe as there is too much risk of something falling off with the severe vibration and temperature changes experienced inside the engine.

The temperature display employed in our project uses ten LEDs in a 'dot' mode (single LED lit at a time) bargraph display and is designed as a matching instrument to our LED Expanded Scale Voltmeter (ETI-326, September 1980). The display covers the range 70°C to 126°C with the first LED lit at temperatures below this range and the last LED remaining lit above this range as well as sounding an optional piezo audio alarm. Yellow LEDs are used for the 'cold range' to 80°C, when acids remain in the oil. Green LEDs are used for 80°C - 100°C in the normal operating range and red LEDs are used for the 'hot' range above 100°C. As we mentioned previously, some engines operate safely up to 110°C and may light the first red LED.

The instrument is easily calibrated by adjusting a trim potentiometer for a reading of 100°C when the thermistor probe is placed in boiling water. Water boils at very close to 100°C at sea level.



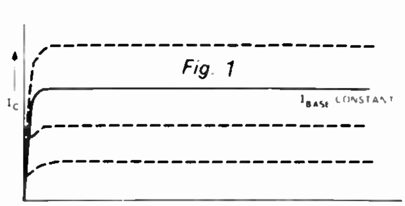
COMPONENT PINOUTS



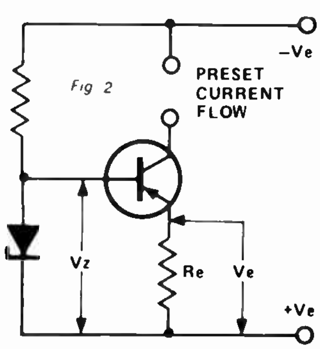
HOW IT WORKS — ETI 328

The circuit consists of a thermistor temperature sensor in a dipstick probe driven by a constant current source, the voltage across the thermistor, which is proportional to the oil temperature, being sensed and displayed by an LM3914 LED bargraph driver chip. The display is a series of ten LEDs, the LM3914 being operated in the 'dot mode' so that only one LED lights at a time.

The LM 3914 is operated at maximum sensitivity, as a 0 - 1.2 V voltmeter, with ten display steps at 120 mV intervals. An alarm function (optional) is provided by a piezo audio alarm driven from the LED that indicates the highest temperature. Reverse polarity and overvoltage protection are provided by the zener diode, ZD1.



First, let's see how a constant current source works. Transistor Q1 and associated components provide the constant current source for the probe. Figure 1 shows the collector characteristics of a typical silicon transistor. They show that, if you hold the base current constant, the collector current will



remain substantially constant for a widely varying range of collector voltage. Figure 2 shows the general circuit of a constant current generator. The voltage between the base and the emitter return (common, the +ve supply line here) is fixed by the zener diode. Thus, the voltage across the emitter resistor (Ve) is fixed at a value equal to the zener voltage (V_z) minus the base-emitter voltage drop of the transistor (0.6 V for silicon transistors). With a fixed voltage across R_e, the current through it will be constant. Thus, the emitter current, and therefore the collector current, of the transistor will be constant. The resistor supplying current to the zener is generally chosen so that zener current is five to ten times greater than the base current of the transistor.

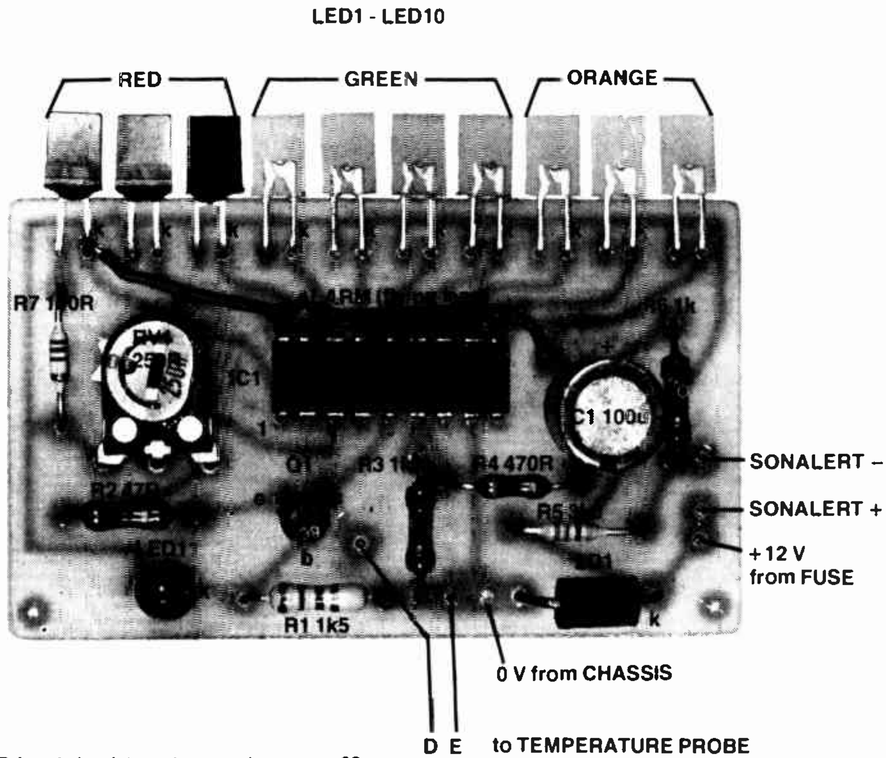
With this circuit, so long as there is about one volt between the emitter and collector, the collector current will remain constant at the chosen value until a load of too large a value robs the collector of its working voltage.

In the project circuit diagram, a LED (LED11) is used instead of a zener diode. The forward-voltage drop of a red LED is about 1.6 V and thus the base of Q1 is 'clamped' at about 1.6 V below the positive supply rail. Thus, the voltage across R2 and RV1 will be 1.6 V less the base-emitter junction drop of Q1, about 0.6 V, leaving 1 V. Thus, with RV1 at minimum resistance, the emitter current (and thus the collector current) through Q1 will be close to 20 mA. With RV1 at maximum, it will be about 3.4 mA, giving a range of about 6:1 variation which is more than adequate for calibration, yet provides a smooth adjustment.

As the temperature of the probe increases, the thermistor resistance will decrease. Since the probe is driven with a constant current, the voltage across the probe decreases linearly with its resistance and independent of supply voltage fluctuations. The temperature scale resulting is non-linear however, because the resistance variation of the thermistor in the probe is not linearly related to temperature. A graph has been provided in the main text.

The temperature range of the instrument, and therefore the calibration, is set by adjusting the current passing through the probe by means of RV1.

A complete description of the operation of the LM3914 was provided in the article on the Expanded Scale LED Voltmeter, ETI-326, published in the September 1980 issue of ETI.



Printed circuit board pattern is on page 32.

Construction

Construction of the unit is simple and straightforward, but take a little care juggling the LEDs into place. In fact, it is best to commence construction by mounting the LEDs. We used rectangular LEDs for our unit, however, conventional types may be used if you wish. Note that there are three yellow, four green and three red LEDs.

The easiest way to ensure correct insertion of the LEDs is to place them on a table in front of you with all their leads oriented just as they are to be mounted in the board. Insert the first LED (red if you're working from left to right with the LEDs facing away from you), but don't solder it in place. Position it so that when you bend it over, the base of the LED comes flush with the board. Don't fumble this and attempt it twenty times or you're likely to end up with very short leads on your LED! When it's right, solder the leads in place and bend it back upright. This LED then becomes a guide for the correct lead length of the others. Insert the rest one by one so that they line up with the first LED and, when the row is finished, bend them all over and they should all lie flush with the edge of the pc board. Refer to the overlay photograph.

The rest of the components can be mounted, taking care with the orientation of the LM3914, Q1, LED11, the electrolytic capacitor and zener diode. The alarm lead is a length of insulated hookup wire, soldered directly to the cathode of the last red LED (see the overlay).

PARTS LIST — ETI 328

Resistors .... all ½W, 5%
- R1 .... 1k5
- R2 .... 47R
- R3 .... 1k2
- R4 .... 470R
- R5 .... 3k3
- R6 .... 1k
- R7 .... 100R

Capacitor
- C1 .... 100u, 16 V electro.

Semiconductors
- IC1 .... LM3914
- ZD1 .... 18 V, 1 W zener
- LED 1 - 3, LED 11 .. TIL220R red LEDs, or similar
- LED 4 - 7 .... TIL220G green LEDs, or similar
- LED 8 - 10 .... TIL220Y yellow LEDs, or similar

(Note: LEDs above are conventional but rectangular types have been used in our prototype).

Miscellaneous

ETI-328 printed circuit board; Piezo alarm - Sonalert or similar type; VDO temperature probe dipstick with NTC thermistor sensor (see text).

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$18 - $22

(excluding the dipstick probe)

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the actual price of a project, whether bought as separate components or made-up as a kit.

Calibration

When construction is complete, the display requires calibration. Basically, this involves putting the probe in boiling water and adjusting RV1 so that the required LED lights. The display can be adjusted to cover a variety of temperature ranges, but we found the range shown to be the most useful.

Calibration is best done away from the vehicle, mainly for convenience. You'll need some place to boil water and a power supply, nominally 12 Vdc, to power the unit. Connect the thermistor dipstick probe and the power supply but keep the probe out of the water to start with. When you apply power, the first yellow LED should light. Hold the end of the probe in the boiling water, but not too close to the bottom of the vessel to avoid hotspots or direct contact with the source of heat, otherwise you may obtain a false reading.

When you put the probe in the water, the display should 'step' towards the hot end (three red LEDs). After the display has stabilised, adjust RV1 so that the *last green LED* just turns off and the *first red LED* just turns on.

As the boiling temperature of water varies with atmospheric pressure, and therefore with elevation above sea level, if you're calibrating the unit at altitudes over several hundred metres above sea level, adjust RV1 so that the second-last green LED just goes off and the last green LED just turns on.

The temperature range of the display should now correspond to the scale shown.

ASSEMBLING THE DIPSTICK PROBE

The VDO dipstick probe is supplied with the probe rod, several steel finger springs, a felt washer, steel collar and connectors. Two probe lengths are available, one 300 mm and the other 500 mm long, to suit a variety of cars. We fitted ours to a Suzuki four-wheel drive with an 800 cc engine and a 1950 model Dodge truck with an engine capacity close to five litres — just to make sure! The supplier of the probe will help you choose the correct one.

After you have purchased the probe, you will have to select the correct spring set and set the probe insertion length inside the engine. The accompanying diagrams show the assembly of the probe.

Panel 1
Three spring sets are supplied with the 500 mm probe and two with the 300 mm type. The spring set selected depends on the dipstick hole diameter in the engine block.

Panel 2
Compress the spring fingers with your finger and slip on the felt washer.

Panel 3
Holding the springs compressed, insert the ends into the steel collar. Release the springs and ensure their ends catch in the groove inside the collar.

Panel 4
Press down the felt washer into the bottom of the collar.

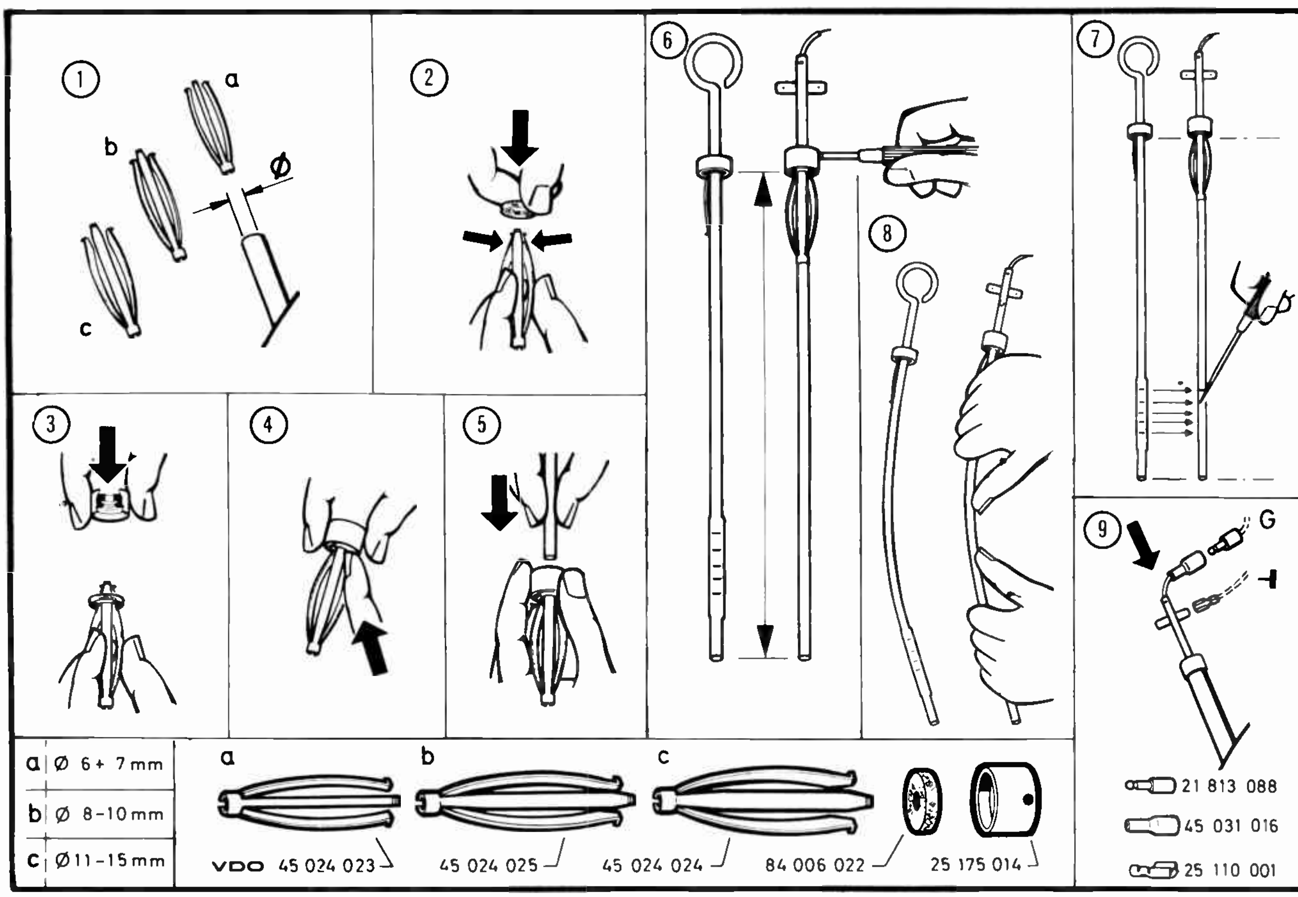
Panel 5
Slide the whole assembly over the probe. This may be a tight fit as the probe holds the ends of the spring fingers in place in the groove inside the collar so there is no danger of the springs falling out.

Panel 6
Remove the original dipstick and place it next to the dipstick probe. Slide the collar and spring assembly along the probe so the length to be inserted into the engine block is exactly the same as with the old dipstick. This is **very important** as an incorrect length will give a false oil level indication as well as possibly colliding with the crank shaft! Tighten the grub screw in the collar firmly.

Panel 7
The oil level mark can be scribed on the new dip stick or lightly engraved.

Panel 8
If your original dipstick is bent, the new dip-stick probe can be carefully bent to the same shape.

Panel 9
Finally, connect sufficient wire to pass through the firewall and under the dash to the display pc board. We used 'figure-8' power flex soldered to the spade and in-line connector supplied with the probe.



Installation

The display pc board can be mounted in any convenient position in or under the dash of the vehicle, to the side of the driver's field of vision. For good visibility it should be mounted away from direct light. As mentioned earlier, the instrument has been designed to match the LED Expanded Scale Voltmeter and the two can be 'sandwiched' together, track side to track side with a spacer between the boards, and mounted in the vehicle. The high voltage end of the voltmeter will then be opposite the high temperature end of the Oil Temperature Meter.

The wires from the dipstick probe should be passed through the firewall alongside existing wiring or the speedometer cable, and taped to a support to prevent them catching in the fan. The battery supply can be taken from any convenient point under the dash, such as the fuse box, but make sure the instrument is switched off with the ignition. The 0 V connection can be made to any convenient chassis point. ●

Versatile electronic stethoscope

Design: Ray Marston
Development: Simon Campbell

This unusual device can be a very handy tool for those who work with mechanical contrivances — anything from tractor engines to drill presses to watch mechanisms. Thrill to the clatter of clagged-out tappets, the grind of graunched bearings, the tick-tock of escapements . . .

"DOCTORS DO IT with stethoscopes ..." said the bumper sticker on the expensive imported car parked in the street near our offices. With this project, you can do it too! The purpose of a stethoscope is to enable you to hear what's happening inside an operating mechanism when it's difficult or impossible to see what's happening — in fact, listening may be better than seeing in some instances.

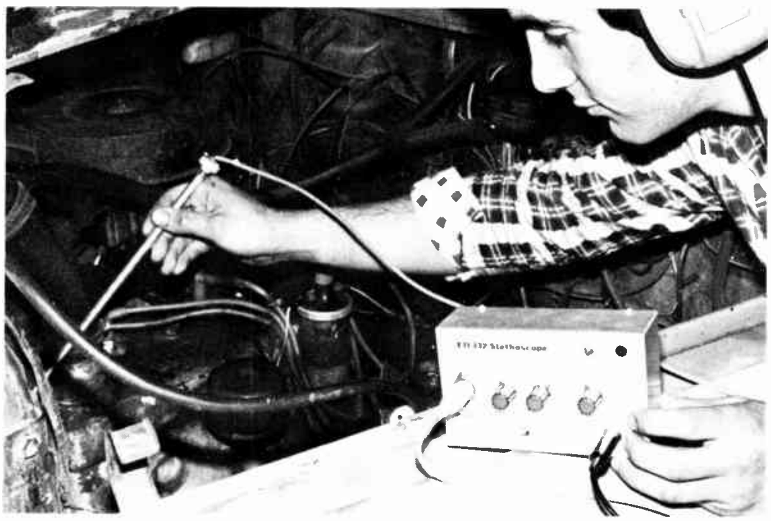
With this electronic stethoscope, you can effectively and effortlessly get right inside a car engine, for example, and listen to or locate all its internally generated sounds — the noise of bearings, pistons, tappets, etc. The various sounds produced by different parts of moving machinery have different characteristics, so this stethoscope incorporates a double filter network that can be used to pick out one set of sounds and attenuate others, thus facilitating fault-finding.

The stethoscope comprises an acoustic probe unit using some sort of microphone (several combinations are possible), the electronic 'clever bits' and a pair of standard stereo headphones. The probe unit is arranged to make mechanical contact with the machinery or object being examined and is coupled to the electronics, which are housed in a separate box, via flexible leads. The mechanical coupling provides an acoustic path to the microphone in the probe, and can be by direct contact or via a metal rod or tube.

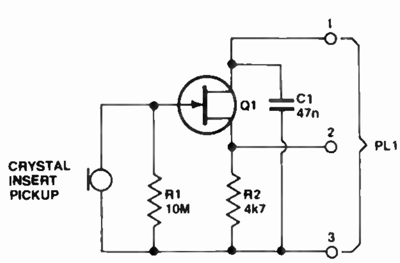
Sound is readily transmitted through the housing of any machinery, be it the engine block of a petrol motor, the case of a watch or clock, etc. This can be further transmitted through an object, such as a metal rod or a screwdriver, brought in contact with the machinery.

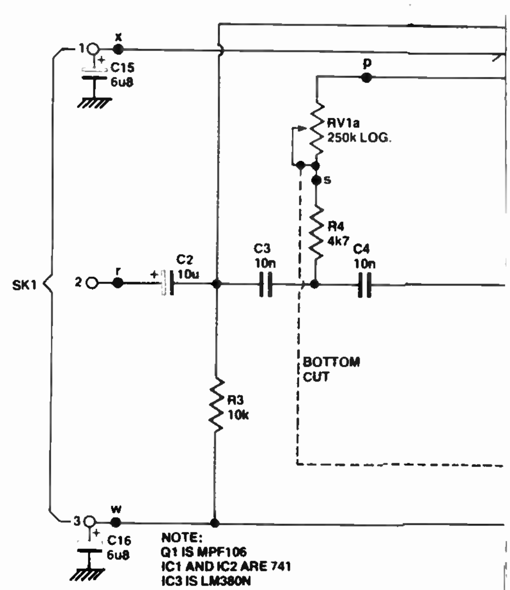
The electronics

The circuitry used in this stethoscope comprises two filters, each of which has a variable cutoff, followed by a high gain IC power amplifier. The first filter is a *high-pass* type that attenuates frequencies *below* the cutoff frequency, which can be set anywhere between about 80 Hz and 3 kHz. The second filter is a *low-pass* type that attenuates frequencies *above* the cutoff frequency, which can be set anywhere between about 70 Hz and 15 kHz. The filters can thus be used to attenuate unwanted sounds, enabling you to pick out the desired sounds to a considerable extent in the right circumstances. The filter stages can be switched out if desired and the probe's microphone output coupled directly to the audio output stage. A common LM380 has been employed for the latter, principally for convenience, as it provides a considerable amount of gain and requires few components. A volume control potentiometer has been placed at the input to the LM380, since a level control is a very necessary item — as no doubt you will discover!



Using the stethoscope to listen to the tappets in a car engine.





The unit is powered from two internal 9 V batteries as portability is a necessary requirement. Headphones were employed rather than having a loudspeaker output, as they reduce ambient sounds which in some situations make listening to a speaker impossible as well as enabling you to concentrate on the sounds picked up by the stethoscope. Only low-cost headphones are necessary and any type having an impedance between 8 ohms and 500 ohms or so will do the job nicely.

The input impedance of the electronics is relatively low and a buffer is necessary when using high impedance microphones on the probe. The low input impedance also serves to reduce extraneous electrical noise pickup, to which high input impedance circuitry is prone. Crystal microphone inserts or earpieces are cheap, sensitive and effective for probe use, although we did try a rocking armature insert successfully, coupled directly to the high pass filter input. The buffer necessary with crystal microphones we mounted on the rear of the mics, as you can see from the photographs and drawings.

The stethoscope electronics are housed in a *metal* box — and for a very good reason. It provides shielding for the circuitry, preventing extraneous electrical noise pickup — which can be quite severe when using the project on a car engine. The ignition wiring radiates a considerable amount of noise energy and, while it's not possible to completely eliminate it, we have reduced the problem by using a metal box, low impedance input and bypassing at the input socket.

Construction

It's probably best to commence with the mechanical work. We housed our unit in a K&W box, model C642, made by Ballarat Electronics Supplies and stocked by many retailers. It measures 150 mm wide by 95 mm deep by 55 mm high. Any metal box that will accommodate the pc board and major components may be used, however. Our Scotchcal front panel has been de-

HOW IT WORKS — ETI 332

Mechanical noises are coupled to a microphone or mic insert by a convenient means in a probe, the mic converting the mechanical noise to electrical signals. The resultant signal is passed to a filter/amplifier unit and converted to sound by headphones. Two active filters are employed. The first is a high-pass type employing a second-order RC network. This circuit has the advantage that the response rolls off below the cutoff frequency at a rate of 40 dB per decade. Thus, signals at one-tenth the cutoff frequency are attenuated by 40 dB. The R and C values may be designed to provide the cutoff at the desired frequency. The filter response is 3 dB down at the cutoff frequency. In our circuit, the resistors have been replaced by a combination of fixed and variable resistors to provide a variable cutoff frequency. The high-pass filter consists of IC1 and RV1, C3, C4, R4, R5. The filter has been designed to provide a cutoff that can be varied between a minimum frequency of 80 Hz up to a maximum of 3 kHz. Thus, with RV1 set to provide a cutoff of 1 kHz, signals at 100 Hz will be attenuated by about 40 dB.

The second filter, following the high-pass filter, is a low-pass type, again using a second-order RC network to provide a roll-off of 40 dB per decade, above the cutoff frequency. Again, the filter response is 3 dB down at the cutoff frequency. In our circuit, the resistors have been replaced with a combination of fixed and variable resistors to provide a cutoff frequency which can be varied at will. The low-pass filter consists of IC2 and RV2, C6, C7, R6, R7. The cutoff may be varied between about 700 Hz minimum and 15 kHz maximum. When RV2 is set to provide a cutoff at about 1 kHz, for example, signals at 10 kHz will be attenuated by about 40 dB.

The filter stages provide no gain. The op-amps employed require a split supply and the 'virtual zero volt rail' is provided by ZD1, which is biased via the buffer amplifier involving Q1. Capacitor C8 provides an ac bypass for the virtual zero volt rail.

The output from IC2 is coupled to the audio output stage via SW1, which permits the filter stages to be switched out of circuit.

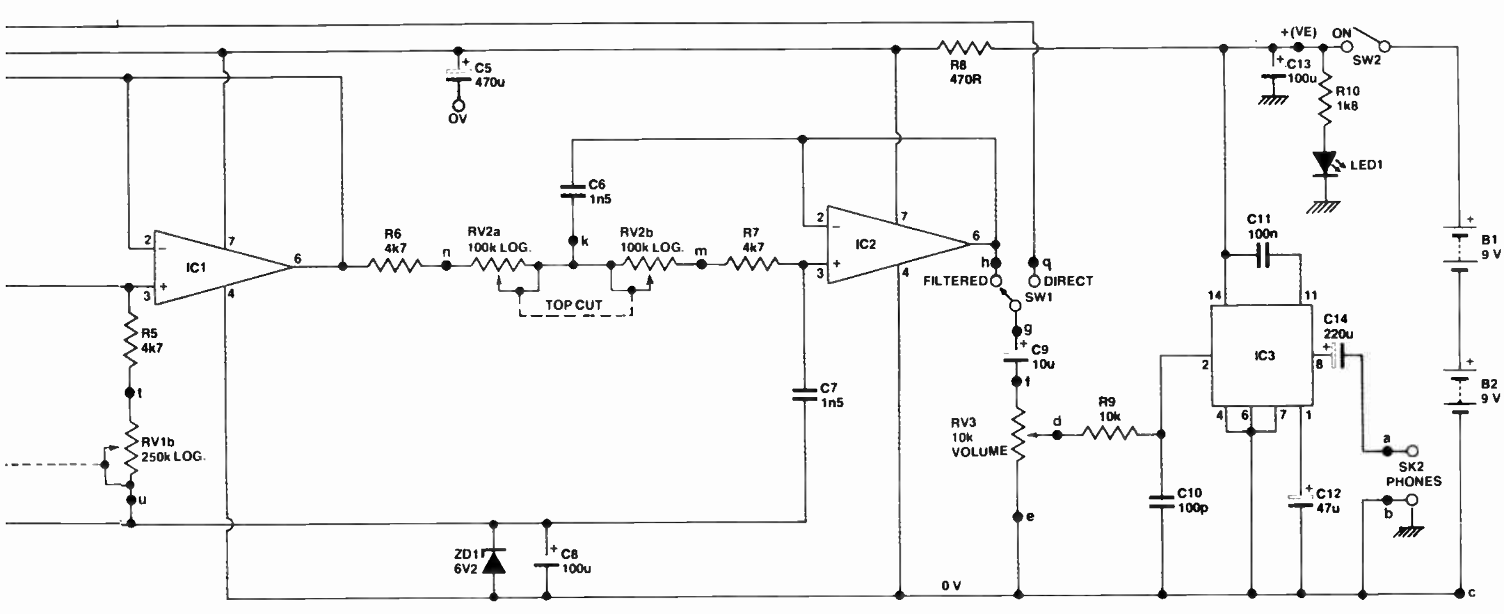
As stated earlier, high impedance crystal type mics require a high-to-low impedance buffer. This is the function of Q1 and associated components, R1, R2, C1. This is a simple source follower circuit, Q1 being a JFET device. Capacitor C1 provides a supply rail bypass.

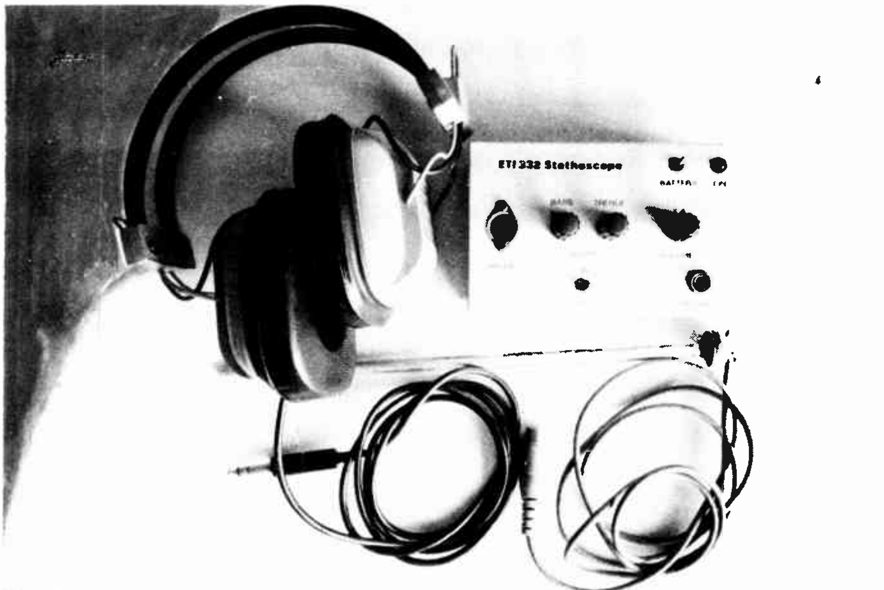
Signals are passed either direct to the output stage or through the filters via SW1. Capacitor C9 provides dc blocking and couples signals to the volume control, RV3. The audio output stage employs an LM380 high gain preamp/power amp IC. Signals from the volume control are coupled to the input via R9/C10, which is a low-pass network with a cutoff around 150 kHz. This provides a measure of high frequency stability for the IC as well as reducing RF pickup that can upset the operation of the unit. Audio output is coupled via C14 to the headphones. Capacitors C11 and C12 are bypasses.

Power supply for the electronics is provided by two 9 V batteries connected in series. Supply rail bypassing is provided by C13 and R8/C5. LED1 and its associated current limiting resistor, R10, provide an 'on' indicator.

Capacitors C15 and C16 bypass any extraneous electrical noise induced onto the input cable. These are mounted directly at the input socket.

If a rocking armature insert is used for the probe, a 4k7 resistor should be connected between pins 1 and 3 of the input DIN plug to provide bias for the virtual zero volt line provided by ZD1.





Completed stethoscope, ready for action! The probe here was made from a crystal earpiece, a length of 10 mm tubing being pushed over the ear plug.

signed to suit the K&W box. The artwork for this has been reproduced below, full size, and can be used as a template to mark out hole centres for drilling. The pots, switches, etc, all mount on the box lid. Use a centre-punch to locate hole centres before drilling as this stops the drill wandering. Once you've completed this, clean off any burrs with a small rat-tail file and see that the pots, switches, etc, fit properly. If all's well, carefully cut the Scotchcal panel to size (if you're using it) and apply it to the box lid. Then cut the holes on the Scotchcal panel where you drilled the lid.

Next, mount all the pots, switches and sockets, etc. Solder the input bypassing capacitors, C15 and C16, to the DIN socket as shown in the wiring diagram. Note that the value of these two capacitors is not critical and may be anything between 1u and 10u. Solder R10 in place.

You can tackle the pc board next. This is fairly straightforward. We recommend you use our pc board, as the LM380 is prone to instability unless its surrounding circuitry is mounted in a particular fashion. Our pc board will avoid any instability problems with this stage. The ICs may be mounted first, noting they are all oriented the one way, followed by the resistors, greencaps, the ceramic capacitor (C11) and the zener diode (watch its polarity), leaving the electrolytics until last. All the electrolytics are single-ended, pc mounting types, you'll notice. Take care you mount these the right way round.

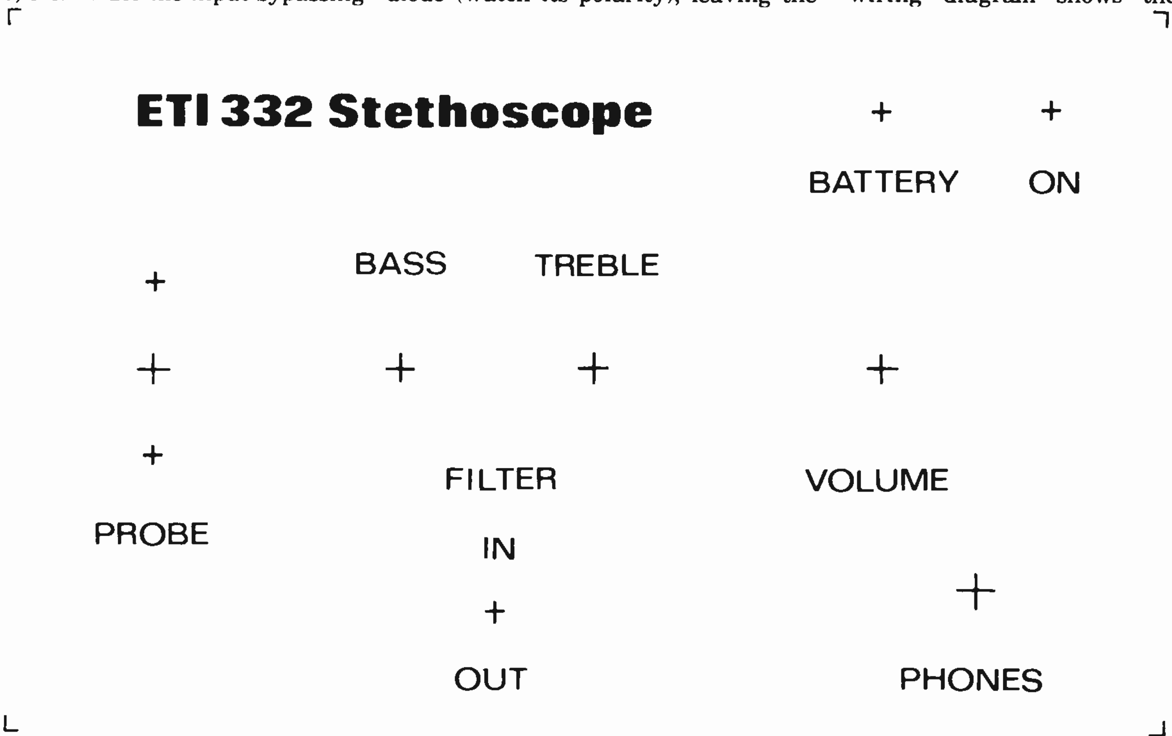
Having completed the loading of the board, check everything *carefully*.

The wiring between the pc board and external components may be tackled next. Follow the wiring diagrams for this stage of the construction, checking each set of wires as you proceed.

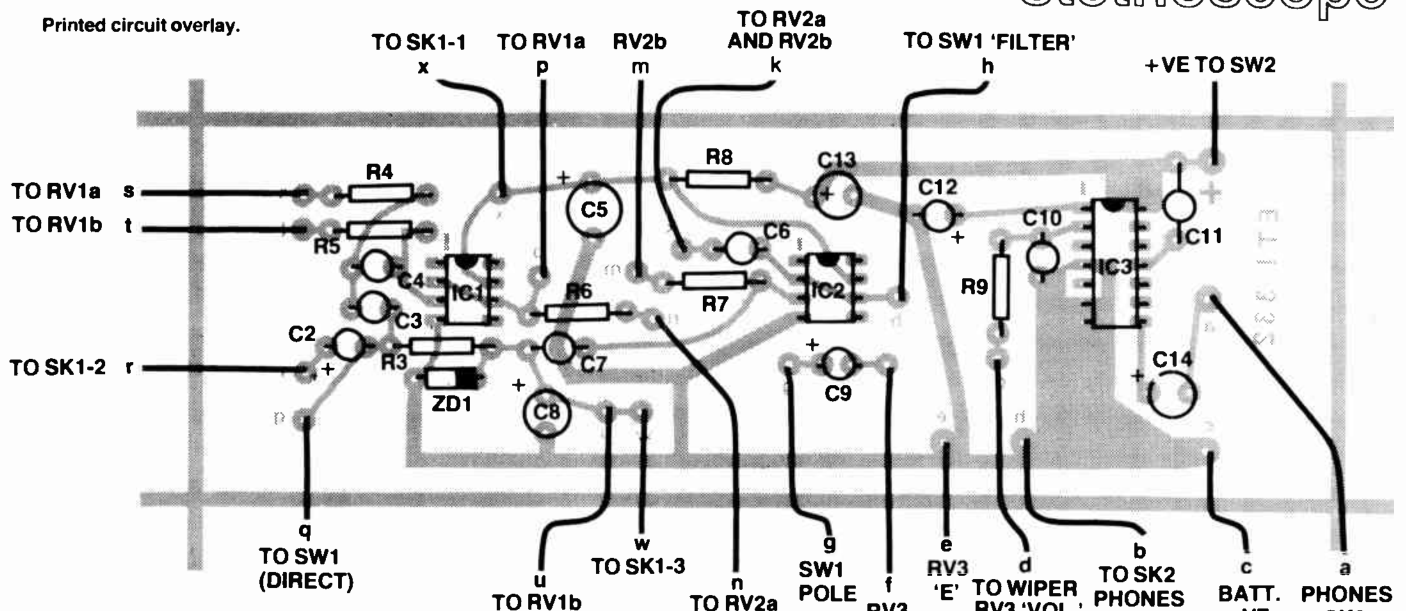
You can make a preliminary check of the electronics once you've completed this stage. Check your wiring first, then connect the two batteries, turn the volume control to minimum, plug in your headphones and switch on. Some hiss should be evident; this is normal. With the filter switched in, turning the volume control fully up (do it slowly) should result in a slight increase in the noise level. Turn the volume control to minimum gain and switch the filter out. Touch your finger to pin 2 of the DIN socket and slowly advance the volume control. This should produce some audible noise and hum. The hum level will depend on the local hum field. If it is low, you may have to advance the volume control a fair way.

If all checks out well you can mount the pc board in the bottom part of the case, along with the batteries. We used double-sided sticky pads, as they're effective, convenient and save drilling!

Making the probe(s) comes next. Exactly how you go about this will depend on what you want to do. With crystal insert mics, the buffer is mounted on the rear of the mic terminals. The accompanying probe wiring diagram shows the general



Printed circuit overlay.



Printed circuit board pattern is on page 32.

technique. The buffer electronics is protected by encapsulating it in quick-setting epoxy. The mechanical coupling arrangement will depend very much on the particular mic insert employed and the application you have in mind. We made up several probes to suit different applications. If the mic has a metal case connect it to the probe cable's shield.

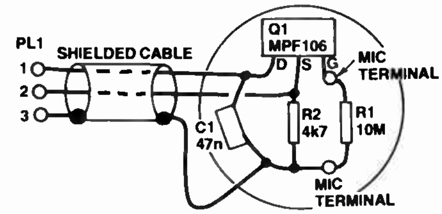
When you've finished your probe you can test it by simply coupling it to the speaker of a small portable transistor radio. Check that the filter controls function by varying them across the full range.

Using it

The best way to get to know how to use the instrument is to practise on a few things. Clocks are wonderful for this! The old-style mechanical wristwatch also provides an excellent signal source. You can hear your heartbeat by using a microphone insert without a mechanical probe, and we even discovered that the main bearing in our workshop drill press was 'cactus' when trying out the stethoscope!

When working on a vehicle engine, watch out for fan blades. We found we could effectively sort out various engine sounds by judicious adjustment of the filter controls and careful placement of the probe.

Happy listening! ●



General construction for the buffer, mounted on the rear of a mic insert.

PARTS LIST — ETI 332

Resistors all ½W, 5%

R1	10M
R2, 4, 5, 6, 7	4k7
R3, R9	10k
R8	470R
R10	1k8
RV1	250k/C dual log.
RV2	100k/C dual log.
RV3	10k/C log.

Capacitors (all electros single-ended)

C1	47n polycarbonate
C2, C9	10u/25 V electro.
C3, C4	10n greencap
C5	470u/25 V electro.
C6, C7	1n5 greencap
C8, C13	100u/25 V electro.
C10	100p ceramic
C11	100n greencap
C12	47u/25 V electro
C14	220u/25 V electro.
C15, C16	6u8/25 V tantalum.

Semiconductors

IC1, IC2	741
IC3	LM380
Q1	MPF106 or similar
LED1	TIL220R red LED, or sim.

Miscellaneous

SW1	SPDT toggle switch
SW2	SPST toggle switch
PL1	3-pin DIN plug
SK1	3-pin DIN socket
SK2	6.5 mm stereo headphone socket (or to suit plug-on headphones)
B1, B2	No. 216 9 V batteries and clips to suit

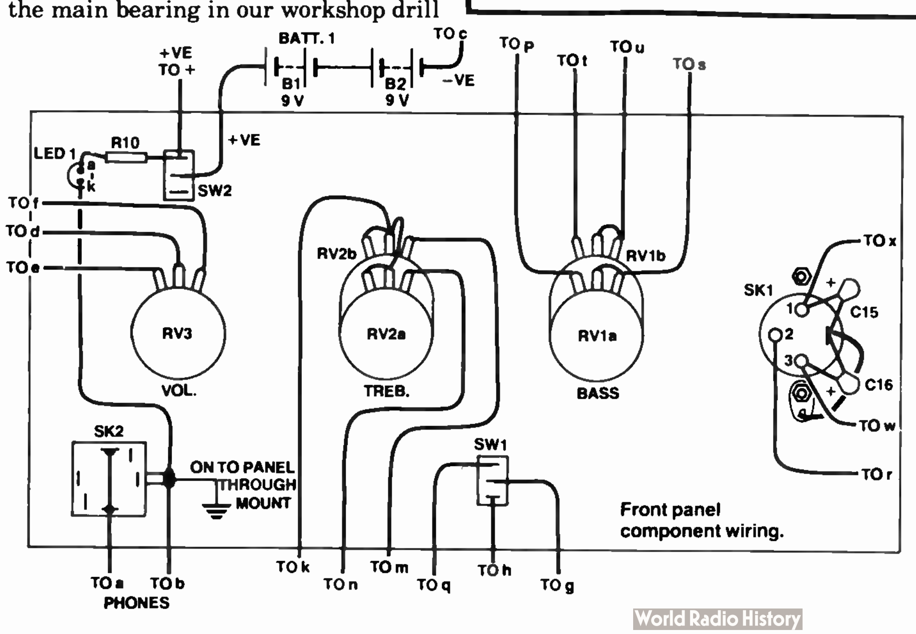
ETI-332 pc board; case — 150 x 95 x 55 mm or similar (we used a K&W model C642); three small collet knobs or similar; Scotchcal front panel; one crystal earpiece or crystal mic insert; rod or tube for probes; two-core shielded cable; one pair of 8 ohm headphones (higher impedance types will also be OK); wire, nuts, bolts, etc.

Price estimate

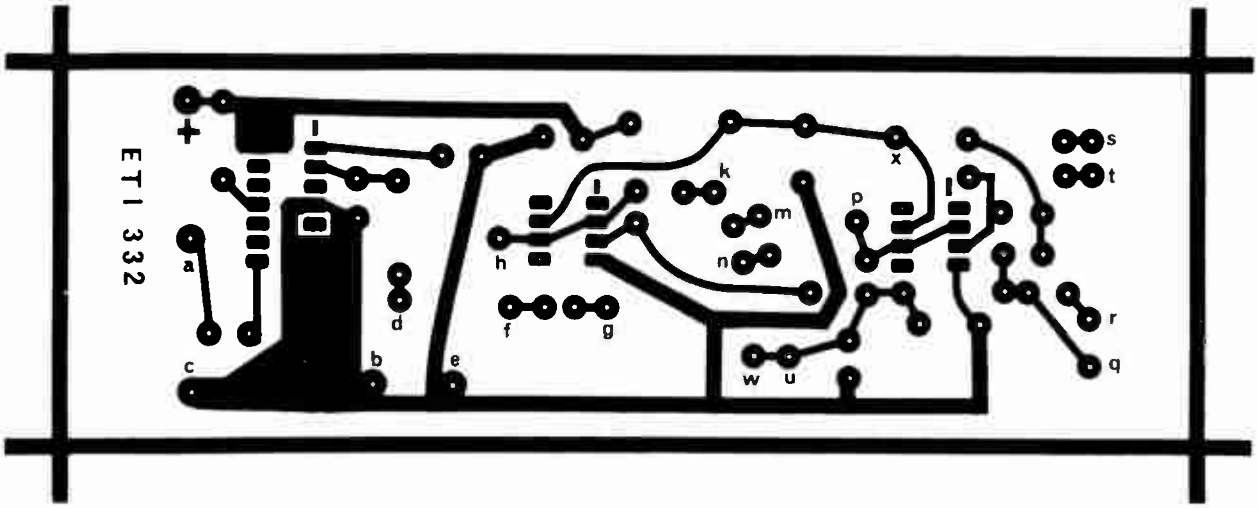
We estimate the cost of purchasing all the components for this project will be in the range:

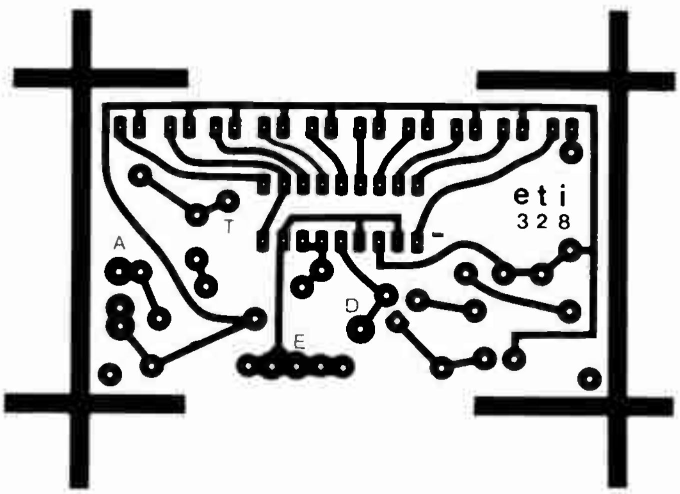
$35 - $40

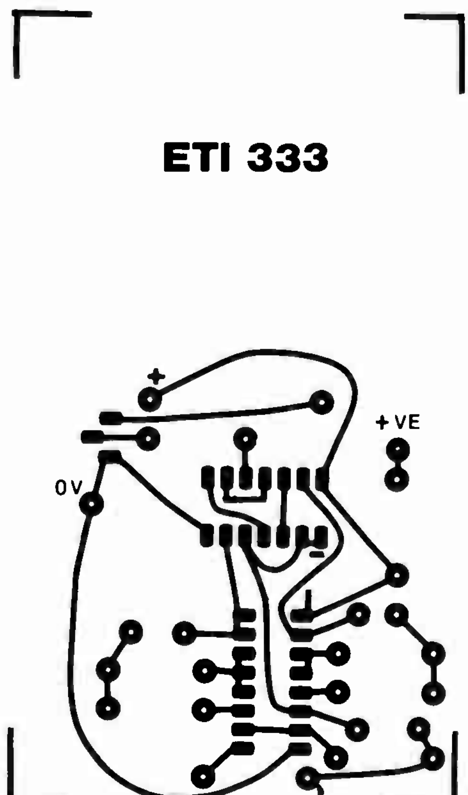
Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

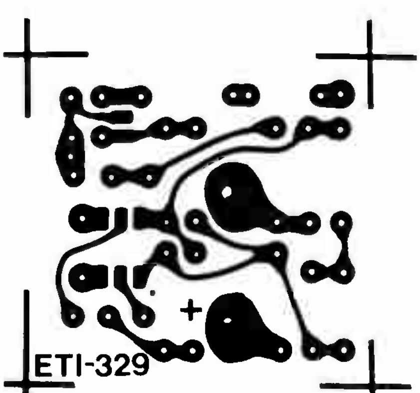


Front panel component wiring.


ETI 332
+
a
b
c
d
e
f
g
h
k
m
n
p
x
s
t
r
q
w
u


eti
328
A
T
D
E

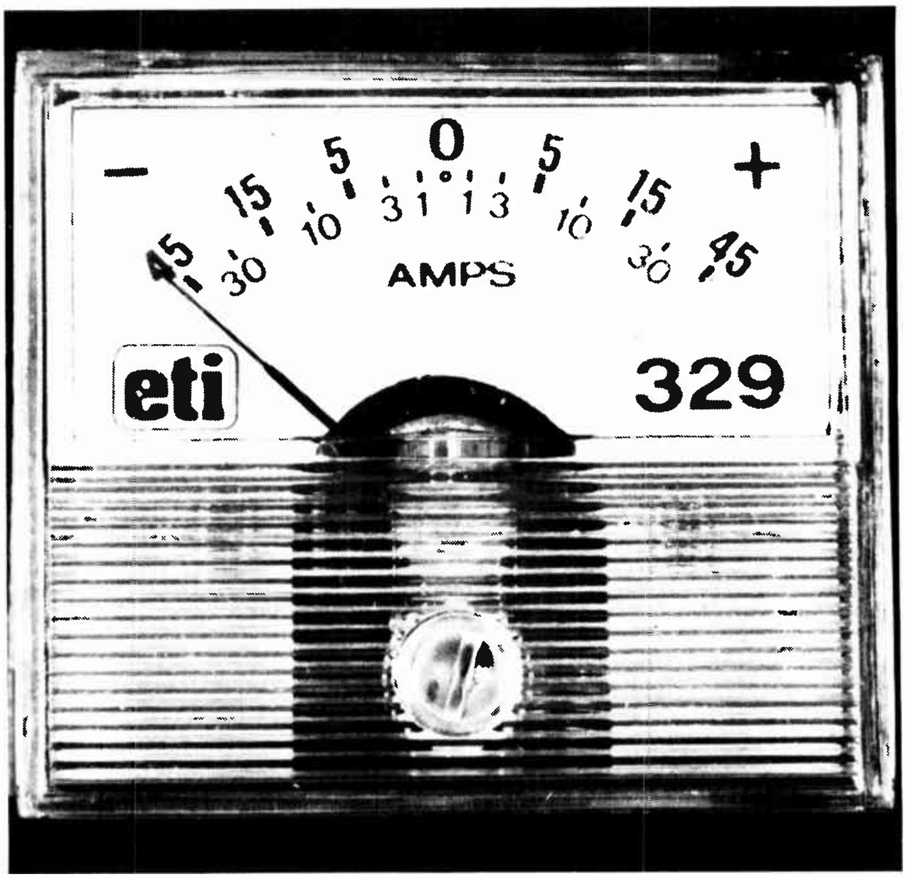

ETI 333
+
+VE
0V


+
ETI-329

Expanded scale vehicle ammeter

This 'electronic ammeter' can be installed without disturbing the vehicle's existing wiring, will operate on 12 V or 24 V systems and features an easy to read scale indicating charge and discharge currents up to 45 amps.

Jonathan Scott



THE CONVENTIONAL current meter, usually a moving iron type, has long been one of those instruments included in the better-equipped 'up market' vehicles. It indicates charging system or other electrical faults more quickly than any other device and warns the perceptive driver of any abnormal currents — even momentary variations.

However, the conventional vehicle ammeter has two main disadvantages: (1) In order to provide a full-scale deflection (FSD) of, say, 30 or 40 amps, it sacrifices the sensitivity necessary to show small currents that might completely discharge the battery in one or two days if the vehicle is left standing for any short or long period. (2) If you wish to install one in a vehicle that does not already include the instrument, it is necessary to interrupt the heavy, main current carrying cables and either install a 'current shunt' and cables to the ammeter, or divert the cables to the ammeter in the dashboard. This may require adding heavy cables (as they will be called upon to carry current up to 40 amps or so). One hardly need point out the inconvenience, not to mention the electrical drawbacks. In addition, off-the-shelf instruments are usually rather expensive for the function they provide because of their rather specific nature and the general cost of automotive bits.

In addition, moving iron types have a cramped scale at the low current end.

This project overcomes these problems. Our instrument offers a non-linear ('expanded') scale so that currents as low as one amp or as high as 45 A can be easily seen. It employs the earth strap of the battery as a current shunt, thus avoiding use of any cable thicker than hookup wire and not requiring the car's current path to be disturbed at all. In addition, it uses readily available components and features a centre-zero scale employing either a centre-zero meter or conventional meter movement. It may be installed in 12 V or 24 V systems and incorporates reverse-polarity protection in case you connect it the wrong way round or try to destroy it by some devious automotive electrical fault. (I recently had the unpleasant experience of momentarily disconnecting a wire on my car which resulted in the *instant obliteration* of every semiconductor in the vehicle.)

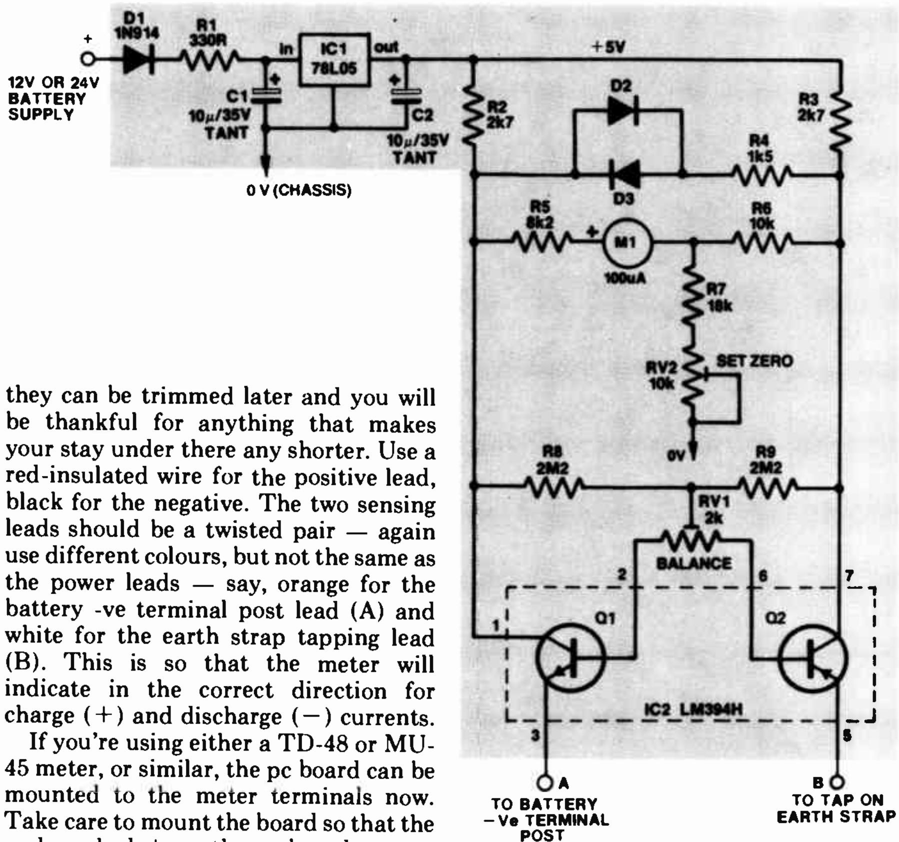
Meters and scales

We have provided artwork of scales to suit several commonly available meters: the University types TD-48 (45 mm face width) and TD-66 (62 mm face width) plus the Minipa MU-45 (51 mm face width).

As mentioned earlier, either a conventional meter movement (100 uA), with zero on the left of the scale, or a centre-zero movement (50-0-50 uA) may be used. The pc board has been laid out to suit the TD-48 meter and it mounts ▶

directly on the meter's terminals. However, the board can be fitted to the MU-45 by drilling the mounting holes through the pads on the board to suit the differently spaced terminals. If you use a larger meter, the pc board will have to be mounted separately.

Obviously, a 50 uA movement can be used provided a shunt equal to the movement's coil resistance is connected in parallel with the meter terminals.



Construction

Before commencing the construction of the electronics, the wisest move is to prepare the dash mounting place for the meter movement. As this is rather a matter for the individual vehicle owner, we will have to leave the details to you. First, though, a word of caution — choose a position for the meter where the rear is accessible and where the pc board will fit if you plan to have the board mounted on the rear of the meter as we have done.

Next step is to drill the pc board to suit the meter chosen. Having taken care of that, you can tackle the electronics. Mounting the components on the pc board is a simple job — which means it's easier to make mistakes! Take care with the orientation of the two tantalum capacitors as well as with the ICs and the three diodes. Attach power supply leads more than long enough to reach suitable termination points under the dash — they can be trimmed later and you will be thankful for anything that makes your stay under there any shorter. Use a red-insulated wire for the positive lead, black for the negative. The two sensing leads should be a twisted pair — again use different colours, but not the same as the power leads — say, orange for the battery -ve terminal post lead (A) and white for the earth strap tapping lead (B). This is so that the meter will indicate in the correct direction for charge (+) and discharge (−) currents.

If you're using either a TD-48 or MU-45 meter, or similar, the pc board can be mounted to the meter terminals now. Take care to mount the board so that the pad marked + on the pc board goes to the meter's positive terminal. If you're using one of the larger meters, attach leads to the pads and connect them to the meter terminals — again, use differently coloured insulated wire to identify each lead so that the meter is connected the right way round.

Setting up

If you have a bench supply that can deliver 12 V or 24 V, it can be used to set up the instrument initially. If you don't have one, then you'll have to do this with

HOW IT WORKS - ETI 329

The circuit senses the voltage drop across a section of the vehicle battery's earth strap, amplifies it and displays the result on a meter having a centre-zero scale so that both charge (+) and discharge (−) currents are indicated.

Heart of the circuit is a transistor differential pair contained on a single slice of silicon, IC2 (Q1-Q2). This ensures that the two transistors, though electrically separate, have closely-matched characteristics. The differential pair is operated as a common-base amplifier, the two emitters being connected across the vehicle battery's earth strap.

The differential pair requires a well-regulated supply and this is provided by IC1, a low power three-terminal regulator. Output is 5 V. Diode D1 protects the unit against the ravages of reverse polarity connection, while R1 and C1 remove supply line transients. Capacitor C2 prevents oscillation of IC1.

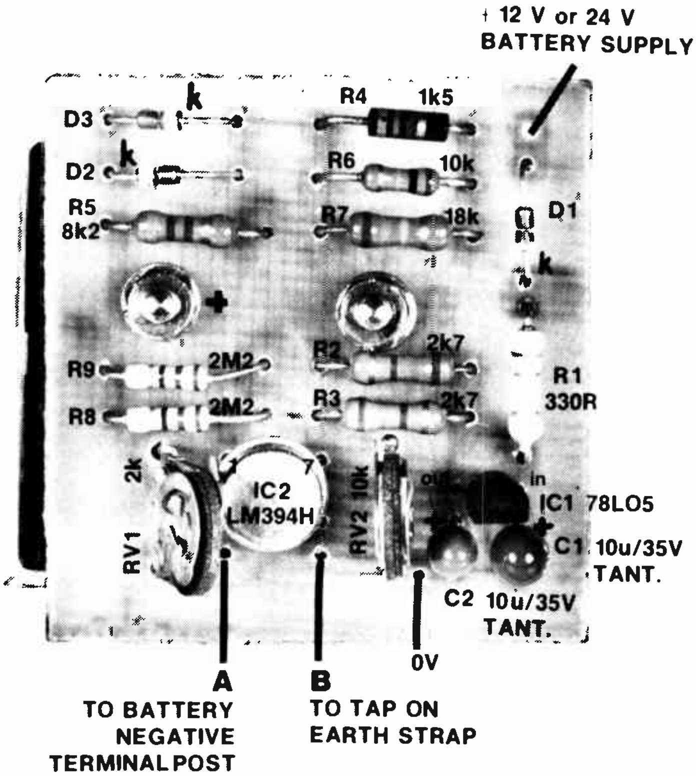
The meter is connected between the collectors of Q1 and Q2 from IC2. The centre-zero function (regardless of which type meter you use) is obtained by shunting some current to the common (0 V) rail via R7 and RV2. The latter provides a zero-point adjustment. Scale-linearity is achieved by the addition of R4 and D2-D3, which effectively shunt the meter circuit. Let's look first at the circuit as if these weren't connected.

When no current is being drawn from or passed into the vehicle battery, the emitters of Q1 and Q2 will be at the same voltage. As the base-emitter voltages of these two transistors will be very nearly identical, each will draw very nearly the same collector current. Only a small amount of base current is applied to each, via R8 and R9, with RV1 serving to balance the base currents, and therefore the emitter-collector currents, of the two transistors to compensate for the differences which inevitably occur. This trimpot is capable of compensating for more than twice the expected maximum error.

With the values chosen, Q1 and Q2, when balanced, will each have around 3 V on their collectors (with respect to 0 V). Now, when the battery is being charged, the current through the earth strap will raise the emitter of Q1 to a slightly higher voltage than the emitter of Q2. Thus Q1 will draw less current, Q2 will draw more, and the collector voltage of Q1 will rise to a higher value than the collector voltage of Q2 (with respect to 0 V). The current will therefore flow through the meter from the positive terminal to the negative terminal and the meter will indicate the current on the + side of the scale (i.e: charge). The reverse happens when current is drawn from the battery.

Now let's have a look at what happens when R4, D2 and D3 are in circuit. When the voltage between the collectors of Q1 and Q2 rises to a value greater than about 0.6 V, either D2 or D3 will conduct, depending on which collector is at the higher voltage. When one of these diodes conducts, some of the meter current will be diverted through R4, reducing the effective reading on the meter for further current increases. The result is a meter scale which is 'compressed' at the higher currents.

Resistor R7 and RV2 are arranged so that equal quiescent currents will flow through R6, R5 and the meter (M1), allowing centre-zeroing of the meter without upsetting the balance of the differential pair. These two components can be deleted if a centre-zero meter is used.



Component overlay for the pc board (pc board pattern is on page 32). Trimpot RV1 is for BALANCE while RV2 is for ZERO SET. The latter, along with R7, is left out if you use a centre-zero meter.

PARTS LIST - ETI 329

Resistors .... all ½W, 5%

R1	330R
R2,R3	2k7
R4	1k5
R5	8k2
R6	10k
R7	18k
R8,R9	2M2
RV1	2k min. vertical mount trimpot
RV2	10k min. vertical mount trimpot

Capacitors

C1,C2	10u/35 V tantalum

Semiconductors

IC1	78LO5, or similar 5 V reg.
IC2	LM394H supermatch pair
D1,D2,D3	1N914, EM401 etc silicon diode

Miscellaneous

ETI-329 pc board; M1 - 100 uA conventional meter or 50-0-50 uA centre-zero meter (see text); meter scale; hookup wire etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$15 - $17

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the actual price of a project, whether bought as separate components or made up as a kit.

the unit connected in the vehicle, but not mounted.

Connect up the power supply leads, join leads A and B (the sensor leads) and connect them to zero volts. Adjust both trimpots and see if they both have some effect on meter reading. This will confirm correct operation, and you can proceed with the setting up. If the meter goes hard over in either direction you have a wiring fault. Disconnect the unit *immediately* and trace the fault before proceeding.

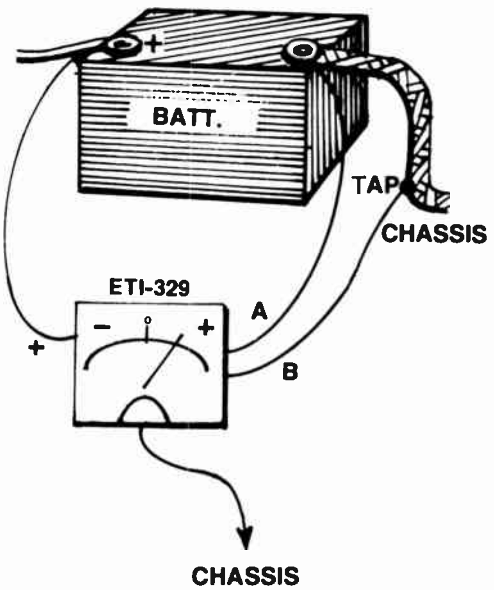
With a multimeter, measure the voltage on the collector of each transistor in the differential pair IC (pins 1 and 7). Adjust RV1 so that these voltages are equal. If you do not have a multimeter, remove R7 and short out R5 and R6. Then adjust RV1 for zero meter reading (i.e: centre scale). This last method is not recommended as accuracy is affected to some extent, but it will suffice in the absence of a multimeter. Restore the circuit when you've finished.

When doing this initial setup, whichever method you use, allow a couple of minutes (with the unit still connected) and check the circuit balance again as it may drift briefly after initial switch on.

When you are confident that the balance is correct, adjust RV2 for exactly half-scale deflection on the meter — zero on the scale. This trimpot functions as a 'set zero' adjustment. If you wished, you could have a scale zero at some position other than centre scale — there is no reason why you couldn't have the zero at quarter-scale, to the left or the right. However, if you're using our meter scale and component values, you can only have zero at centre-scale, and that settles it.

If you cannot achieve balance within the range of RV1 (equal voltages on pins 1 and 7 of IC1), proceed as follows: if you're only a short way off balance then you possibly have an IC and resistors that are all on the edge of their specifications. In this case, reduce the value of R8 and R9 to 1M5 or so and try balancing the circuit again. If there is a gross imbalance you are almost certainly using a meter of the wrong coil impedance. It may be possible to rectify the situation by halving the value of R8 and R9 and substituting a 5k trimpot for RV1, sacrificing some sensitivity.

When you have the unit correctly set up, install it in your vehicle. Be careful to ensure that the sensor leads (from A and B) are of equal length. If all is well, next step is to calibrate the unit. You can leave it connected permanently to the battery (i.e: not via the ignition switch) as it draws very little current. Lead A should be securely connected to the battery negative terminal connector. It is best to solder it to the copper strap just as it terminates at the clamp which attaches to the battery post. Temporarily connect the other sensor lead (B) about 200 mm down the earth strap, toward the chassis termination. ▶



Calibration

To calibrate the ammeter you will either need to have a 'load' of known resistance and a multimeter or temporarily connect an ammeter (say, 10 A or 15 A FSD) between the battery's positive terminal post and the positive terminal clamp.

In the former case, connect the known load between the positive supply rail and *vehicle chassis*. Measure the voltage across the load and calculate the current through it. Note the reading on the meter (it should read in the negative portion of the scale) and adjust the position of sensor lead B on the battery earth strap so that the meter reads the correct current. Move it *towards* the battery terminal to *decrease* the reading, *away* from it to *increase* the reading.

If you don't have a known load, then the series ammeter method will be necessary. With the ammeter connected in series with the battery positive lead, turn on a few accessories until you are drawing a current of say 5 A or 10 A. As before, move sensor lead B along the earth strap until the project indicates the correct current.

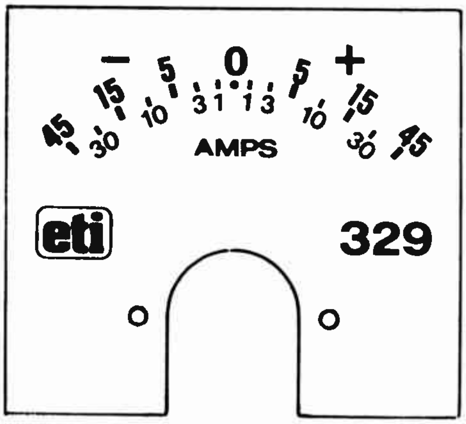
Once the unit is calibrated, permanently connect sensor lead B to the position determined. The length of strap between this point and the battery negative terminal has a resistance of around 1½ milliohms!

Some vehicles have insulation on the earth strap. Small sections may be removed with a sharp penknife or lino cutter.

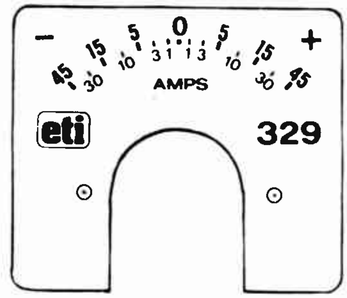
Finished? — that's it!

Once operational, you will notice that your vehicle has characteristic charge and discharge patterns under the usual driving conditions. Get used to them — you can then quickly tell at a glance if and when something may be going wrong.

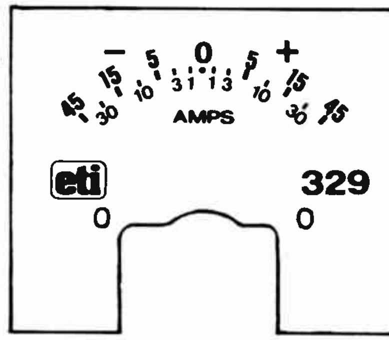
Illumination of the meter scale is useful, although we haven't included details. This will depend on the individual situation and the particular meter used. A hole may be drilled in the rear of the meter case and through the scale panel so that a small 'pea' or bayonet type globe can be fitted. (Be careful!) These lamps can be obtained in 12 V (or 24 V) ratings; lower voltage types will require a series resistor. If the light is too bright, reduce the current through the globe with a series resistor. ●



Scale for the University TD-66



Scale for the University TD-48



Scale for the Minipa MU-45

METERS, SCALES AND SHUNTS

We have provided artwork of scales to suit several commonly available meters: the University types TD-48 (45 mm face width) and TD-66 (62 mm face width), plus the Minipa MU-45 (51 mm face width).

As mentioned in the text, either a conventional meter movement (100 uA) with zero on the left of the scale, or a centre-zero movement (50-0-50 uA) may be used. The pc board has been laid out to suit the TD-48 meter and it mounts directly on the meter's terminals. However, the board can be fitted to the MU-45 by drilling the mounting holes through the pads on the board to suit the differently spaced terminals. If you use a larger meter, the pc board will have to be mounted separately.

Obviously, a 50 uA movement can be used provided a shunt equal to the movement's coil resistance is connected in parallel with the meter terminals. For some types, meter impedance is 1400 ohms, while for others (particularly the University models) it is 2000 ohms. Resistors having a 1% or 2% tolerance can be used (E48 or E96 series), and values of 1k4 and 2k are available. Alternatively, a parallel combination of standard value, 5% tolerance resistors can be used and will result in sufficient accuracy in this application. For a 1k4 shunt, parallel a 1k5 and a 22k. For a 2k shunt, parallel a 2k2 and a 22k.

LM394

general description

The LM194 and LM394 are junction isolated ultra well-matched monolithic NPN transistor pairs with an order of magnitude improvement in matching over conventional transistor pairs. This was accomplished by advanced linear processing and a unique new device structure.

Electrical characteristics of these devices such as drift versus initial offset voltage, noise, and the exponential relationship of base-emitter voltage to collector current closely approach those of a theoretical transistor. Extrinsic emitter and base resistances are much lower than presently available pairs, either monolithic or discrete, giving extremely low noise and theoretical operation over a wide current range. Most parameters are guaranteed over a current range of 1μA to 1 mA and 0 to 40V collector-base voltage, ensuring superior performance in nearly all applications.

To guarantee long term stability of matching parameters, internal clamp diodes have been added across the emitter-base junction of each transistor. These prevent degradation due to reverse biased emitter current—the most common cause of field failures in matched devices. The parasitic isolation junction formed by the diodes also clamps the substrate region to the most negative emitter to ensure complete isolation between devices.

The LM194 and LM394 will provide a considerable improvement in performance in most applications requiring a closely matched transistor pair. In many cases, trimming can be eliminated entirely, improving reliability and decreasing costs. Additionally, the low noise and high gain make this device attractive even where matching is not critical.

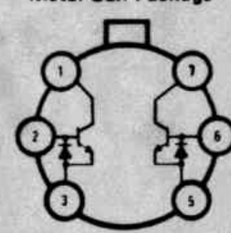
The LM194 and LM394/LM394B are available in an isolated header 6-lead TO-5 metal can package. The LM194 is identical to the LM394 except for tighter electrical specifications and wider temperature range.

features

- Emitter-base voltage matched to 50μV
- Offset voltage drift less than 0.1μV/°C
- Current gain (h_{FE}) matched to 2%
- Common-mode rejection ratio greater than 120 dB
- Parameters guaranteed over 1μA to 1 mA collector current
- Extremely low noise
- Superior logging characteristics compared to conventional pairs

connection diagram

Metal Can Package



TOP VIEW

Reversing alarm for your car

Ever had a 'near miss' with a pedestrian or a member of your family while reversing your car or station wagon? This little reversing alarm will let people know, in no uncertain fashion, to watch out when you're reversing.

Roger Harrison
Graeme Teesdale

ALMOST EVERY driver, some time in their driving career, will back into something while reversing. All you do is wince and say a few expletives deleted if it happens to be the gatepost, garage door, etc, but it's a horrifying experience if you run into a person. Apparently, in a large number of accidents where people are injured while a driver is reversing a car, a friend or member of the family is the victim. Too often, it's a child. Whilst it's not possible to completely eliminate the risk, you can go a long way towards reducing it significantly by alerting people when reverse gear is selected in the vehicle. A loud, attention-getting audible alarm is a good way to do it, hence this project.

Our alarm is intended to be installed at the rear of the vehicle, connected across the 'reversing' lights. Reversing lights have been commonly fitted to vehicles, as part of 'standard' equipment, since about 1968-70. They have been a compulsory fitment in cars (sedans, etc) sold in Australia since January 1972 and 'general purpose' vehicles (off-road types, etc) since January 1973, and in trucks up to 4½ tonnes since July 1973, trucks over 4½ tonnes since July 1975. Reversing alarms for trucks or other vehicles are not a compulsory fitment, but many Japanese trucks have included them for the past few years.

Getting attention

This alarm has been designed to get your attention in two ways. Firstly, it is LOUD . . . *piercing,* in fact. The noise maker is a piezoelectric alarm. These employ a ceramic piezoelectric element and generate an audio signal at a few kilohertz at sound pressure levels *in excess of 90 to 100 dB* a few metres from the alarm. Their electrical energy to sound energy conversion efficiency is very high. They are somewhat directional, but that's fine for this sort of application. A variety of types are available and may be used with this project. However, we suggest you purchase a type which is specified to produce a sound pressure level (spl) of at least 90 dB at 2 m distance from the alarm.

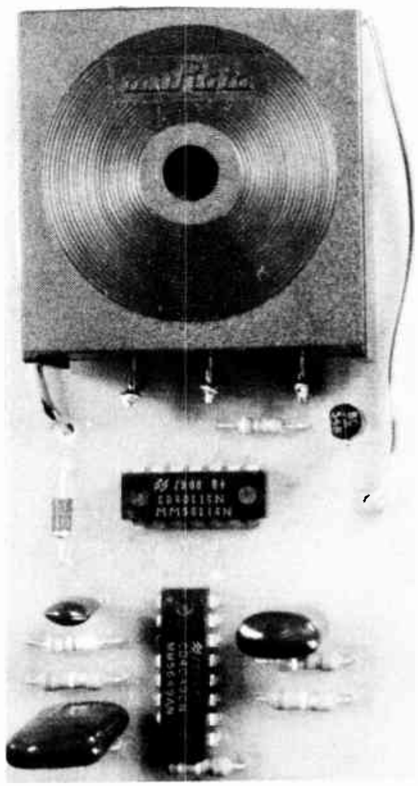
The second attention-getter we have incorporated is to *pulse* the alarm. But, to improve its attention-getting, it is a staccato pulse rate rather than an even rate. The project will work on 6 V or 12 V electrical systems, positive or negative (conventional) 'ground'.

Two CMOS ICs are used. One is a 4049 hex inverting buffer with three pairs of inverters arranged as pulse oscillators, each set to a different pulse rate. Another IC combines outputs of the oscillators to produce the staccato pulse rate. The composite pulses drive a transistor, which turns the piezo alarm on and off.

Construction

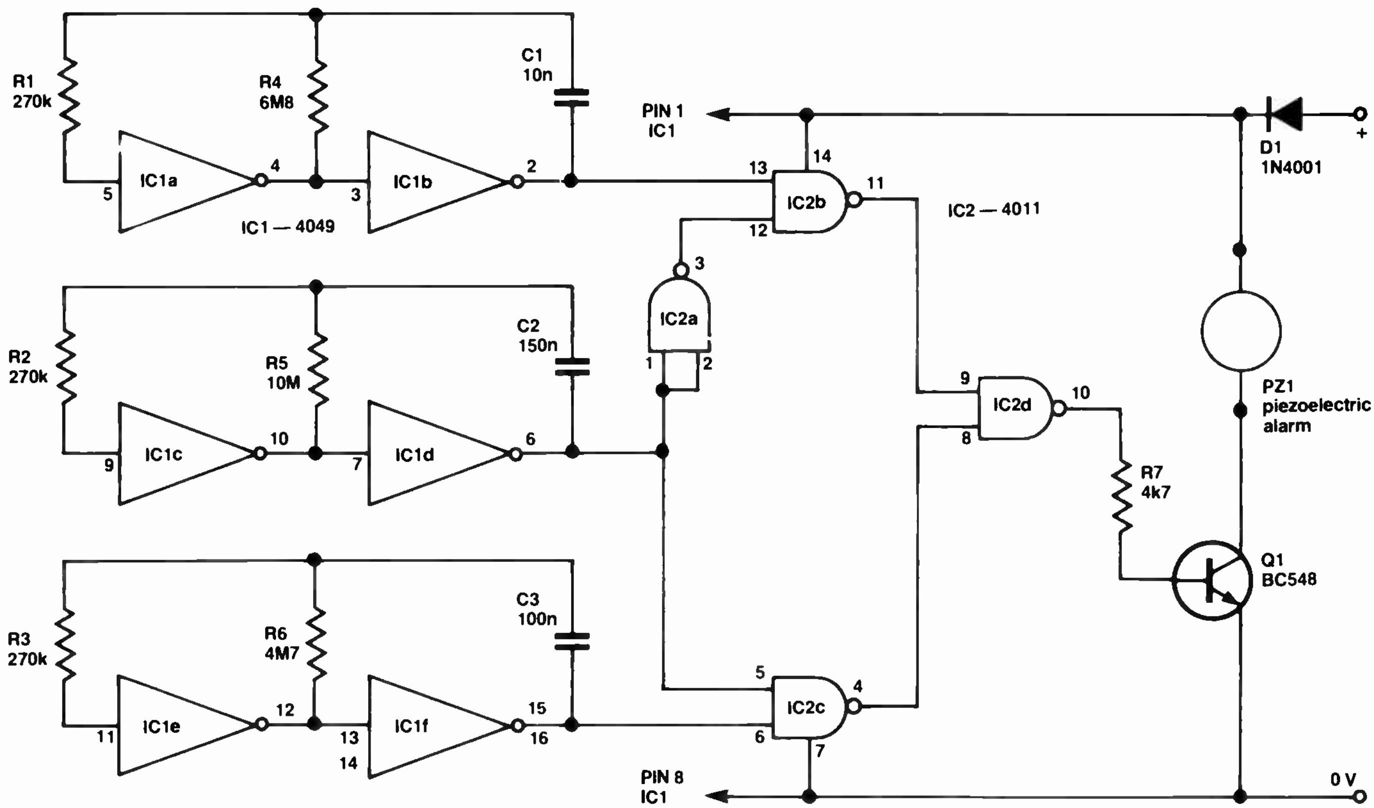
While we have designed a printed circuit board for this project it is not essential to use one and the unit could be constructed on matrix board, Uniboard or Veroboard if you wish. However, our construction description applies to the pc board we designed.

First thing to do is make sure all the component holes are drilled. There's nothing more infuriating than getting most of the components in place only to find one won't fit because the hole is undrilled. It's especially infuriating if you've made the board yourself! Undrilled holes are generally a rarity with commercially-made boards.



Simple, but effective. Built around a piezoelectric alarm, our project will operate on 6 V or 12 V systems.

The next thing is to insert all the resistors and capacitors. As with most projects assembled on pc board, all the components are mounted on the plain side of the board. The resistors and capacitors do not have any particular orientation, but make sure you put the correct values in the right places. Next, ▶



The printed circuit board pattern is on page 32.

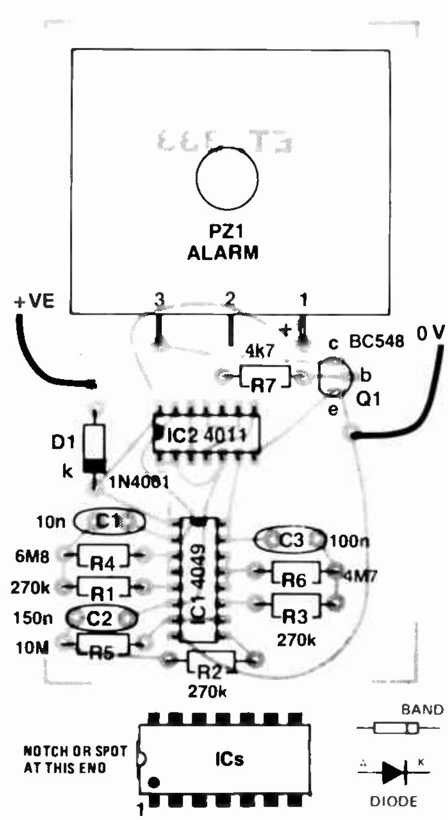
HOW IT WORKS — ETI 333

Three pairs of gates from IC1, a 4049 hex inverting buffer, are arranged as three 'ring-of-two' oscillators, each having a different period. The outputs of these three oscillators are gated together and the composite signal drives the base of Q1. A piezoelectric alarm in the collector of Q1 is thus pulsed on and off by the composite signal. Because the three oscillators are not synchronised their phases are random and an attention-getting staccato sound is produced, something like: beep-beep/bip-bip-bip-bip/beep-bip/beep-bip-bip-bip, etc.

The shortest period oscillator is formed by IC1a, IC1b, R1, R4 and C1. It has a period of about 140 ms (70 ms on, 70 ms off). The longest period oscillator is formed by IC1c, IC1d, R2, R5 and C2. It has a period of about four seconds (2 s on, 2 s off). The last oscillator has a period of only one second and is formed by IC1e, IC1f, R3, R6 and C3.

The four gates from IC2, a 4011 quad NAND, are employed to gate the oscillator outputs together to provide the composite signal. The base of Q1 is driven from the output of IC2d, via R7, which limits the base current to Q1 to an appropriate value.

The piezoelectric alarm may be any suitable type that can operate over a voltage range of five to 15 volts. This type of alarm was chosen as it is very efficient and produces a very loud, high-pitched noise. Diode D1 protects the circuit against damage from reverse-supply connection. The circuit will work over a voltage range from 5 V to 18 V (limited by the operating voltage range of the CMOS ICs).



PARTS LIST — ETI 333

Resistors .... all ½W, 5%
R1,2,3 .... 270k
R4 .... 6M8
R5 .... 10M
R6 .... 4M7
R7 .... 4k7

Capacitors
C1 .... 10n greencap
C2 .... 150n greencap
C3 .... 100n greencap

Semiconductors
D1 .... 1N4001, 1N4002 or similar
IC1 4049
IC2 4011
Q1 .... BC548, BC108 or similar

Miscellaneous
PZI — Murata piezoelectric alarm; ETI-333 pc board; wire etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$8 — $10

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

insert the transistor, Q1. Take care to get it the right way round, otherwise the alarm won't work at all and you may destroy the transistor when you first apply power.

Now you can install the two integrated circuits. As they are CMOS devices handle them only by the ends of the package, not by the pins, and insert them carefully in the board, taking care to orientate them correctly. Identify pin 1 on the package before you take them out of their protective packaging. You'll find a notch in the pin 1 end or an indentation adjacent to pin 1 on the IC package.

When soldering the ICs in place, solder pin 8 and then pin 1 of IC1 first, then pin 7 and pin 14 of IC2. Let the ICs cool down and then solder all the other pins. Use a hot iron with a fine tip and do it quickly. You can pause every few pins to let the ICs cool down before continuing.

Next comes the protection diode, D1. It is important you get this in the right way round, otherwise it may offer no protection at all! The piezo alarm is attached last of all. The Murata type we used has three connections, marked 1, 2 and 3 on the package. Pin 1 connects to the collector of Q1 and pin 3 connects to the pad on the board that goes to the cathode of D1 (it's marked with a '+' on the copper side of the board). Whatever piezo alarm you use, the '+' lead will be identified in some way. We mounted our Murata alarm on the pc board using a double-sided sticky pad.

Testing

Now you can attach leads to the supply +ve and 0 V pads on the board and test the project. Use different coloured wires to identify the leads. Just check, last thing, that all the components are the correct ones and inserted the right way round. You can use an ordinary 6 V or 9 V battery to test the project; it only draws between 20 and 30 mA on 12 V, somewhat less at lower voltages.

All you have to do is connect it up and see if it emits a staccato series of piercing beeps!

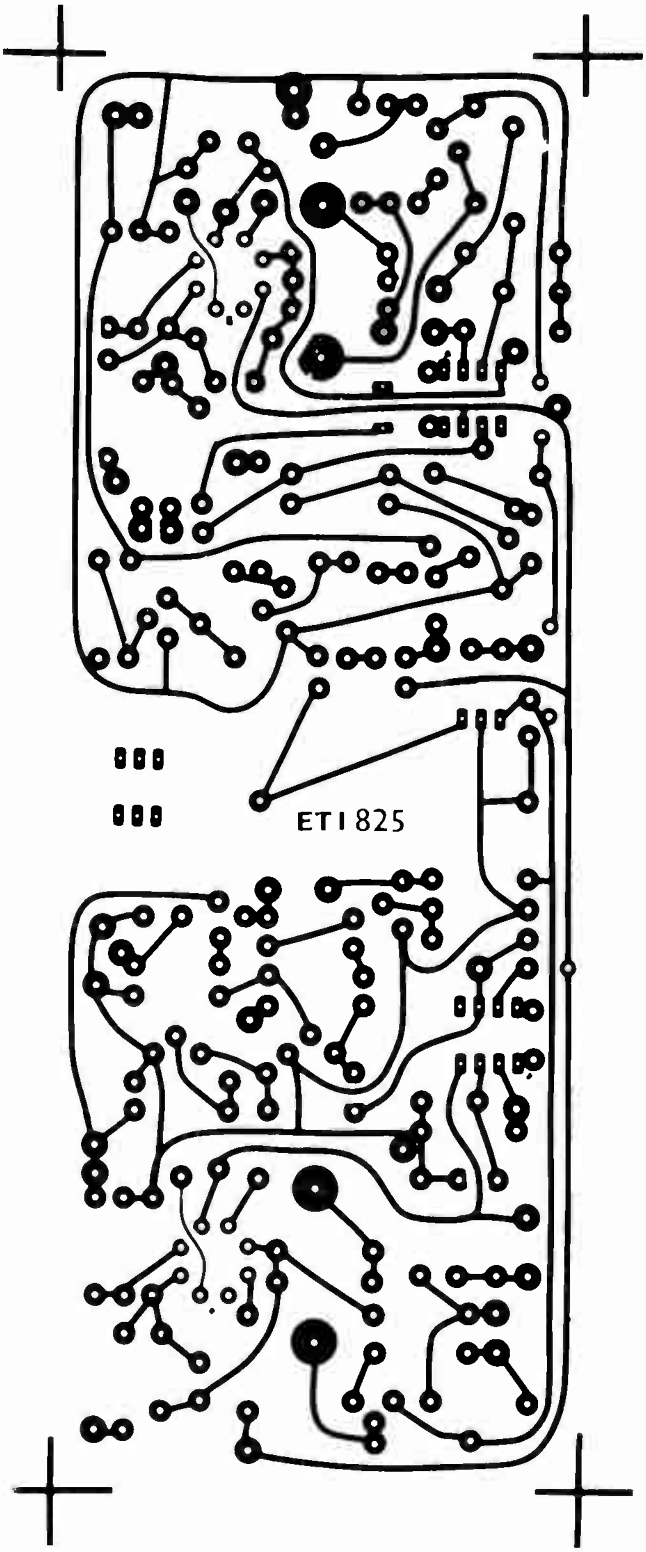
If it doesn't, disconnect the supply and check you have the components correctly placed on the board. Check the polarity of D1 and the piezo alarm. Check with a multimeter that the supply is getting to the supply pins on the two ICs. You might also check that the unit is drawing current. Any problems here will give clues to where the fault may lie.

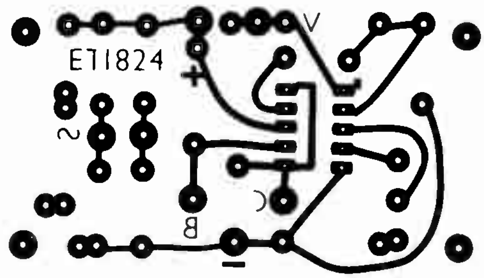
Installation

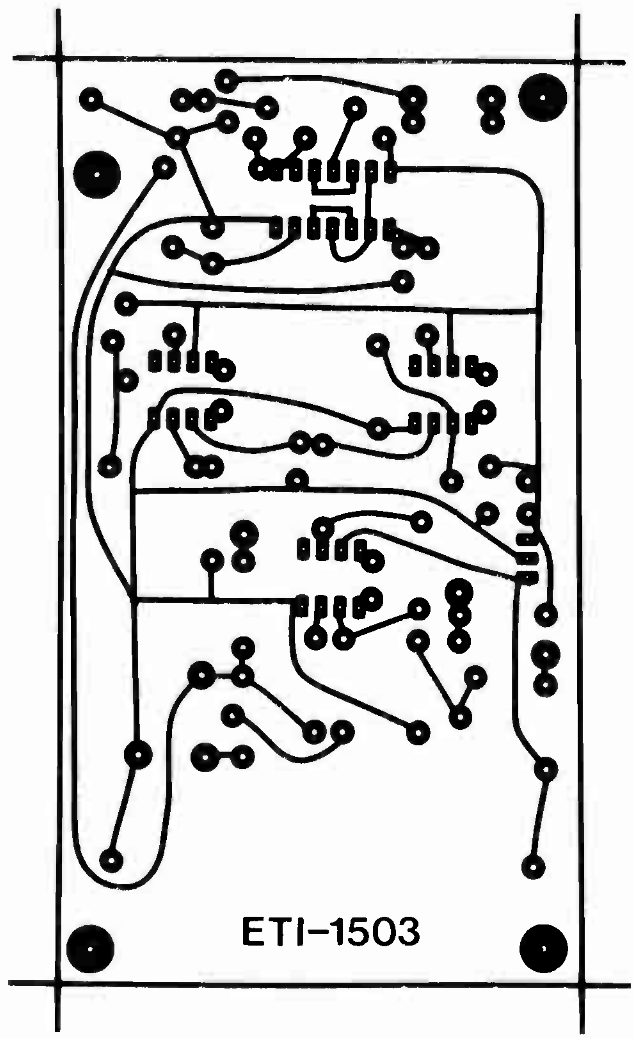
We'll have to leave the installation details up to you. However, a few pointers may assist. The board may be mounted anywhere convenient and the piezo noise maker put remote from the board, in a spot where it is protected from the weather, but can be readily heard — but *always* at the rear of the vehicle, *facing rearward.* The supply connections from the board should be connected in parallel with one of the reversing lights. In some vehicles, the whole pc board and piezo alarm assembly will fit inside the rear light housing.

Make a trial fitting and test it out before permanently mounting the unit. Make sure it can be heard above other loud sounds (such as a revving car engine a metre or two away). ●

PCB's







The negative ion generator
— product of the future, or no future for the product?

Apart from electrons, ions and ozone, a cloud of suspicion hangs around negative ion generators. And not without reason. 'Hard' evidence to support the myriad claims made for them is difficult to come by. We hope this article provides some background to readers wanting to investigate the subject for themselves.

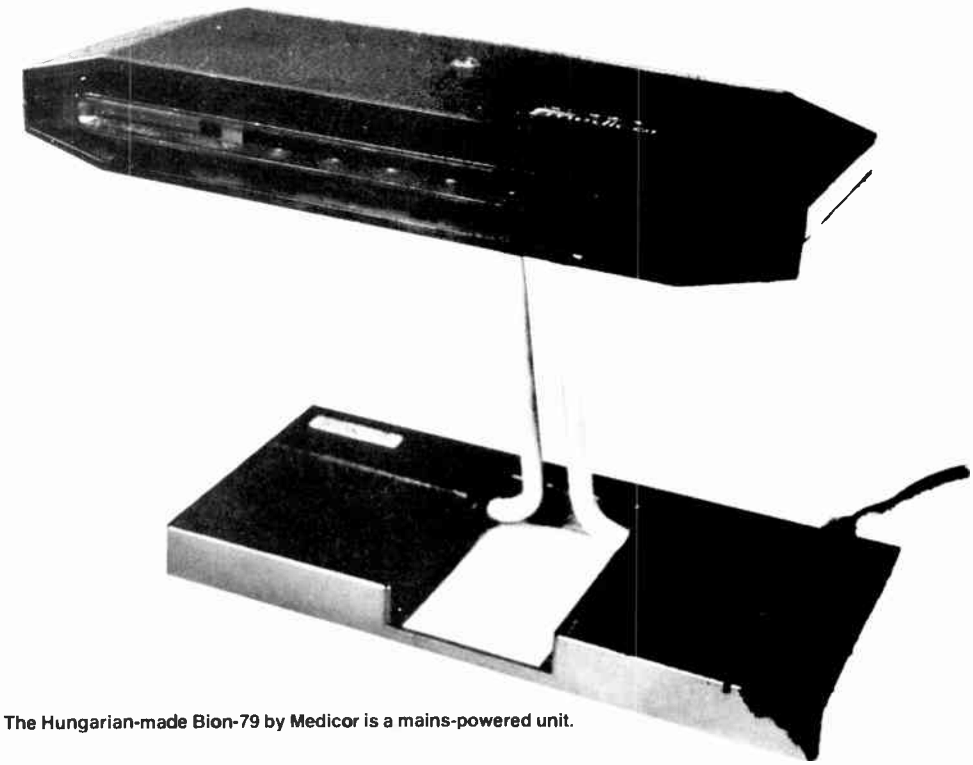
Dee Warring

THE 'NEGATIVE ION INDUSTRY' is booming. In the last three years in the United States the number of companies manufacturing negative ion generators has jumped from three to fifty-seven.

In Australia, the two companies which have been importing generators for several years, Bionic Products and Wentworth Electronics, were joined last year by several other importers and the first Australian manufacturer.

Buyers and users of generators are said to come from all walks of life and from all parts of Australia — parliamentarians, surgeons and GPs, hospital staff and patients, office workers, shop workers, mothers and health nuts. They pay anywhere between $85 and $300 for a generator. Considering the simple construction of the devices this seems a high price, but the manufacturers argue that their prices are not high considering the benefits people can expect to gain. They claim that the generators will give you a feeling of relaxation and well-being, clean the air of tobacco smoke and bacteria, increase concentration and alertness, and give relief from asthma, allergies, bronchitis, sinusitis and migraines. Asked why the prices are so high, Joshua Shaw, manager of Bionic Products, said: "If you're an asthmatic and faced with paying out $500 every year on drugs for the rest of your life, to spend $300 on a machine which can cure you for life seems a small price to pay."

The manufacturers also claim that the high cost of research has forced the prices up. Worth it or not, the list of benefits ascribed to negative ion generators is growing embarrassingly long. It is hard to believe that these small black boxes can do so much.



The Hungarian-made Bion-79 by Medicor is a mains-powered unit.

They are not a new invention. The Nazis were apparently using them during WWII to keep crews more alert in U-Boats. Throughout the 1920s and 1930s scientists in Europe — in Germany particularly, and in Japan and Russia — had conducted experiments that led some to claim that ions had a pronounced effect on all life forms.

With the outbreak of the Second World War, ion science was suspended as scientists were put to work devising war machines. After the war, the new sophistication in electronics led already sceptical scientists to disregard earlier ion science on the grounds that the measuring techniques that had been used were suspect. Even now there is a scarcity of studies being done under properly controlled conditions.

Lack of money in the form of grants has also hampered the progress of research into the subject. ▶

Regulations

Negative ion generators have not yet been made a proscribed article in Australia, which would make it mandatory for every model to be submitted for testing and approved before sale. The Energy Authority of NSW is investigating some of the products on the market to see if they comply with the Standards Association of Australia wiring specifications.

The lack of regulations governing ionisers worries some of the distributors, who fear that negative ion generators will become just another gimmick with everyone trying to sell them and make a fast buck. Most concerned is Joshua Shaw. "If you gimmickise ion generators," he said, "we will have the same thing happening here as happened in the States."

In the 1950s the US Food and Drug Administration (FDA) banned the sale of ionisers to the general public. US companies had been commercially exploiting the units as cure-alls and some devices were found to produce unsafe levels of ozone.

Because of its highly oxidising properties, ozone is very effective in neutralising smells and has in the past been misrepresented as being equivalent to "invigorating mountain or sea air". However, ozone is highly toxic and has been shown to accelerate the aging of blood cells. The legal limit allowed by the FDA is 0.05 parts per million, and the FDA still only allows the sale of air ionisers for environmental, not medical applications.

In Australia, the Commonwealth Department of Health approves air ionisers for personal use. It considers that *they have no scientifically proved benefits but that they present no health hazard.*

It is against the law to make claims of medical benefits in advertisements for ionisers.

This hasn't deterred some distributors. Bionic Products' advertising, for example, claims 85% alleviation of asthma, 70% alleviation of migraines, and 90% alleviation of hay fever and sinus.

In 1979, the Health Commission of NSW wrote to Joshua Shaw warning him to cease making such claims. Shaw ignored the warning. He says he wants to be prosecuted because he's so sure he would win the case.

"Within 24 hours, I'd fly in Dr. Sulman from Jerusalem and Dr. Krueger from California with enough evidence to convince any jury," he said.

Dr. Felix Sulman MD, of the University of Jerusalem, Israel, and Professor Albert P. Krueger MD LLD (Emeritus Professor of Bacteriology at the University of California) are two of the world's most famous ion researchers.

Dr. Sulman's research has centred on the effects on humans of the Sharav — the hot, seasonal wind which blows out of the deserts of the Middle East. The Sharav is one of the world's notoriously 'evil' winds, known everywhere as 'Witches' Winds'. These include the Santa Ana in California, the Chinook in Canada, and the Foehn in Germany, Austria and Switzerland. Australia, too, has its 'Witches' Winds' — the north winds of Victoria and the westerlies of NSW.

When these hot, dry winds blow they are apparently accompanied by an alarming increase in the incidence of murder, suicide and car accidents, and people complaining of asthma attacks, aching joints, depressions, unbearable tensions or just feeling "under the weather".

What all Witches' Winds have in common is a very high concentration of positive ions. Research done by Sulman and other scientists purportedly shows that an excess of positive ions increases the production of serotonin, an important neurohormone.

Serotonin is a depressant and is associated with sleep, mood and the transmission of nerve impulses. Too much serotonin, it seems, can result in sleeplessness, fatigue, irritability, headaches and dizziness, nervousness, inability to concentrate and a sharp reduction in physical and mental efficiency.

When the Sharav blows, Dr. Sulman found that some people overproduced serotonin as much as 1000 times. Negative ions apparently decrease the production of serotonin in the brain,

HOW A NEGATIVE ION GENERATOR WORKS

This is a brief description of the physical aspects of the operation of an air ioniser or negative ion generator and should not be taken as a rigorous explanation of how they work. Suffice to say that the physics of the process appears to be poorly understood in detail — or is a proprietary secret!

The point

We know from basic physics that a sharp conductor raised to a high potential will have an intense electrostatic field around the point — as illustrated in Figure 1. If the conductor is at a high negative potential, free electrons from the metal will flow towards the point, and if the potential is high enough some will be repelled from the point. The latter will occur because electrons, having a like (negative) charge, will repel one another and the mass of electrons building up behind the conductor's tip will repel those electrons at the very tip. At a certain potential the air will 'break down' and a spark will be seen to emit from the conductor's tip. Catastrophic ionisation of the air occurs, photons being emitted in the process — thus we see a spark along the path of ionisation.

However, at potentials well below the air's breakdown potential, the electrons leaving the tip of the sharp conductor are found to combine with gas atoms and molecules in the air.

Most of the atoms and molecules of the gases comprising the air we breath will have 'vacancies' in the outer electron shell of the free atoms or in the outer electron shell of at least one of the atoms in the gas molecules. Electrons escaping from the conductor will 'fill' these vacancies, giving the atom or molecule to which it attached a net negative charge; this is how they become negative ions.

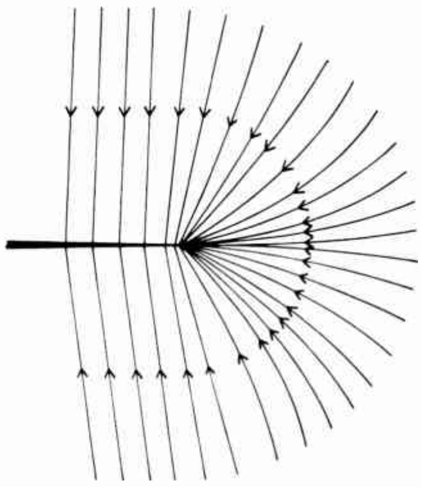


Figure 1. **Field around a needle-point conductor raised to a high potential.**

These ions, termed "small" or "primary" ions, may then combine with other molecules or ions to form larger ions of various sizes and mobility. Research indicates (. . . as all good review papers say) that it is the small primary ions that appear to be "biologically active", while the larger ions appear to be inert — see Robinson and Dirnfield (1963), Krueger and Reed (1976), Krueger and Smith (1960) and Kranz and Rich (1961).

If, for some reason, some of the atoms and molecules of the atmospheric gases have been positively ionised (that is, they are deficient an electron or two) then the electrons streaming from the conductor's tip will be attracted to the positively-charged ion, neutralising it when they combine.

Again, "research indicates" that an excess of positive ions in the air is biologically deleterious. See Kimura, Ashiba and Matsushima (1939), Sulman (1962) and Sulman et al (1974).

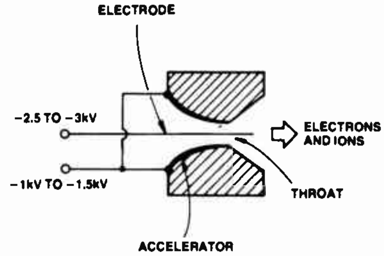


Figure 2. **Simplified cross-section of the emitter head of a commercial air ioniser.**

Heads

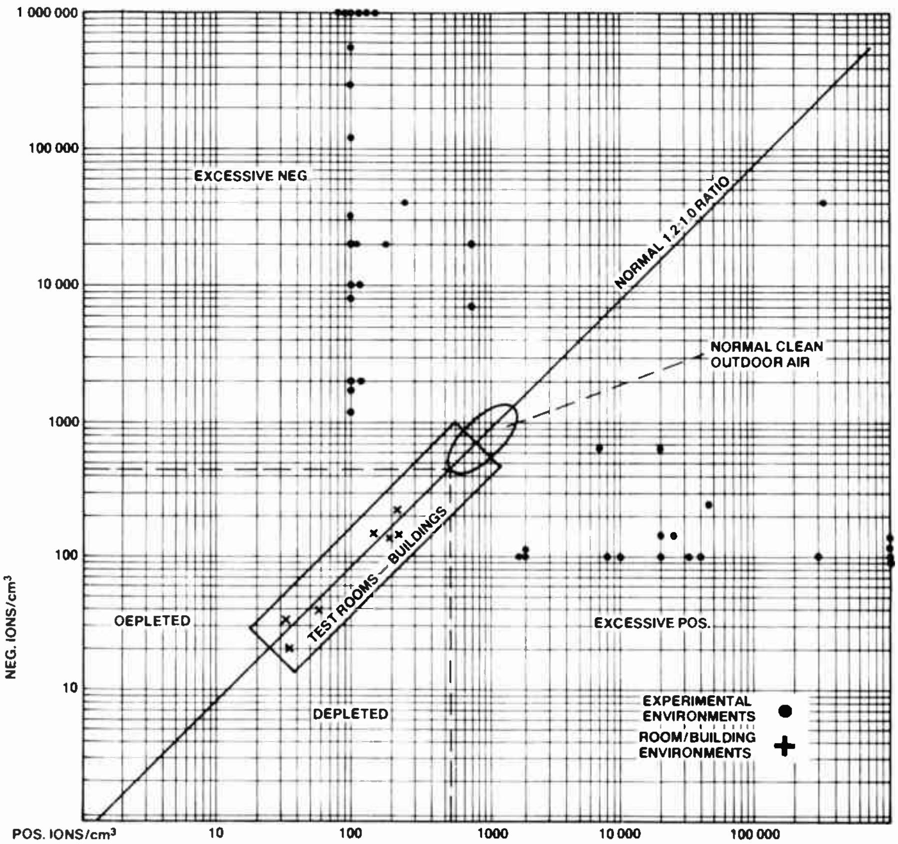
A cross-section (simplified) of the 'emitter' of a commercial negative ion generator is shown in resulting in a calming, tranquillising effect.

Negative ion imbalance or ion depletion is at its worst in cities. For a worthwhile environment there needs to be between 1000 and 5000 negative ions per cubic centimetre, according to various researchers. The average city worker spends his day breathing air with only 200 to 300 positive and 150 negative ions per cubic centimetre. Air pollution in cities quickly depletes or neutralises negative ions, which attach themselves to positively charged pollution particles and lose their charge. This leaves an abundance of positive ions which, along with the pollution particles, are then inhaled.

Negative ions and tobacco smoke

Experiments in the mid-1960s showed that the cilia (microscopic hairs) of the trachea, or windpipe, are stimulated by negative ions and depressed by positive ions.

These microscopic hairs under normal conditions maintain a whiplike motion of about 900 beats per minute while cleaning the air we inhale of dust, pollen, and other matter that should not reach the lungs. Subjected to tobacco smoke, which absorbs negative ions, the cilia slow down; tobacco smoke plus positive ions make this slowing down take place from three to ten times more quickly. This obstructs the ability of the cilia to clean the air that finally ends up in our lungs. ▶



This chart, from a review of the subject by K.R. Robertson of the University of Auckland (see Bibliography), shows "... various types of air ion environments and the relationship of existing research to these environments. Only experiments dealing with humans are presented. The 45° line represents the balanced positive-to-negative ion ratio of 1.2:1.0 across the environments of depleted, normal fresh outdoor, and excessive ion concentrations."

The points and crosses marked on the graph represent measurements of ion environments taken in buildings and test rooms and type of ion environment created in various research designs (base ion count assumed to be 100 +ve and 100 −ve ions per cm³ of air for test rooms).

Figure 2. The 'electrode' has a potential of around −2.5 kV to −3 kV applied. The 'accelerator' has a potential of around −1 kV to −1.5 kV applied. This makes it more positive than the electrode. The shape of the accelerator produces a very complex electrostatic field between itself and the electrode. The apparent object is to 'push' more electrons toward the tip of the electrode. The latter projects well beyond the throat area of the emitter head and the electrons and (negative) ions stream away from the emitter in the direction indicated. Some electrons will accumulate on the flared portion of the throat, giving it a slight negative charge, but this is generally quite small.

The object of the design of the head is to produce a large number of mobile small ions, and as little ozone as possible.

Ozone

There's a drawback that has to be avoided — the production of ozone, O_3. This is a highly reactive form of oxygen that is a very effective oxidising agent and has a known deleterious effect on the mucous membrane and lungs of animals and people if inhaled in quantities above a certain level. (The US FDA sets this level at 0.05 ppm). Ozone is that distinct, acrid, somewhat 'coppery' smell apparent near any continuous spark discharge.

Circuitry

The voltages applied to the emitter are generally derived from a simple Cockcroft-Walton voltage multiplier with input direct from the mains — as shown in Figure 3. The component values used and the addition of a high value series resistor between the rectifier output and the emitter's electrode serves to reduce the possibility of nasty accidents if you happen to touch the electrode of an air ioniser — the short circuit current is only tens of microamps. Nevertheless, we recommend you *do not* dismantle one.

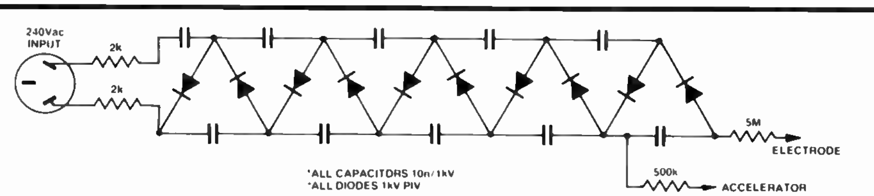


Figure 3. **Circuit of a commercial negative ion generator.**

The result

What happens, or is claimed to happen, with an air ioniser in operation you can read about for yourself in the numerous research papers. Certainly, the 'coronal wind' produced by one will rapidly precipitate pollutants in the air — particularly those in tobacco smoke. If an air ioniser is operated in one position in a room for some time the surrounding area will become coated in a sticky, dark film of material — which presumably you would otherwise have breathed in. Just why, and how, an air ioniser does this is not clearly apparent.

Trotting out that phrase again, "research indicates" . . . that an air ioniser will have a decidedly destructive effect on bacteria. It's controversial, but this is generally attributed to the ozone produced.

Many claims made of air ionisers relate to 'restoring' the 'natural' balance of negative-to-positive ions. For a machine to do this, clearly, it would need to produce not only sufficient electrons to neutralise the positive ions in the atmosphere surrounding it, but sufficient to balance the ratio as well. As the machines are clearly quite simple at present, no 'feedback' of ion production or negative-to-positive ion ratio is employed, so their effectiveness under variable or uncontrolled conditions must be hard to gauge and their 'control' of the environment crude at best.

If you accept that an excess of positive ions in the atmosphere (as in the 'Witches Winds') can have a detrimental effect on some people, and you believe than an air ioniser has the ability to restore the natural balance of positive-to-negative ions, then you could accept that the machines may have a positive effect (no pun intended).

At this stage, we leave you to decide for yourself.

Roger Harrison.

An article in *New Scientist* for 2 October 1980, entitled "The perils of second-hand smoking", by Sherridan Stock, (pages 10 to 13), said: "Tobacco smoke removes negative ions from the atmosphere, which is already grossly depleted of its natural complement by urban pollution and various other factors associated with modern, man-made environments . . . In recognition of this effect of tobacco smoke, some company executives have installed negative ion generators in their offices and conference rooms."

The article also reported on the effect of secondary smoking (breathing in other people's smoke) on the cilia. Poisoning the action of the cilia by tobacco smoke is believed to facilitate the development of lung cancer by causing the retention of inhaled carcinogens (a substance or combination of substances that can produce a growing cancer from normal cells).

An excess of positive ions in the atmosphere also reduces the body's ability to absorb oxygen and therefore cuts down lung capacity.

Accepting all this, it is then possible to believe that negative ion generators do have a beneficial, if not curative, effect on respiratory ailments. But 'hard' proof is lacking, particularly with respect to the required production and mobility of negative ions to counteract positive ions and pollutants.

Air ionisers in the office

Manufacturers of air ionisers are looking increasingly at the potential market for their products in offices. The combination of air-conditioning, cigarette smoke, synthetic furnishings and large numbers of people in a confined space creates problems in offices ionically speaking.

Hot or cool air forced through duct work of central heating and air-conditioning systems sets up friction that can bring about a reduction of negative ions in the air, according to several researchers. What finally comes out of most heating and air-conditioning outlets in the offices we work in is likely to be an eternal Witches' Wind. To make matters worse, most modern offices are carpeted with synthetic fibre which, as we walk across it, tends to generate a positive charge in the air.

Bacteria thrive in positive ion atmospheres, so besides having to cope with positive ion-induced fatigue, loss of concentration, irritability, tension and headaches, there is also the problem of spreading of disease.

One widely-reported study of the effect of ion-depleted air on office workers was carried out in the New York Swiss Bank. Between January and March of 1973, at a time when there was an epidemic of 'London Flu', negative ion generators were placed in two working areas of the bank and left running throughout the three-month period. Both areas had 16 people working in them, who were told only that the machines were 'air cleaners'. At the end of the test period it was found that of the 32 employees, only nine were absent for two or more days, and that a total of 53 days' work was lost through sickness. The year earlier (during the same three months) every one of the 32 people was off for two days or more and a total of 89 days of work was lost.

Air-conditioning manufacturers in the States — like Westinghouse, General Electric and RCA — are now designing new systems that increase negative ionisation.

Vehicles

Cars are also said to be ion-depleted atmospheres. Traffic exhaust fumes destroy negative ions, and friction between the air and the vehicle as it is moving sets up a positive charge on the metal bodywork that attracts negative ions to the metal.

A subjective investigation into the effects of ionisation on truck drivers was conducted in Australia in 1979. Drivers from all over Australia were sent a questionnaire to complete. A negative ion generator was installed in each truck and drivers were instructed to make weekly reports.

The results were: 81% of drivers reported an increase in alertness and awareness while driving; 13% could not discern any difference. 80% stated that they slept better and deeper for shorter periods. 73% said they had become less irritable, while 27% found no difference. 93% said they found their cabin cleaner and fresher. 7% failed to comment.

Burns, asthma and negative ions

Dr. Igho Kornblueh of the American Institute of Medical Climatology explored the use of negative ionisers in the treatment of burn patients at Philadelphia's North-eastern General Hospital. After a number of controlled experiments using ionisers in which 57% of burn patients showed improvement, rapid healing and less pain, the entire hospital's post-op wards were equipped with ionisers.

Dr. Kornblueh was also responsible for introducing negative-ion treatment for hay fever and bronchial asthma patients at two major hospitals in Pł. ladelphia. Of the hundreds of patients treated, 63% experienced partial to total relief.

"They come in sneezing, eyes watering, noses itching, worn out from lack of sleep, so miserable they can hardly walk," one doctor said. "Fifteen minutes in front of the negative ion machine and they feel so much better they don't want to leave."

A two-year study of the effect of negative ions on asthmatics is presently in progress in England.

The local scene

We could find no local research efforts into the negative ion question being carried out by independent scientific bodies. However, several of the local air ioniser equipment suppliers said they were carrying out some investigations. Pat Mulligan of Creative Electronics, who markets air ionisers under the aegis of Bionaire International, has spent the past 15 months or so gathering documentation on the subject and is ". . . keeping a low profile in the market" while his researches continue.

Joshua Shaw of Bionic Products has been doing some work on the construction and operation of air ionisers. He claims to have spent half a million dollars already in funding research. The most recent project financed by his company is an investigation of the size and mobility of ions produced by air ionisers. It seems these are the two most important factors influencing their effectiveness.

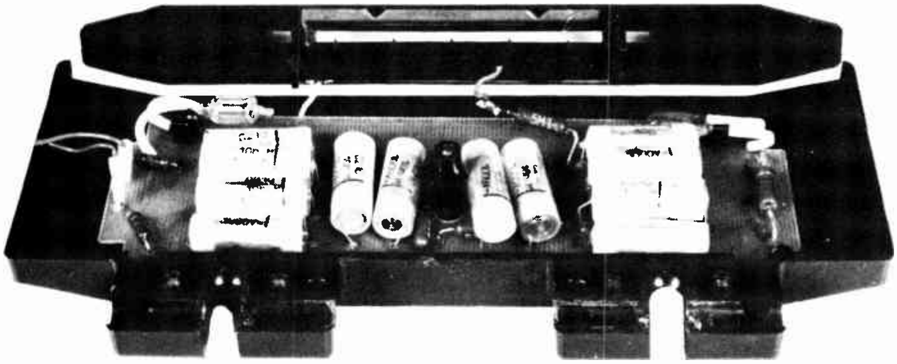
"Ion mobility is one of the toughest nuts to crack," said Joshua Shaw. He is waiting for the results of this latest research before going into generator manufacture himself. Even so, he plans to be manufacturing six models in Australia within a year. In the meantime, he is content to watch sales of his imported models grow higher every day. Since he first started importing two years ago, he claims to have sold 6000 generators.

Shaw first became intrigued by negative ions in 1969 after the presence of a negative ion generator healed a bad burn on his arm. He immediately wrote to the manufacturers to find out more about the machines. Nine years later he brought in his first shipment of generators and he hasn't looked back since.

Bionic Products have six models on the market at present. Two of the most popular products are the Mobilion and Modulion, both made by Amcor — the 'General Electric' of Israel.

The Mobilion is a 12 V car model, the Modulion a room model. It operates from the 240 Vac mains and is claimed to produce an output of 250 billion negative ions per second.

Shaw also imports two models from Medion Limited, a British firm which



Inside the Medicor Bion 79 — simple, isn't it? The basic circuit of this machine appears on page 43.

has been in the ion business for many years. The Medion desk model is claimed to have an output of 5×10^9 to 10^{10} ions per second and an effective range of four to five metres. The Medion portable is claimed to be the only battery-operated unit in the world. Its output and range are similar to the desk model.

Bionic is the only company in Australia, and one of the few in the world, to possess an Atmospheric Ion Analyser (also made by Medion) according to Shaw. The Analyser measures ion charges of either sign independently and the three scale ranges enable density of between 50 and 250 000 ions per cubic centimetre to be recorded. With this, Shaw has tested the effectiveness of all the generators currently on the Australian market. He reports that three of his products gave the following results:

Mobilion — 100 000 ions/cc (measured at 1m),
Medion — 110 000 ions/cc.
Medion (portable) — 60 000 ions/cc.

Another well-established company in Sydney is Wentworth Electronics. The director, Ian Maclachlan, has imported, manufactured and sold electronic equipment, particularly electronic health aids, for some years. Since 1977 he has been importing generators from Hungary and has recently started to import from Germany. His range includes desk and car models, a large room unit, appliances for special medical use and a car unit with an electrostatic ceiling strip "designed to produce the same ion conditions in the car as are found outside". Prices range from $68 for a car unit to $295 for a specialised medical unit.

Wentworth Electronics claims to have sold over 2000 units.

Bionaire International (Creative Electronics) imports American- and Canadian-made ionisers. They avoid any medical claims and stress only their benefit as air fresheners and purifiers.

Bionaire has three models — the Bionaire 300, a car model priced at $159, the Bionaire 100-A for caravans ($169) and a large spherical room model, the 'Ionosphere' ($159).

Autex International is a Queensland-based company specialising in car accessories. It markets an American automobile ioniser unit called Air-Alive, which plugs into the cigarette lighter and costs $139. Autex markets the machine as an air freshener and makes no health claims.

The latest product on the market is a room unit assembled in Australia from American components for Ion Environment Australia of Sydney. Called the Saucer, it is priced at $136.

The distributors vary in their approach to the product. Some stress health benefits and will only sell directly to the public. Others rely on the benefits of clear and fresh air, and some would like to see ionisers widely sold through retail outlets.

Shaw of Bionic Products believes in a personalised service. "I only sell eyeball to eyeball," he said. He has a small sales team who "know everything there is to know about ions and ionisers". A 12-month guarantee comes with all models. If there are any complaints or faults the company immediately replaces the faulty model or refunds the money.

Gerard Marceau of Belle Lumiere, Australia's only manufacturer of negative ion generators, is one distributor who would like to see generators sold through a wide range of retailers. The company recently ran an intense advertising campaign through electronics magazines and on radio promoting their product, the Aironic.

"We want people to know us so well that when they think of negative ion generators they will think automatically of the Aironic," Marceau said.

The company is also about to launch two new products — a car model and a larger model, twice the size of the Aironic, for industrial use.

Two hundred Aironics are produced each week in the company's Lane Cove (Sydney) factory — and they're going like hot cakes, says Marceau. At $57 wholesale and $85 retail, the Aironic is one of the cheapest generators on the market but is also one of the simplest designs. Marceau himself admits that an amateur could make one.

Belle Lumiere moved recently to safeguard their product when they had a 25% import duty on generators introduced in November last year. When asked about this, Shaw of Bionic Products said he wasn't at all concerned. He is more worried about the retaliatory actions of the drug companies who, he says, stand to lose billions of dollars in lost drug sales if the ioniser market keeps growing at its present rate. And according to the ioniser manufacturers, it will happen.

"One day there will be a negative ion generator in every home." ●

The Biotech from Bionaire International is powered from a 12 Vdc source and intended for use in cars, trucks, etc. The makers claim it produces 10 billion ions per second.

Experimental negative ion generator

For those experimenters who just have to find out for themselves what the subject is all about, this negative ion generator should provide a good basis for experiment.

Design: **Jonathan Scott** Development: **Graeme Teesdale**

THE RISE in popularity of negative ion generators, the claims made for them, and the attention they have received in newspapers and magazines recently has undoubtedly intrigued many readers with a technical background or interest, as evidenced by the deluge of letters and phone calls we've received in recent months requesting information and project material to be presented in ETI.

Having read the article presented elsewhere in this issue, undoubtedly many of you will be 'hot to trot' to experiment with an air ioniser but have been daunted by the cost of commercial units. As the electronics associated with a negative ion generator is relatively simple, generally employing readily available components, this article describes how to build a unit that can be used as the basis for experiment. The cost of commercial units, at least in part, is justified by the design and construction of the emitting head, which requires somewhat more specialised parts and construction than are available to the average constructor in order to work efficiently.

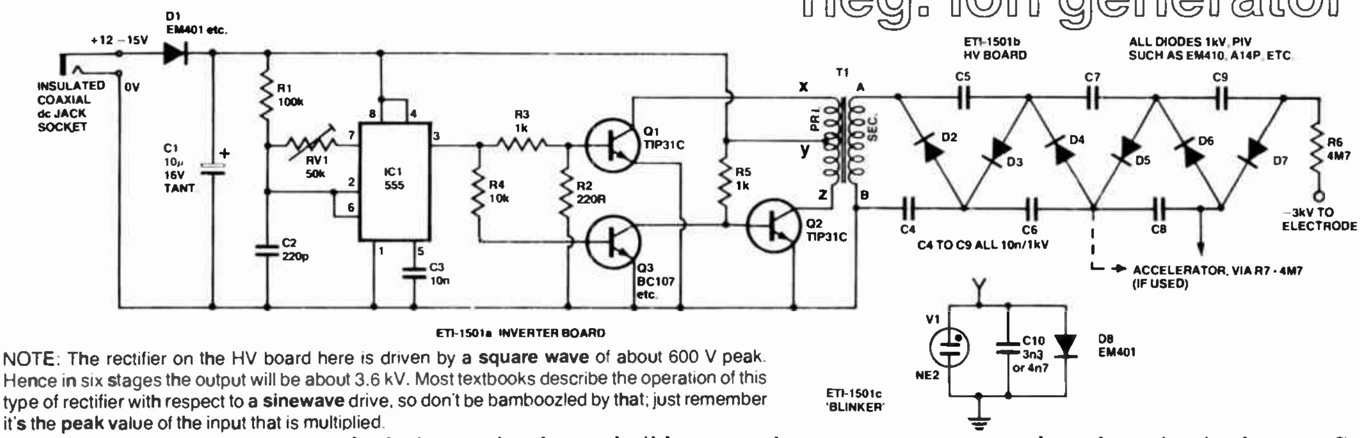
All the present negative ion generator designs that we have examined operate on the 'corona discharge' principle. This requires relatively high voltages — around 2.5 kV to 3 kV. In mains-operated units this is usually obtained by a voltage-multiplier rectifier operated direct from the 240 Vac mains. While this is economical and efficient and, in an assembled plastic box, fairly safe, it is not at all safe for anyone without a great deal of experience to tinker with on the workbench or kitchen table, etc. With this in mind, we have designed our unit to work from a 12-15 volt supply, employing a dc-to-ac inverter and voltage-multiplier rectifier, giving a relatively safe high tension (HT) voltage to operate the emitting head. This has the added advantage that it is portable and can be used in a car or run by a plug pack from the mains. In addition, we have kept in mind that many of the victims of electrocution each year are people who should have known better. Our project design was partly motivated by the desire to avoid the necessity of having to replace design staff — who are hard to come by, expensive and cannot run the risk of being zapped like the occasional 20¢ transistor! Prime motivation behind the design was to avoid losing readers, though.

Our unit can be powered from 12 Vdc or a plug pack. The blinker testing device is at left.

Circuit design

The negative ion generator electronics can be separated into three components: an oscillator, a driver and step-up transformer comprising the dc-to-ac inverter, and the voltage-multiplier rectifier.

A 555 timer IC (IC1) is arranged as an astable multivibrator. A trimpot is included in one of the timing inputs (pin 7) to allow adjustment of the mark-to-space ratio of the output to ensure equal drive to the two driver transistors, Q1 and Q2. These two transistors alternately switch current through the



NOTE: The rectifier on the HV board here is driven by a **square wave** of about 600 V peak. Hence in six stages the output will be about 3.6 kV. Most textbooks describe the operation of this type of rectifier with respect to a **sinewave** drive, so don't be bamboozled by that; just remember it's the **peak** value of the input that is multiplied.

primary of transformer T1. As both Q1 and Q2 are NPN transistors, one has to receive an inverted drive signal so that it is off when the other transistor is on and vice versa. Thus Q3 is employed to invert the drive to Q2.

Transformer T1 steps up the drive applied to its primary, providing a 500-600 V peak-to-peak output at the secondary (depending on the supply voltage).

As about 3 kV dc is required to operate the emitter head, a Cockcroft-Walton voltage multiplier circuit is employed, multiplying the secondary voltage of T1 six times. A large value series resistance, together with the inherently poor regulation of the rectifier circuit, ensures that the output short-circuit current is very low to reduce shock hazards.

To enable you to test the operation of this unit a 'blinker' has been provided. This simply consists of two large 'pads' on a piece of pc board with a diode, capacitor and neon connected between them. With the pad to which the diode cathode connects held with your thumb, the other pad acts as an 'antenna' or 'collector' when held in front of the emitter head of any negative ion generator.

As charge builds up on the antenna pad, the capacitor will charge up. When this reaches a voltage that exceeds the breakdown voltage of the neon, the neon will conduct briefly while the capacitor discharges and you will see a flash. The charge will build up again and the whole process will be repeated.

The 'blinker' thus provides a crude measure of the ion production of the generator being tested. The closer the blinker is held to the emitter head, the faster it will flash. Alternatively, if held a fixed distance from the emitter heads of different air ionisers in turn, the one in front of which it blinks fastest will have the greater ion output.

Design of the emitter head

The object of the emitter head is to take in the HT, in our case about 3 kV, and produce a stream of negative ions flowing forwards into the room in which the generator is placed. The ions are produced by a very intense field gradient, which is induced by the high voltage and the geometry of the head assembly. This ion flow is a corona wind. It is a basic principle of electrostatic physics that the field gradient is stronger in the immediate vicinity of a point projection, the gradient being greater when the point is sharper. So most ion generators employ some combination of sharp projections and high voltage. A number of other matters affect the choice of head geometry. Firstly, the design should expel the ion stream away from itself to allow more ions to be emitted. Secondly, it should achieve its aim with a minimum of ozone production. Thirdly, it should employ points made of a hard metal to resist cathode stripping and hold their edge, without being too hard to work or too expensive or exotic to get easily. We will briefly discuss these aims and the relevant principles behind their realisation, then give you a couple of examples to act as a guide for experimentation.

If the point is spaced well away from other parts of the unit the ions will naturally repel themselves away from the region of emission. However, if the point or points are partially enclosed in the case of the device there may need to be either a chimney-shaped assembly around the emitters or some sort of accelerator electrodes to help eject the ions from the emitter head.

Wherever there is ion production there will be ozone production. Ozone, O_3, is a product of higher energy ▶

HOW IT WORKS — ETI 1501

One board contains a dc-to-ac inverter, a second board a high voltage multiplier rectifier and a third a 'blinker' test unit.

The dc-to-ac inverter on board ETI-1501a consists of a 555 astable multivibrator, the output of which is used to drive two transistors operated in push-pull, the collectors of which switch current through each side of the transformer (T1) primary in turn. Diode D1 prevents any damage from a supply connected with reverse polarity. Capacitor C1 is a bypass. IC1 oscillates at around 25 kHz, determined by R1 and C2. The exact frequency is unimportant. The mark-to-space ratio of the output of IC1 (via pin 3) may be adjusted by RV1, which is connected in series with pin 7 of IC1.

The output of IC1 drives the base of Q1 directly, via R3 and R2. Q1 turns on when the output of IC1 goes high. Resistor R3 is there principally to limit the base current supplied to Q1, while R2 serves to discharge the base-emitter junction capacitance so that Q1 turns off quickly when the output of IC3 goes low.

When pin 3 of IC1 goes high, Q3 also turns on, preventing Q2 from turning on. When pin 3 of IC1 goes low, Q1 and Q3 turn off and Q2 will turn on as base bias will be supplied via R5.

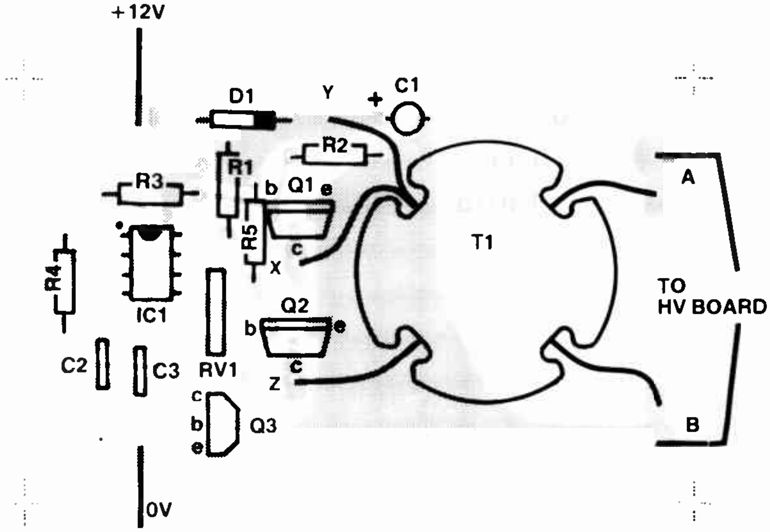
Thus current is alternately switched through each side of the primary of T1. The secondary provides a voltage step-up of 25:1. If the supply voltage is 12 Vdc, then the peak-to-peak output from the secondary of T1 will be 600V. The voltage-multiplier rectifier, on board ETI-1501b, employs the well-known Cockcroft-Walton circuit, where the output of successive half-wave rectifiers is connected in series with the previous one. This circuit provides a multiplication of six times. Thus, with a 12 Vdc supply, the output will be about −3.6 kV. With a 10 Vdc supply (as can be obtained from a 9 Vdc plug pack), about −3 kV is obtained. An output for an 'accelerator' is provided.

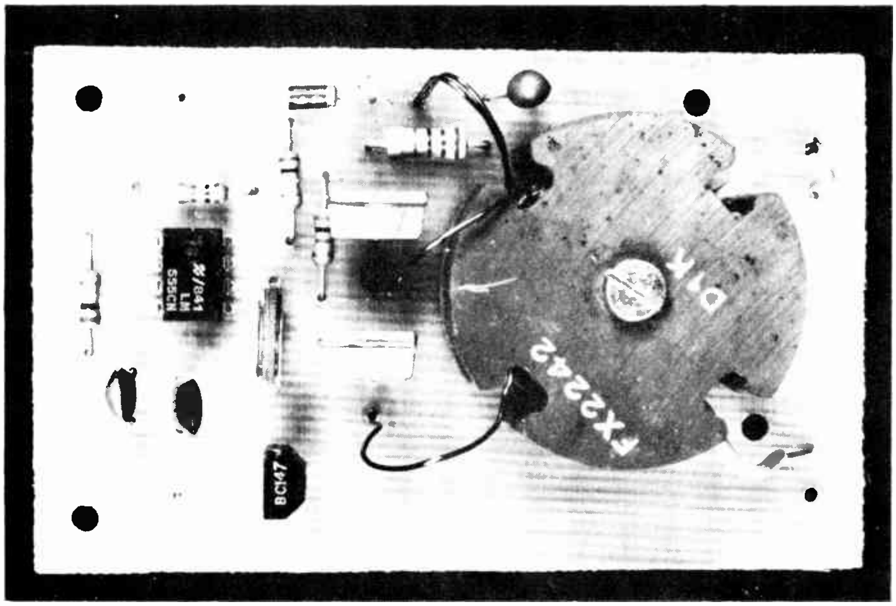
The high voltage output to the emitter head is taken via a 4M7 resistor to ensure that only low short-circuit current occurs if the emitter head is accidentally contacted or excessively humid air causes 'flashover' from the emitter.

The blinker is simply a crude relaxation oscillator. When a charge builds up on the 'antenna' pad, it will charge C10. When the voltage on C10 reaches the breakdown voltage of the neon, V1 (about 70 V), the neon will conduct. This will discharge the capacitor, the voltage across it falling until it reaches the extinguishing voltage of the neon (about 30-40 V), which will then cease conducting. While the neon conducts, it will emit light, but as it discharges C10 fairly rapidly, all you will see is a brief flash from the neon. Diode D8 ensures only negative charges operate the blinker.

When the neon ceases conducting, the charge on C10 will build up again and the whole process will be repeated.

activity than is necessary for more ion production. It is a corrosive as well as a strong antibacterial agent, and is poisonous in sufficient concentration. About 0.025 to 0.05 parts per million (ppm) is recognised as a safe level. Ozone is what you smell after there has been arcing, such as in a motor commutator; an acrid, coppery smell, distinctly metallic. It is produced in some quantity in all ion generators, though some are so well designed that it is negligible. In order to keep it to a minimum, as low a voltage as possible should be used. Our project has been designed to give the lowest voltage compatible with adequate ion production. The design should be such as not to allow any arcing or serious breakdown. This is really only likely if you try using an "accelerator", as there will be no metal in close proximity to the emitter otherwise.



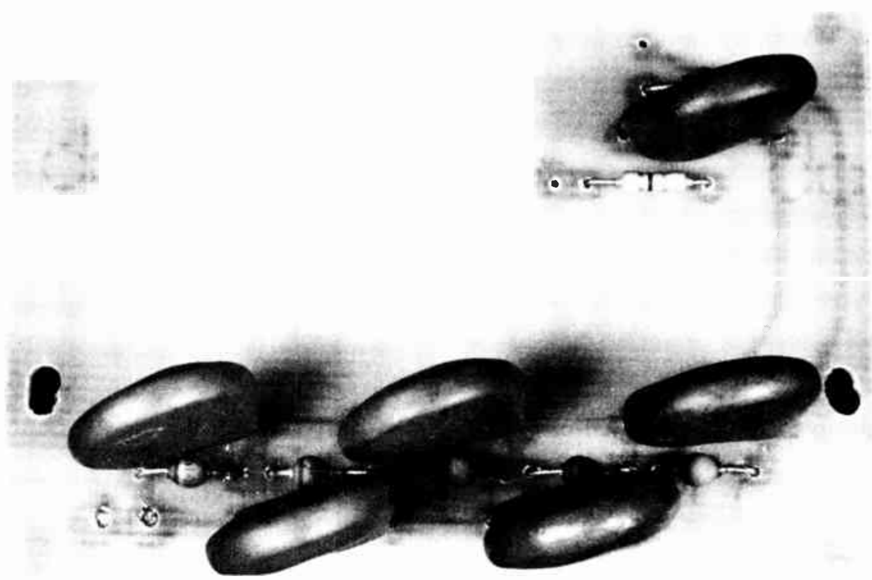


The inverter board, ETI-1501a. Compare this to the overlay above.

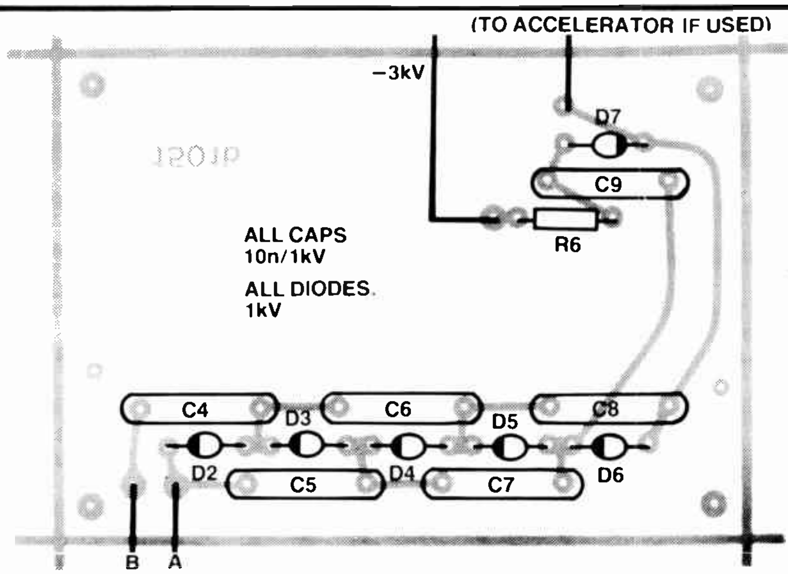
The best metal for the points which is easily obtainable is steel, preferably stainless. This is hard enough to hold an edge, and will resist the effects of cathode stripping. The latter is undesirable both because the fine point will be eroded away, and also because the heavy metal ions which are ejected are undesirable agents in the air we breathe (stick to getting your minerals from cornflakes).

Figure 1 shows the emitter head assembly of our prototype. The plastic we used was clear perspex, but this is purely to show you what is inside the gizmo. We recommend some aesthetic colour for your version if you use perspex. There was found to be no need of an accelerator as the points actually protrude beyond the slot in the faceplate. If they are to be recessed an accelerator may be necessary, as the ions soon collect on the plastic parts and build up a field, inhibiting further ionisation or ejection. There is no shock hazard as the unit is not mains powered and there is a very large series resistance between the points and the multiplier output. At most, there results something between a nip and a tickle if you touch the emitter points. The points are steel needles soldered to a brass rod; the needles are probably sharp enough normally, but we struck them against a fine whetstone to sharpen them further. This enhances ion production a little.

Figure 2 shows one commercial unit's layout. It employs an accelerator and points of phosphor-bronze. It has a similar voltage potential to ours, but is physically smaller, due to custom plastic components. The points are



The high voltage board, ETI-1501b. Compare this to the overlay above right.



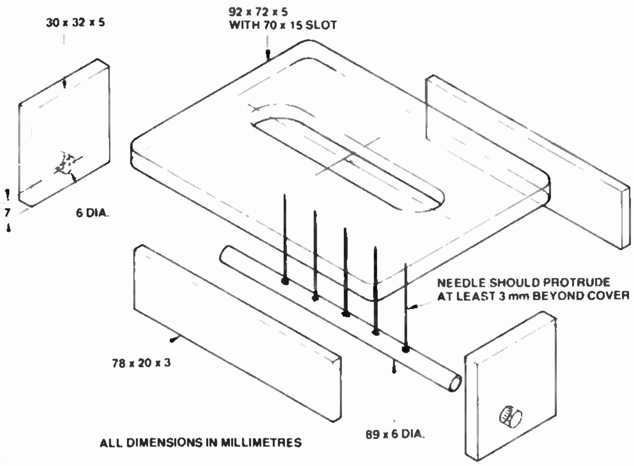


Figure 1. **Exploded view of our emitter head assembly. We used 5 mm and 3 mm thick perspex, but it could all be made from 5 mm perspex. The two pictures below show the completed head. Brass tubing supports the needles, which are soldered to it.**

partially recessed. This unit derives the HT directly from the mains.

Perspex for the emitter head may be obtained from plastics suppliers, such as Cadillac Plastics (where we bought our piece) and you'll find them listed in the Yellow Pages of the telephone directory. We used a piece with a thickness of 5 mm.

ETI-1501 NEGATIVE ION GENERATOR

Resistors .... all ½W, 5%
- R1 .... 100k
- R2 .... 220R
- R3, R5 .... 1k
- R4 .... 10k
- R6, R7 .... 4M7
- RV1 .... 50k

Capacitors
- C1 .... 10u/16 V tantalum
- C2 .... 220p ceramic
- C3 .... 10n greencap
- C4 to C9 .... 10n/1kV ceramic
- C10 .... 3n3 or 4n7 greencap

Semiconductors
- D1, D8 .... EM401 or similar
- D2 to D7 .... A14P, EM410, BYX80 or sim. 1 kV PIV diodes.
- IC1 .... NE555
- Q1, Q2............ TIP31C
- Q3 .... BC547, BC107 etc

Miscellaneous

Three pc boards — ETI-1501a, b and c; T1 — FX2242 potcore and former; coaxial dc jack socket; 9 V 200 mA or 300 mA plug pack (if required); V1 — NE2 70 V neon; piece of perspex about 100 x 100 mm, 5 mm thick; five needles; about 80 - 100 mm of 6 mm diameter thin-walled brass tubing; Horwood case type 34/7/DS; nuts, bolts etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$35 - $42

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.

Suitable steel needles can be obtained from your family sewing drawer! Failing that, any sewing accessories supplier can help you.

The brass tubing you'll find in hobby and toy stores. The thin-walled variety is best, as it is easy to solder to and easy to cut. We used a piece measuring 6 mm outside diameter.

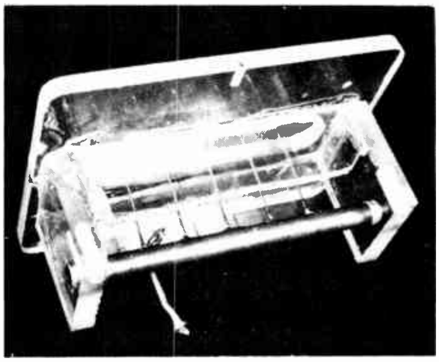
Construction

The ioniser electronics are contained on two circuit boards — designated ETI-1501a and ETI-1501b respectively. The first contains oscillator, driver and transformer, while the second contains the high voltage rectifier. We housed both of these in a small Horwood extruded box, type 34/7/DS, the emitter head being designed to fit in one end.

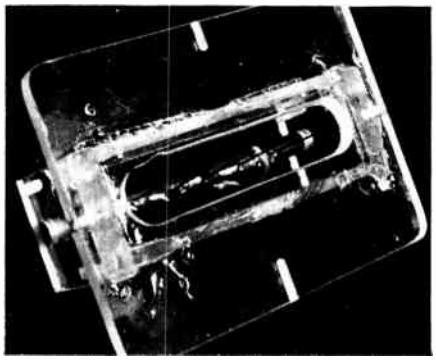
First stage of construction is to assemble the components on the pc boards. Commence with the 'a' (inverter) board. Insert the resistors, capacitors, IC and transistors before assembling the transformer to it. As usual, take care with the orientation of the diode, IC1 and the transistors. Next, wind the transformer — details are given in the box on page 50. The transformer employs a potcore and this can be held on to the pc board with a nylon bolt — do not use a metal bolt. Cut the transformer coil wires to length, scrape off the insulation and solder them in place. The TIP31C transistors, Q1 and Q2, do not actually require any heatsink, though they do get warm in operation.

The high voltage board ('b') may be assembled next. Take care with the orientation of the diodes. Stand the capacitors erect on the board so that they do not touch each other or you may have arc-over problems between these components.

Mount the appropriate components on the 'blinker' board ('c') next, as you'll ▶



Rear view of our emitter head, showing general construction of the perspex 'chimney' and assembly supporting the needles.



Front view of our emitter head, showing the slot and positioning of the needles. Note that the needles protrude about 3 mm beyond the front face.

Figure 2. **Picture of a commercial air ioniser's emitter head, showing construction.**

need this for a testing aid. It is important to watch the diode polarity here. The cathode of the diode goes to the pad marked with the 'ground' symbol. Note that the components are mounted on the *copper* side.

The emitter head is constructed from clear perspex and its assembly is detailed in Figure 1. We mounted our high voltage board on the rear of the emitter, gluing it in place with a little epoxy cement. This allows a short lead between the rectifier output and the brass tube supporting the needle points of the emitter.

A short length of figure-eight mains flex or a twisted pair of well-insulated hookup cable links the rectifier input (A and B) to the inverter board. This board we mounted on the end plate of the Horwood box using four nuts and bolts and short spacers.

The dc input socket we mounted on one side of the box, as can be seen from the photographs. Exactly how the dc coaxial jack socket is wired will depend on how your plug pack output plug is wired. Some have the outer connector connected to positive, while others have it connected to the negative. Watch the wiring of this socket if you plan to operate your unit in a vehicle. The outer connector is electrically connected to the socket's mounting and this automatically connects the case to that side of the supply. If your plug pack has the outer of its dc connector connected to positive then you will not be able to operate your ioniser project in a vehicle that has the battery negative connected to the vehicle chassis, without running the risk of shorting the supply if the ioniser's case comes in contact with vehicle ground.

With everything assembled, you can proceed to test it.

Getting it going

You will need a multimeter and a supply of between 9 Vdc and 14 Vdc. It would be handy, but not essential, to have a high voltage probe for your multimeter, having an impedance of 10M or more.

If you do not have a high voltage range on your multimeter to enable you to measure voltages greater than 3 kV, switch it to the current range to read 300 mA full scale or more, and connect it in series with the dc supply input.

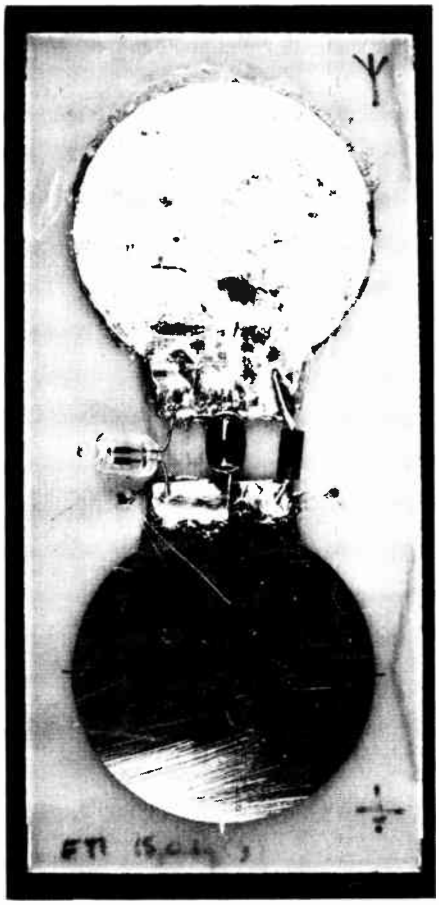
Switch the supply on and, assuming all is well, adjust RV1 on the inverter board for *minimum* current. This could be between about 220-280 mA.

Alternatively, measure the rectifier output (at the anode of D7) and adjust RV1 for *maximum* output. With a supply rail of 10 V, you should get around 3 kV; at 14 V, a little over 4 kV.

Run the unit for a few minutes, then switch off, discharge the rectifier capacitors and feel Q1 and Q2. One should not be markedly hotter than the other, otherwise you have adjusted RV1 incorrectly or you have a fault — most likely a transistor inserted incorrectly or a dry joint between the output of IC1 (pin 3) and the bases of Q1, Q2 or Q3.

Having confirmed everything works as it should, and having adjusted RV1, assemble it all into the case and you can check its operation with the blinker.

Turn the ioniser on and grasp the blinker so that your thumb is in good contact with the pad marked by the 'ground' symbol. Hold the blinker such that the 'antenna' pad is about 10 mm in front of the emitter. You should be able to count around one blink per second if all is well and this is a good 'bench mark' for successful operation when you experiment with different head designs and geometries.



Our 'blinker'. Components are positioned as per the circuit diagram on page 43. Cathode of D8 is at the bottom.

Notes

This project shows but one way to construct a negative ion generator and the electronics can readily serve as the basis for experimenting with different designs. Higher voltages are unnecessary — and are not usual in commercial designs — and can lead to problems with ozone generation, breakdown, etc. A connection is available on the high voltage board for supplying an 'accelerator' on an emitter head. It should be connected via a 4M7, ½W resistor. The accelerator voltage could be tapped off lower down the rectifier chain if desired — we suggest at the junction of C6 and C8.

The high voltage board may be mounted separate to the emitter head and four bolt-hole positions are provided on the board.

The exact value of capacitors C4 to C9 on the high voltage board is not important and may be any value between about 1n and 22n or so, but should not be lower than 1n. The voltage rating of these capacitors should not be less than 1000 volts.

The dc supply should not be greater than 15 volts, otherwise insulation breakdown within the transformer may be experienced. Likewise, more turns should not be wound on the secondary of T1 or you may experience insulation breakdown. ●

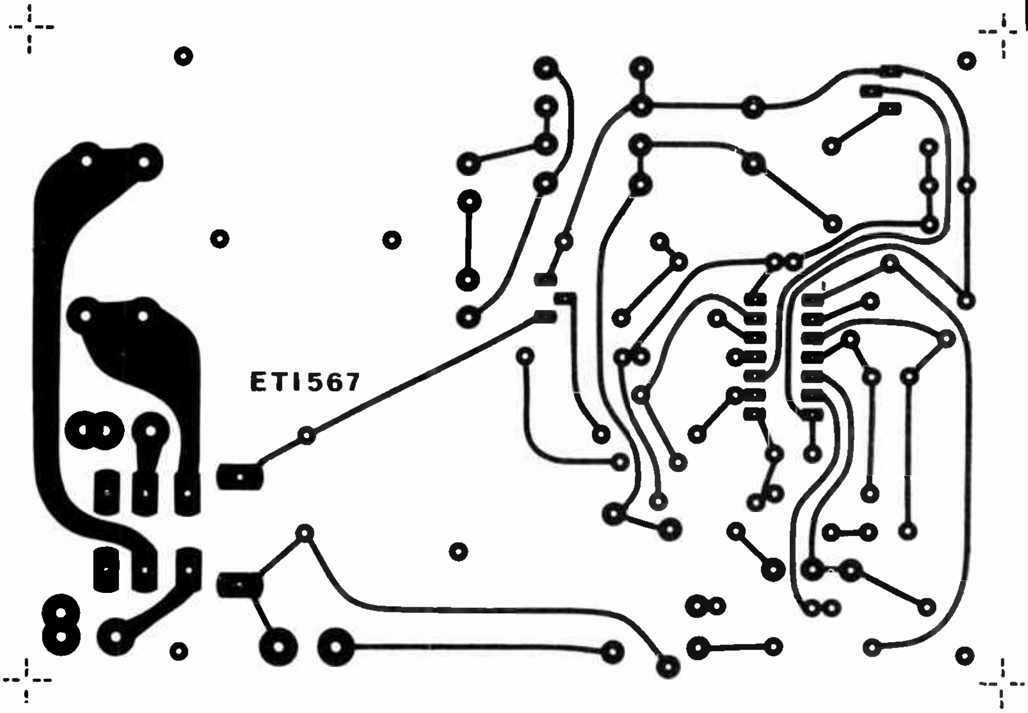
ETI-1501 WINDING DETAILS FOR TRANSFORMER T1

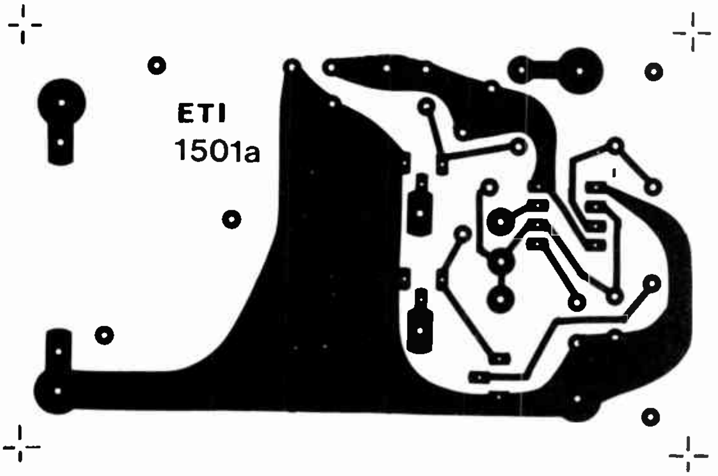
Potcore: FX2242
Secondary: 125 turns of 0.2 mm dia. enamelled copper wire.
Primary: 10 turns, centre-tapped, of 1.0 mm dia. enamelled copper wire.

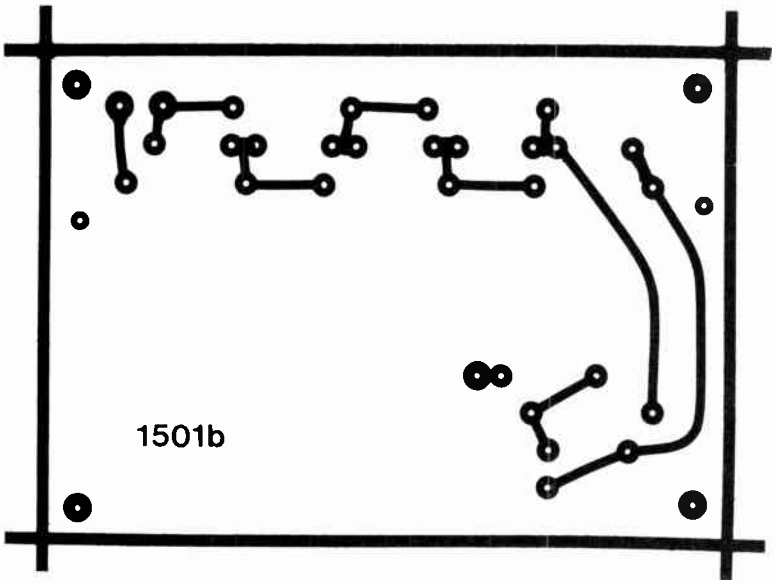
The secondary is wound on the potcore bobbin first. Wind it in five or six neat layers. Slip thin plastic spaghetti over the start and finish leads so that the spaghetti is held well inside the bobbin. As you finish winding each layer, insulate it with 1 mm mylar sticky tape (if you can obtain it) or electrical insulation tape (a bit heavy, but it will do the job). Wind the next layer on the insulation of the previous layer, etc, until you finish the winding. Wind several layers of insulation over the completed secondary. Leave the start and finish wires protruding from different sides of the bobbin so that they exit via different slots of the assembled potcore.

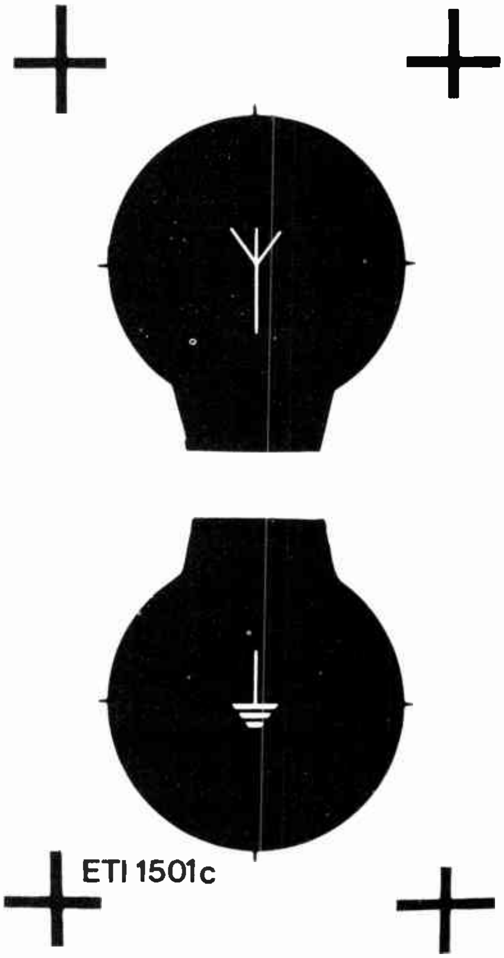
Wind the primary over the secondary; it can be wound bifilar (two wires together, five turns, connect finish of one to start of other to provide centre tap) or in one winding — but don't forget the centre tap. Wind the primary so that its wires exit the potcore opposite the secondary wires.

In operation, if you have breakdown problems (arcing sounds inside the potcore) it means you have not wound or insulated your secondary carefully enough and you'll have to rewind the transformer.


ETI567


ETI
1501a


1501b


ETI 1501c

A portable electronic core-balance relay

Design: **Jonathan Scott** Development: **Graeme Teesdale**

Mains-operated equipment that goes faulty is potentially lethal. Electro-mechanical 'core-balance relays' which sense earth-fault currents and trip a circuit breaker have been available for house-mains installation for some years. Portable core-balance relay units have obvious advantages. Protect yourself — and your equipment — with this simple, inexpensive project.

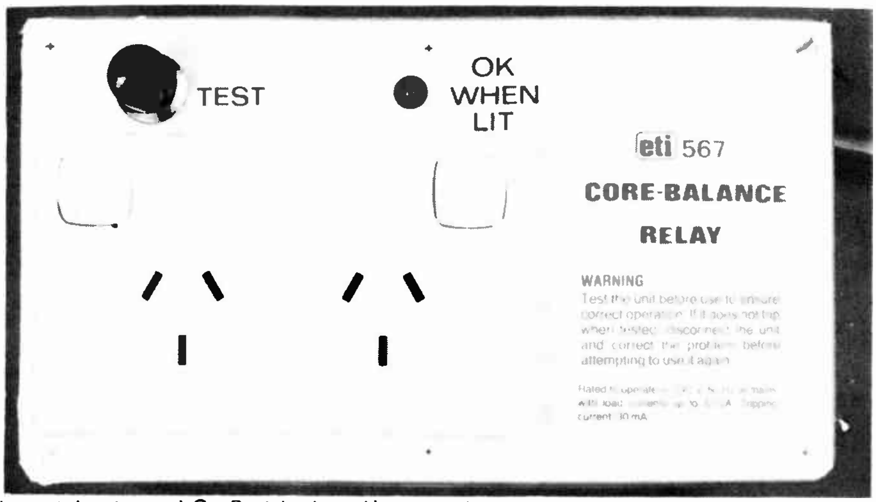
A FAULT in mains-operated equipment can place any external metal parts at mains potential — if you then happen to complete a path between the equipment and earth, you'll get a nasty surprise at the least or become another victim in the electrocution statistics. In some circumstances a fault may create a leakage path that permits a current to flow through flammable material — with obviously dangerous consequences. A suitable protection device that can sense such fault conditions can prevent possible disaster.

Also, when servicing mains-operated equipment — particularly such things as light sequencers, dimmers, etc — it is often necessary to work around lethal mains voltages. A device that trips a circuit breaker or relay should you accidentally touch live mains wiring is clearly good for your health!

Every hobbyist or serviceman should have such a device.

When a fault current finds a path to earth in mains-operated equipment the currents flowing in the active and neutral lines are found to be different. This fact can be put to use to sense 'earth faults', as they are called, and trip an isolating relay or circuit breaker. Such a sensing device is referred to as a 'current operated' or 'core-balance' earth-leakage device.

We have designed a portable electronic core-balance relay that can be set to sense earth-leakage currents as low as a milliamp or so, or a maximum of about 25 mA. It is designed to operate on 240 V, 50 Hz ac mains and with rated load currents up to 5 A or 10 A, depending on the relay used. Once tripped, the unit can only be reset by turning off the mains and removing the faulty load.



The completed project. Our Scotchcal panel is essential — see page 128 for suppliers.

Australian Standard

The Australian Standard relating to core-balance relays is AS3190-1980, titled "Approval and Test Specification for Current-Operated (Core-Balance) Earth-Leakage Devices". It is published by the Standards Association of Australia, Standards House, 80 Arthur St, North Sydney NSW.

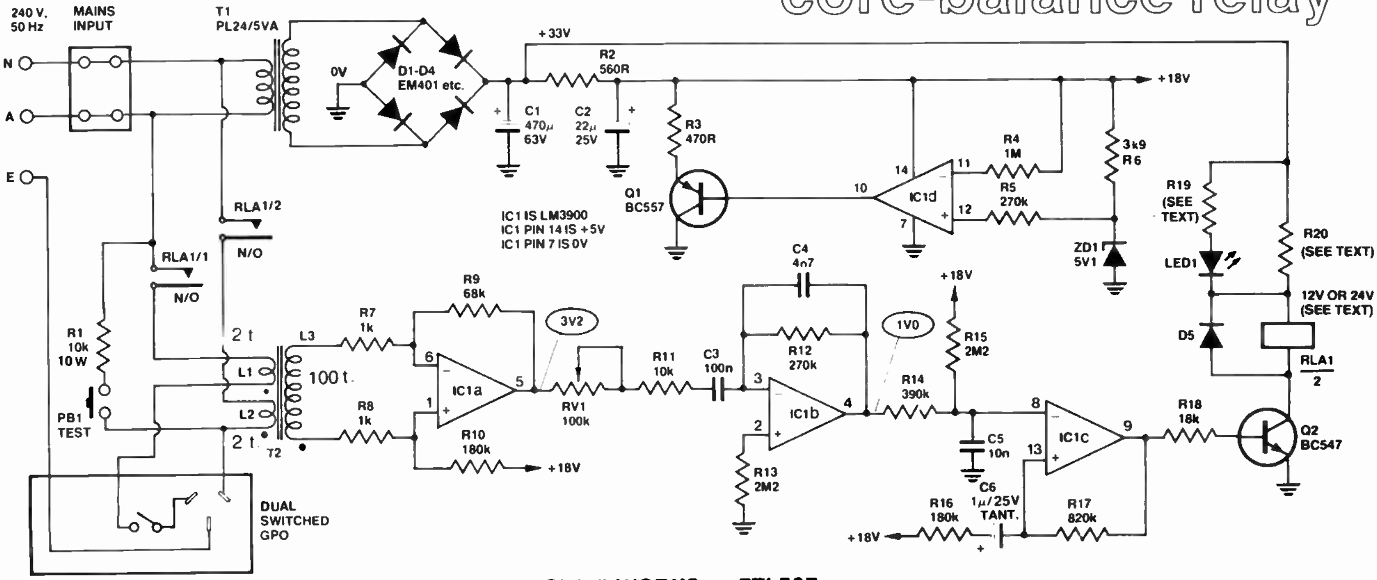
The Standard requires the unit's ratings to be marked on the front panel along with a warning notice. These have been included on our front panel artwork. In addition, the Standard requires any portable device to be double insulated (as per AS C100) between the external surface of the enclosing case and any wiring and component which does not form part of the protected circuit, and the enclosing case to be double insulated from any earth conductor incorporated in the device. Therefore we chose to construct our unit in a plastic case, using nylon bolts to secure the internal components. The Standard also requires that the flexible cord should be of a type not inferior to a heavy duty sheathed type (see AS3191), correctly wired (as per AS C100) and have a free length of not less than 1.8 metres.

So far as we are aware, our prototype conforms to the construction requirements of AS 3190-1980.

Construction

It would be best to commence construction by marking out and drilling the plastic case. We used a BIM Box, No. 2006-16-ABS, measuring 190 mm long by 111 mm wide by 60 mm high. These are imported and distributed by Crusader Electronics of Sydney. We bought ours at Radio Despatch Service. However, several similar all-plastic 'jiffy'-style boxes are available and you should have little difficulty getting one to suit.

The mains input cable should be secured with a clamp grommet, the leads



HOW IT WORKS — ETI 567

The circuit can be divided into three parts: the unbalance current sensor (T2), the trip circuit, and the power supply. We'll examine each in turn.

TRANSFORMER T2

This senses the unbalance current that occurs with an earth-leakage fault between the active line and earth. The two primary windings, L1 and L2, are bifilar wound (parallel wires, wound in the same direction). Primary L1 is connected in the active line, between the mains input and the output to the load. Primary L2 is connected in series with the neutral line, between the mains input and the output to the load. The two primaries are connected such that the load current through L1 flows in the opposite direction to the load current through L2. Thus the currents are in phase opposition, and if no earth fault is present, will be equal and there will be no output from the secondary of T2 (L3). The spots adjacent to the end of each winding on the circuit diagram indicate the phasing of each winding, showing that L1 and L2 are oppositely phased.

If an earth fault occurs, more current will flow in the active line than the neutral line. Thus, the currents through L1 and L2 will be different, or unbalanced, and an output will appear from the secondary. This output serves as an input for the trip circuitry.

THE TRIP CIRCUIT

We shall have to describe the operation of this circuit 'back to front' in order to make its operation clear. The trip circuit involves three op-amps from IC1 — IC1a, b and c — plus Q2, RLA1 and associated components. IC1 is a quad op-amp, type LM3900.

When power is first applied, capacitors C5 and C6 will first appear as a low impedance (virtually a short circuit) as they are not charged. Thus, C5 will hold the inverting input of IC1c (pin 8) at 0 V and C6 allows a current to flow into the non-inverting input (pin 13) via R16. These two initial conditions will cause the output of IC1c (pin 9) to rise rapidly towards the positive supply rail. Positive feedback via R17 ensures that this op-amp will latch in that condition. When pin 9 of IC1c goes high, base current will flow in Q2 via R18, and Q2 will turn on. When Q2 turns on, collector current will be supplied via the relay and LED indicator circuits, the relay will operate and the LED will light.

When the relay operates (on switch-on) the two relay contacts, RLA1/1 and RLA1/2, close and apply power to the output socket.

A short period after switch-on, C6 will be charged and dc feedback via R17 will hold the output (pin 9) of IC1c high.

When an earth fault occurs, an output voltage will appear across the secondary (L3) of T2. This will be amplified by op-amp IC1a, the output of which (pin 5) drives the input of an active filter involving IC1b, via RV1, R11 and C3. RV1 acts as a sensitivity control, as it is in series with the input of IC1b, the gain of which (at 50 Hz) is determined by the ratio of R12 to RV1+R11.

Op-amp IC1b is arranged as a simple active low-pass filter, having a cutoff of around 130 Hz. This gets rid of high frequency noise spikes passed on from the mains via T2. Any noise transmitted down the mains will not be in phase on the active and neutral lines.

The first positive-going pulse, resulting from the mains earth fault, appearing at the output of IC1b (pin 4) will be applied to the inverting input of IC1c via R14. Now, IC1c will be latched with its output high. When the 'fault' signal appears the output of IC1c will be driven low, removing base current from Q2, which will turn off, causing the relay to drop out and the LED to extinguish. When the relay drops out, its contacts remove power from the output socket.

IC1c will latch into the 'output low' condition as dc feedback via R17 will hold the non-inverting input low.

The CR network R14-C5 helps prevent noise on the mains causing false triggering and only delays the operation of the trip circuit less than 10 milliseconds. The trip circuit will operate no more than about half a cycle after the fault signal occurs, at maximum, and the relay takes about 15 ms to open. Thus, maximum delay is about 35 ms, well under the 50 ms required in AS3190-1980.

POWER SUPPLY

Power supply for the electronics is derived via a small pc-mount transformer, T1. This is a 240 V to 24 V type, rated at 5VA or 7VA. A bridge rectifier is employed, using diodes D1 to D4, feeding a capacitor-input filter consisting of C1, R2 and C2. The nominal output voltage across C1 is about 33 volts. This is used to supply the relay driver (Q2), relay and LED indicator circuits.

A simple shunt regulator is used to derive an 18 volt supply for the trip circuit. IC1d forms a voltage-controlled current source, its output driving the shunt regulator transistor Q1. The emitter-collector current of Q1 flows from the positive supply rail to the 0 V rail via R3. The shunting current via Q1 produces a voltage across C2 of 18 volts, the shunting current being determined by the 5V1 zener diode at the input of IC1d. If the rectifier output voltage attempts to rise, the shunting current via Q1 will rise and the voltage drop across R2 will increase. The opposite occurs if the rectifier output decreases.

This type of supply was chosen for its good noise pulse rejection characteristics.

TEST CIRCUIT

A 10k, 10W resistor is connected via a momentary-action pushbutton from the neutral line of the output socket to the relay (input) side of the active line. When the pushbutton is operated, a current of about 24-25 mA will flow in L2, but not in L1. This simulates a fault condition and the electronics will trip the relay, removing power from the output. IC1c will latch in the 'output low' condition and the unit can only be reset by removing the mains input for a short period.

---

being terminated to a six-way plastic terminal strip. We used a Scotchcal front panel (plastic variety, *not* the aluminium type). These should be available from a number of suppliers; see Shoparound in this issue. After drilling the case front panel, the Scotchcal panel should be attached, taking care to smooth out any air bubbles, before mounting the power output socket, pushbutton and LED indicator.

The blank pc board can be used as a template to mark the positions of the mounting holes for drilling in the bottom of the case. Watch the orientation of the board.

The mains cable may be attached and terminated to the terminal strip, and the wires between the terminal strip and output socket may also be installed ▶

at this stage. Note that the 10k, 5W resistor is mounted off the six-way terminal strip, and this can be installed at this time too.

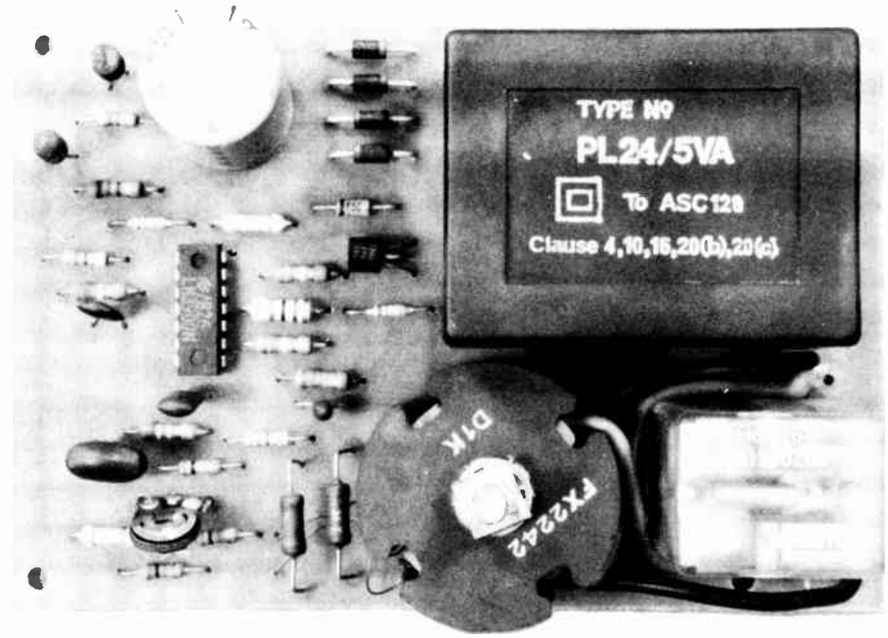
The printed circuit board should be drilled next, if you haven't got one that's pre-drilled. Locate the positions of the mounting holes for the potcore and the power transformer first.

The potcore requires just a single hole, around 4.5 - 5 mm diameter. The power transformer requires three holes. There are two locating pegs that protrude beneath the transformer and holes for these should be drilled about 3.5 - 4 mm diameter. A hole for a securing screw is located between the ac input terminals. This should be drilled about 3 mm diameter.

The relay is soldered direct to the pc board and holes for the pins will have to be drilled, their size depending on the particular relay you're using. We have made the pc board pads large enough to accommodate a variety of relays available. Some, such as the Fujitsu type FRL264, can be obtained with pc mount pins and only a 1.5 mm hole is required for each pin. Others, such as the DEC type MC2U, have flat pins requiring a row of small holes to be drilled in each pad and a slot cut.

The pc board may be assembled next. Mount all the minor components first, taking care with the orientation of the LM3900, the diodes, the two transistors, the electrolytic and two tantalum capacitors. You can leave R7 and R8, which mount adjacent to the potcore, until the potcore is mounted and wired in, as we have done, or pass the secondary leads from the potcore over R7 and R8. Don't forget D5, which mounts between the potcore and the relay — it's difficult to see in the photograph of the pc board, but the overlay should make its location clear.

The potcore should be wound next — see the accompanying box for the winding details. Once you've wound the bobbin, assemble the two potcore halves over the bobbin as indicated in the drawing accompanying the winding details and set the assembly aside for a few moments. You will need a suitable bolt to secure the potcore to the pc board; we used a 4 mm by 35 mm pan head with nut, plus a flat washer and a star washer. Pass the bolt through the appropriate hole in the pc board, from the copper side. Place the potcore assembly over the bolt and secure it with the nut. Use the flat washer against the potcore and the star washer between it and the nut. Terminate the primary and secondary windings to the pc board as indicated on the overlay.



The completed pc board. Assembly is fairly straightforward (pcb pattern is on page 51).

The relay and power transformer may be mounted next. The transformer is secured with a screw which goes between the ac input terminals, as mentioned previously.

Once you have the pc board assembled, check everything carefully — in fact, *double* check. Once you're satisfied all is well, it can be mounted in the box and wired in place. Before mounting the board in the box, attach leads about 150 mm long for the indicator LED (colour code them so you know which is the anode and which is the cathode). Also attach leads for the mains input and output wiring. Use colour-coded 32 x 0.2 mm 240 Vac rated plastic insulated wire for this — red for active, black for neutral. These leads will need to be about 100-120 mm long.

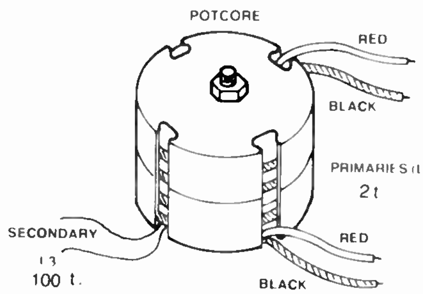
Mount the board in the bottom of the box using nylon nuts and bolts. Raise the board about 5-6 mm off the bottom of the box using fibre spacers.

Wire the ac input and output leads to the six-way terminal block according to the wiring diagram. Once this is done check all your wiring thoroughly, and you're ready for testing.

Test and setup

First thing to do is a series of safety checks before the unit is plugged into the mains. For this you will need a multimeter and a neon test screwdriver. Also, if you can possibly obtain it (beg, borrow or steal ... er, scrounge), a "megger" insulation tester with a rated output of 500 V.

With your ohmmeter on the highest resistance range, measure between the earth and active and neutral pins in turn on the mains input plug. It should read open circuit. Then do the same on the rear of the output socket.

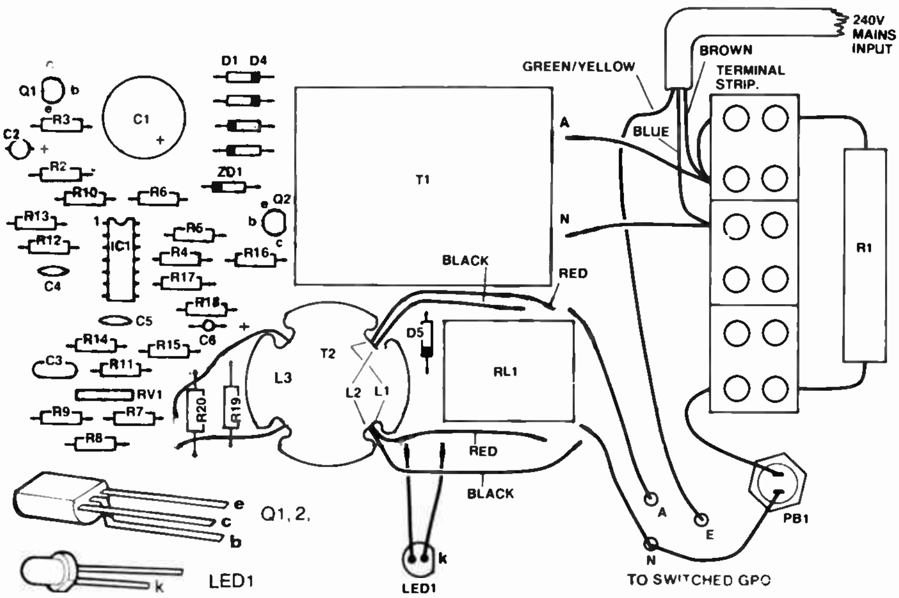


TRANSFORMER T1, WINDING DETAILS

Core: FX2242 36 mm dia. potcore; two halves with bobbin.

Wire: 0.2 mm dia., enamelled copper wire — eight or nine metres will be required; two 300 mm lengths of 32 x 0.2 mm plastic-coated (240 Vac insulation) hookup wire — one red, one black.

Wind the secondary, L3, first, using the 0.2 mm enamelled wire. This may be jumble wound on the bobbin. Put two layers of electrical insulation tape over the finished winding. To wind the two primaries, L1 and L2, lay the red and black insulated wires side by side, place them on the bobbin and wind one turn, followed by almost another turn — such that the start and finish ends come out of adjacent potcore slots. The photograph of the pc board makes this clear, as should the accompanying drawing. Leave about 50-60 mm of lead on each winding for terminating to the pc board.



Component overlay and wiring diagram. Use a clamp grommet for the mains cable. The earth lead input must be the longest of the input leads. Take care with the mains wiring.

Now switch your ohmmeter to a low resistance range (to measure less than 1000 ohms on the scale). Measure between the active and neutral pins on the mains input plug. Your meter should read somewhere between 750 and 800 ohms. This is the resistance of the primary of T1. Do the same on the rear of the output socket. It should read open circuit. Then, manually operate the relay (or connect an external battery or power supply across the relay's coil) and measure across the active and neutral connections on the rear of the output socket. You should measure the resistance of T1's primary again (750-800 ohms).

With the relay operated, check for continuity between the active pin on the mains input plug and the active connection on the output socket. Do the same for neutral line. While you have the relay operated, switch your ohmmeter to the highest range and check for open circuit between the neutral line and earth and the active line and earth.

If you have a megger, you can repeat all the active and neutral to earth checks. Resistance indicated should not be less than 1M. If you then bond all three pins of the input plug together and connect to one terminal of the megger and apply the other terminal of the megger via a flying lead to some part of the case, you should obtain a reading no lower than 10M.

If there are any problems during these tests, sort them out before continuing. If all is well following these tests, you can proceed to test the unit with mains input and set up the trip current.

Set the wiper of the trimpot RV1 to maximum resistance. For the setup test, nothing should be plugged into the output sockets. Plug the unit in and turn it on. The relay should operate immediately and the LED should light. If this does not happen, switch off straightaway, unplug the mains cord and check for wiring or assembly errors. If the LED doesn't light but the relay operates, you've either got the LED connected the wrong way round or R19 is incorrect.

If all is well at this stage, depress the TEST button (the relay should not drop out) and adjust RV1 until the relay just drops out. The LED should go out. Use an insulated handle screwdriver to do this, for safety's sake. Release the TEST button when the relay drops out and turn off the mains input. Wait a few seconds and turn the mains input on again. The relay should operate and the LED should light again. Press the test button again and the relay should drop out, the LED going out also.

Next, reset the unit, plug it in and switch on. Using your neon test screwdriver, check that the active pins on the output sockets are correct. With the earth pin facing you, the active pin should be the upper left hand one. If you find it to be different, switch off and unplug the unit, then test your wall socket to see if it's correct. It is important that the core-balance relay is correctly wired, so that the unit will preserve the active/neutral orientation of the power point with which it is used.

That's it, unless you want to test the unit at ±10% of mains input voltage, etc — the ETI-146 Mainsmaster (Nov. 1979) would come in handy here.

Trip current variation

If you would prefer the trip current to be lower, change the value of R1 and set up the unit as previously explained. For a 10 mA maximum trip current, a 27k, 3W or 5W resistor should be used for R1.

The maximum trip current, according to AS3190-1980, is 30 mA, so it would be wise to keep it below that value by at least 10%, and that's what we have done with the design presented here. ●

(see note, page 56).

ETI-567 CORE BALANCE RELAY PROTECTOR

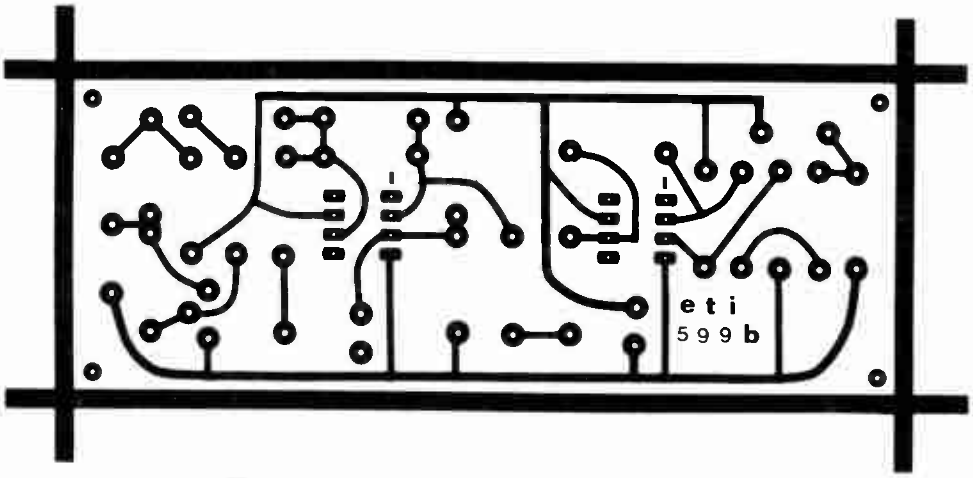
Resistors	all ½W, 5% unless noted
R1	10k, 10 W
R2	560R
R3	470R
R4	1M
R5, R12	270k
R6	3k9
R7, R8	1k
R9	68k
R10, R16	180k
R11	10k
R13	2M2
R14	390k
R15	2M2
R17	820k
R18	18k
R19	1k (12 V relay) or 330R/1 W (24 V relay)
R20	330R/1 W (12 V relay) or 150R/1 W (24 V relay)
RV1	100k
Capacitors	
C1	470u/63 V electro.
C2	22u/25 V tantalum
C3	100n greencap
C4	4n7 greencap
C5	10n greencap
C6	1u/25 V tantalum

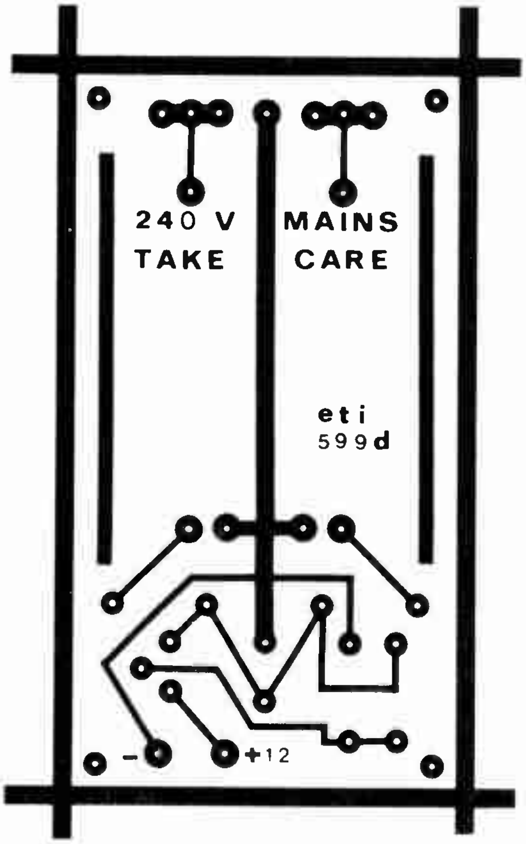
Semiconductors	
D1 to D5	1N4004, EM401 etc.
ZD1	5V1, 400 mW zener
IC1	LM3900
Q1	BC557, BC177
Q2	BC547, BC107
LED1	TIL220R or similar
Transformers	
T1	PL24/5VA Ferguson transformer or sim.
T2	FX2242 pot core

Miscellaneous
ETI-567 pc board; PB1 — 230 Vac rated momentary push button (push-on); plastic case to suit; relay (RL1) Fujitsu D024/02CK (24 V) or D012/02CK (12 V); wire, nuts, bolts etc; terminal block; 2m of 10 A rated mains lead.

Price estimate $42 - $48

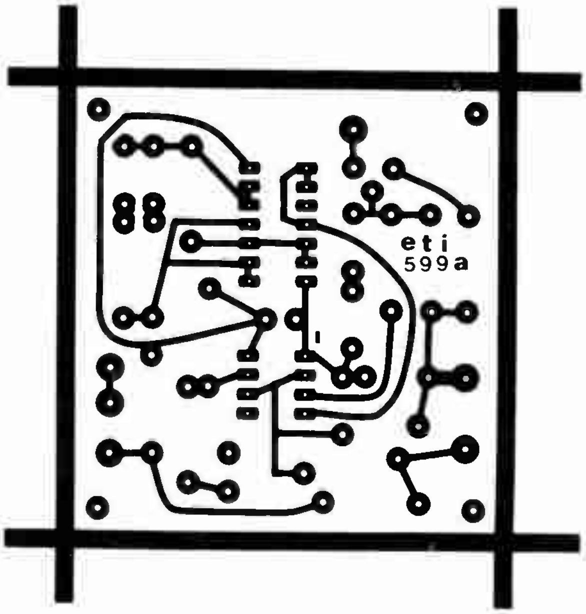
Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.

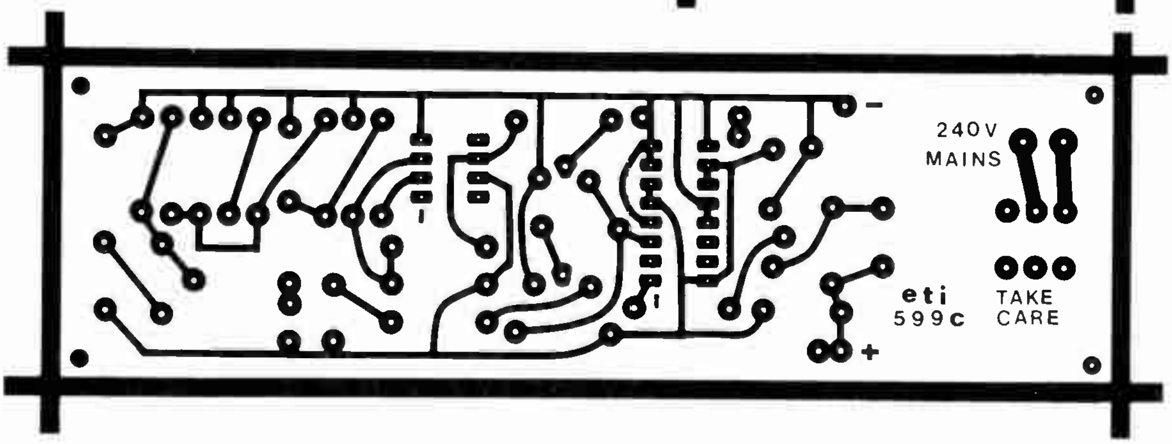




NOTE ON THE CORE-BALANCE RELAY ETI-567

A reader has drawn to our attention a problem he experienced when using the core-balance relay with a long lead plugged into its output where a number of fluorescent lights were operating nearby. The core-balance relay would not trip on test with loads over about 25 watts. On investigation, he found severe RF noise, generated by the fluorescent lights, was preventing the unit's trip circuit from functioning. Looking at each end of L3 (secondary of T2, the sense transformer) using an oscilloscope, he found high amplitude noise on each, but of markedly differing amplitudes. The cure is simple — a 4n7 capacitor connected directly across L3. The unit still functions as designed, even with highly inductive loads plugged into the output. Our thanks to Bill Waters for passing that on.





Infra-red remote control unit

This project can be used to operate mains-run equipment remotely at distances up to 10 metres, and it resists being 'fooled' by spurious infrared sources. The portable transmitter can be carried in your pocket and the controller can operate equipment drawing as much as 5 A from the 240 Vac mains.

Phil Wait
Simon Campbell

THIS PROJECT can be used to turn any mains-powered device, such as a radio, TV, heater, etc, on and off from ranges up to 10 metres, provided that the remote device is in the line-of-sight of the operator. The project uses an infrared remote control 'link' and does not need an operating licence, has no trailing wires to trip the unwary, is not susceptible to acoustic interference and does not generate radio or TV interference.

The control system consists of two separate units, a hand-held infrared transmitter and a remotely-located mains-powered infrared receiver unit with a bistable relay output. The relay output terminals are used as a 'switch' that makes or breaks the power feed to the device (radio, TV, etc) that is being controlled. The transmitter unit contains only one control, a press-button switch, which connects battery power to the circuit and causes a coded infrared beam to be generated. This invisible beam is aimed at the receiver and causes its output relay to change state, thereby giving an alternate ON-OFF-ON relay switching action via the transmitter.

We've taken a lot of trouble with this project to ensure that the system has both good range and high reliability, i.e: high sensitivity but excellent rejection of spurious and unwanted electrical and optical signals. This has resulted in seemingly complex circuitry in both the transmitter and the receiver. The project is therefore not suitable for the absolute beginner, but can be tackled with reasonable confidence by the novice with a moderate amount of constructional experience. The complete system uses only two preset controls, and can be set up without the use of test gear.

Design niceties

The project is built around the CQY89A infrared emitting LED and the BPW50 infrared sensitive opto-diode, both made by Philips. These operate at 930μ. The transmitter is pulse-coded and the receiver has a filter to ensure that spurious infrared emissions do not inadvertently operate the receiver.

The transmitter design takes advantage of the high peak current capability of LEDs to give a useful range of about 10 metres (which is what we obtained on our prototype) indoors, with a combination of daylight and artificial (fluorescent) lighting in the room. Quite positive operation at this distance is obtainable, although your aim has to be reasonably good.

The strength of the infrared beam produced using these LEDs is proportional to the number of LEDs used and the current passed through them. We have used two CQY89A LEDs and the transmitter circuit passes a *peak pulse current* through them of about 700 mA. By rapidly pulsing the LEDs on and off at a rate of about 25 kHz over a period of 300 microseconds, once every 10 milliseconds, the total on-time for a LED is only 150 microseconds in every 10 milliseconds. The *average* current through the LEDs is only 8 mA and well within their specifications.

Secondly, this technique enables the infrared beam to be pulse-coded so that the receiver can be arranged to distinguish between the beam and unwanted infrared emissions such as the sun, cigarette lighters, etc, in normal operation. The receiver sensitivity can also be greatly enhanced.

The receiver is provided with a high gain preamp following the infrared detector diode (BPW50), tuned to 25 kHz, having an adjustable bandwidth which effectively sets the sensitivity. This drives a subsequent ▶

The completed remote control unit. Scotchcal front panel suppliers are listed on page 128.

amplifier and detector, which provides an output to a bistable switch circuit that operates a relay. Thus, keying the transmitter on momentarily will operate the relay in the receiver, which will latch on. Keying the transmitter momentarily again will de-energise the relay, which will latch off. Thus, a simple PRESS-ON, PRESS-OFF operation is obtained.

With the receiver at maximum sensitivity, the unit can be triggered by a cigarette lighter held closer than 100 mm from the detector diode.

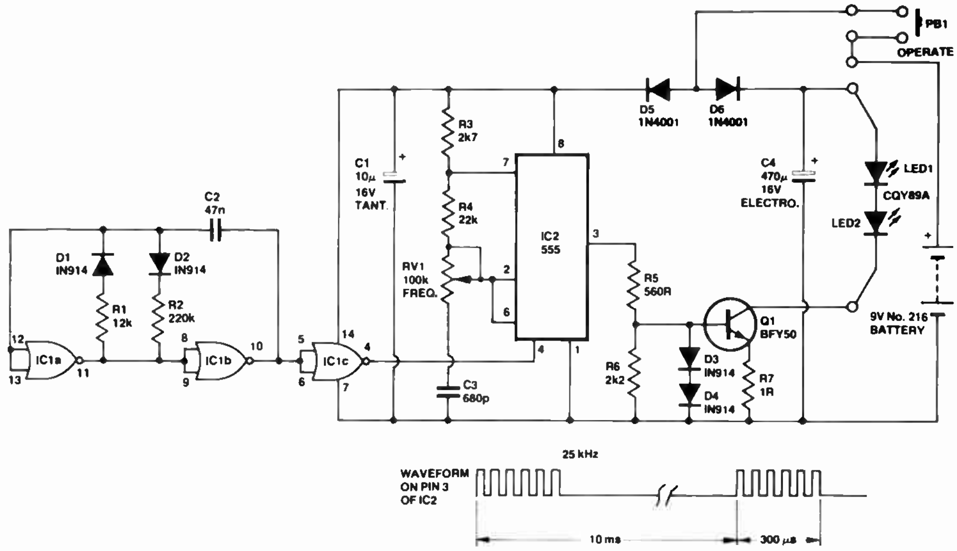
Although there is a multiplicity of pc boards, construction is relatively simple and if you've had a modicum of experience, you should have little difficulty getting this project going.

With the exception of the infrared LEDs and the opto-diode, all parts are readily obtainable. We have given kit and component suppliers plenty of warning regarding the CQY89A LEDs and BPW50 opto-diode, and these items should be widely stocked by the time this issue goes on sale. You can house your project in different cases from the ones we used in our prototype as actual housing is non-critical.

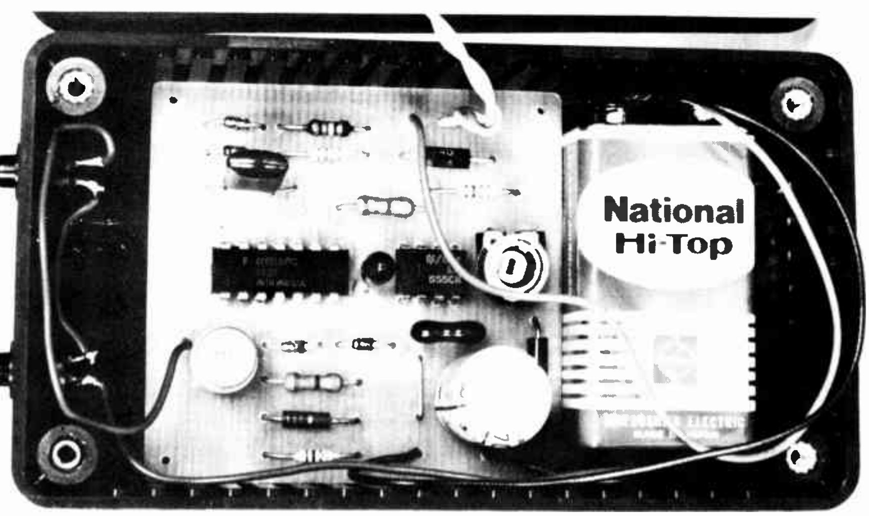
Construction — transmitter

The transmitter is housed in a small, all-plastic box (an English-made BIM box) measuring 110 x 60 x 30 mm. It can be easily held in the hand or slipped into a pocket. Anything similar will suffice, providing the components can be fitted inside it. We mounted the 'operate' pushbutton on the lid and the two infrared LEDs in one end so that they can be easily pointed at the receiver/controller unit when held in the hand while the pushbutton is pressed by the thumb. Mark out and drill the case first of all.

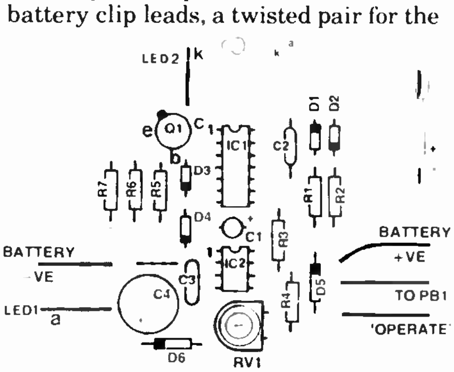
Assemble the pc board (ETI-599a) first, being careful with the orientation of the two ICs, the transistor and the electrolytic capacitors. Attach the battery clip leads, a twisted pair for the



Transmitter circuit.



Internal view of the transmitter



Component overlay for transmitter.

HOW IT WORKS — ETI 599 TRANSMITTER

The transmitter circuit consists of two distinct sections, IC1 and IC2 (the waveform generator section), and Q1 and associated components acting as a high current driver for the infrared LEDs.

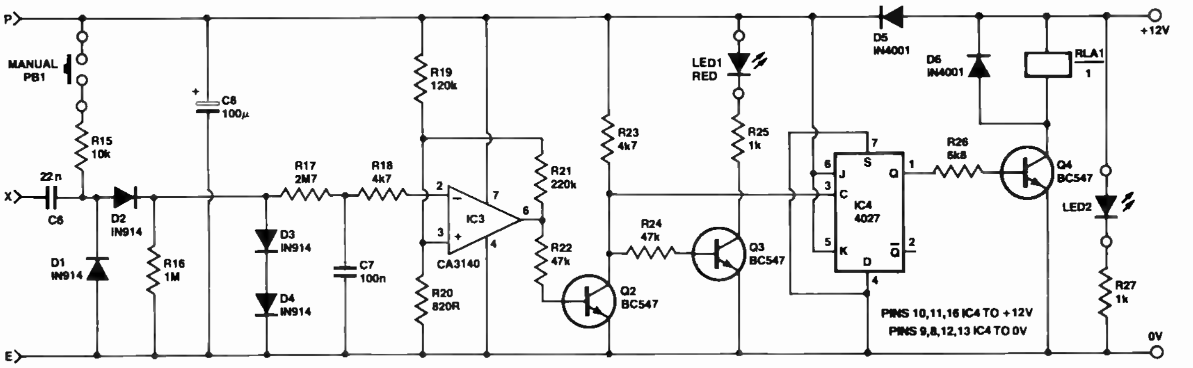
IC1 is a buffered, non-symmetrical square wave oscillator which generates a pulse of 300 µs wide every 10 ms. When power is first applied, C2 is discharged and the outputs of IC1a and IC1c are high. C2 charges from the high output of IC1a via R1 and D1. When C2 is sufficiently charged the output of IC1a goes low, IC1b goes high, and IC1c goes low. C2 starts to charge in the reverse direction, but this time through R2 and D2. The time constant of R1 and C2 determines the pulse width, while that of R2/C2 determines the period between pulses.

The output of IC1 gates a 555 astable oscillator, set to a frequency of about 25 kHz. The oscillation continues for 300 µs while the gating pulse is high and is repeated every 10 ms. The exact frequency of the 555 astable oscillator may be varied over a limited range by the trimpot RV1.

Transistor Q1 is a constant current generator with two infrared LEDs connected in series in its collector circuit. The base voltage of Q1 is clamped to 1.4 V by two silicon diodes in series, and as the base emitter drop in the transistor is about 0.7 V, the emitter voltage is clamped at 0.7 V. As the emitter resistor is one ohm, the maximum collector current before the transistor is cut off is thus 700 mA.

When the operate pushbutton is pressed, pulses from the output (pin 3) of the 555 turn on the constant current generator and cause 700 mA current pulses to flow through the two infrared LEDs. The capacitor C4 supplies the high current pulses to the LEDs as the small 9 V battery will not deliver current pulses of this magnitude. The capacitor is charged during the time between pulses and during the time between bursts. Supply isolation is provided by D5, C1 and D6, C4.

The light output from the LEDs occurs during the current pulses and appears as 25 kHz pulses for a 300 µs period, repeated every 10 ms as long as the operate pushbutton is pressed.



Receiver, detector and relay driver circuit.

HOW IT WORKS — ETI 599 RECEIVER

The receiver circuit can be divided into three distinct sections: a high gain frequency selective preamplifier (ETI-599b), a signal detector and bistable relay driver (ETI-599c), plus a power supply (ETI-599d).

The pulse-coded infrared beam is picked up by an infrared sensitive opto-diode, IRD1 (a BPW50) and appears as a pulsed voltage across R1. The detector diode has a frequency response which matches the transmitter LEDs for maximum sensitivity and rejection of unwanted emissions. The pulses are passed to the inverting input of IC1, a CA3140 op-amp, and amplified by a factor of 33 before being passed to IC2, another CA3140.

IC2 is an active Wien bridge bandpass filter tuned to approximately 25 kHz by C3/R8 and C4/R9. The transmitter frequency is adjusted to the centre frequency of this filter during the set-up procedure. The selectivity, or 'Q', of the filter is adjustable via RV1 and is set for the minimum possible bandwidth for reliable triggering to ensure maximum rejection of unwanted emissions incident on IRD1.

The output pulses from IC2 are further amplified by Q1 and passed to terminal X — the output of the preamplifier.

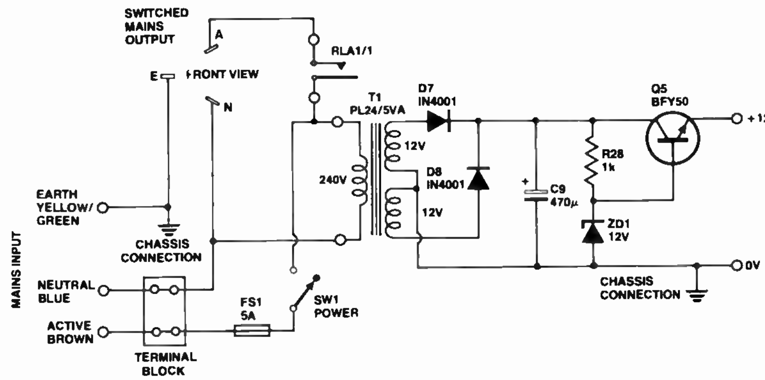
Capacitor C6 ac-couples the pulses into the detector circuit where they are rectified by D1 and D2. The detected pulses are peak limited by D3 and D4 to about 1.4 volts. The rectified pulses are integrated by R16 and C7 and appear as a rising dc level across C7 and the inverting input of IC3. When the transmitted signal ceases, capacitor C7 discharges through R16 and R15.

IC3 is a regenerative comparator whose output switches low when the voltage on the inverting input exceeds 100 mV or so. Because of the integrating action of R16 and C7, however, the input voltage is sufficient to switch the comparator only after the transmitted signal has been present for about 200 ms. This ensures the circuit does not respond to transients or spurious signals.

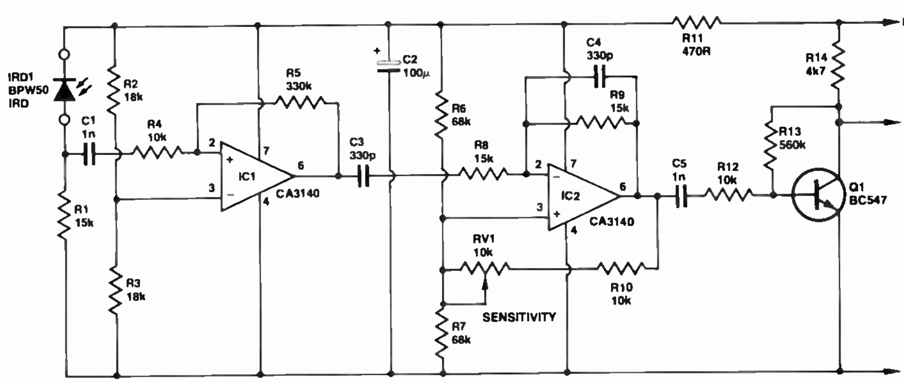
As the output of IC3 switches low, Q2 is turned off and the voltage on its collector goes high. Q3 is turned on and LED1 lights, giving a visual indication on the front panel of the receiver unit that a signal is being received.

When the collector of Q2 goes high, a clock pulse is fed into IC4, a bistable multivibrator, which changes state. The relay is switched, via Q4, from off to on or vice versa each time the coded transmitter signal is received, provided it is sufficiently strong and at least of 200 ms duration. The receiver is powered from a regulated 12 volt power supply using a zener diode, ZD1, as a reference on the base of a series-pass transistor, Q5.

The relay contact is used to switch the active mains through to a panel-mounting mains socket for switching 240 V operated appliances.



Receiver, power supply and mains wiring circuit.



Receiver preamp circuit.

INFRA-RED REMOTE CONTROL UNIT ETI-599a TRANSMITTER

Resistors .... all ½W, 5%
- R1 .... 12k
- R2 .... 220k
- R3 .... 2k7
- R4 .... 22k
- R5 .... 560R
- R6 .... 2k2
- R7 .... 1R
- RV1 .... 100k min. flat-mounting trimpot

Capacitors
- C1 .... 10u/16 V electro.
- C2 .... 47n
- C3 .... 680p
- C4 .... 470u/16 V electro.

Semiconductors
- D1 to D4 .... 1N914, 1N4148 etc
- D5, D6 .... 1N4001
- LED1, LED2 .... CQY89A infra-red LED
- IC1 .... 4001B
- IC2 555
- Q1 .... BFY50

Miscellaneous

ETI-599a pc board; SPST miniature push-button switch; 9 V No. 216 battery; battery clip, LED mounts; plastic jiffy box 115 x 65 x 30 mm, wire, nuts and bolts, etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$70 - $76

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibre-glass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.

pushbutton and flying leads for connections to the LEDs last. The two LEDs are mounted in panel mounts which require two 6 mm holes to be drilled in the end of the case.

The pc board can be mounted in the case using a piece of double-sided sticky tape or pad, but leave sufficient room for the battery in the end opposite the LEDs. See the internal photograph of the transmitter. Wire up the LEDs, watching the anode and cathode connections.

Remember that you won't be able to tell if the unit is working by looking at the LEDs because, as infrared is well outside human visibility, you won't see anything. If you have an oscilloscope, look at the waveform across R7. It should be similar to that shown in Figure 1 here, taken on our prototype.

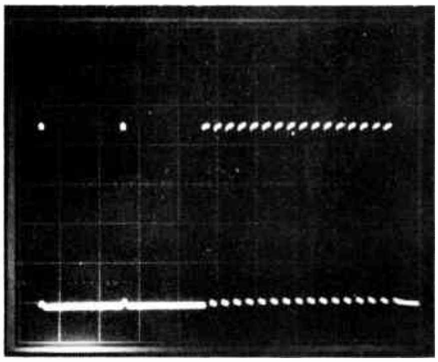


Figure 1. **Transmitter waveform, monitored across R7 on pc board ETI-599a. Vertical scale 100 mV/div.; timebase 5 ms/div. for first four divisions, showing 25 kHz burst repetition, then 100 μs/div. for rest of sweep showing 25 kHz pulses.**

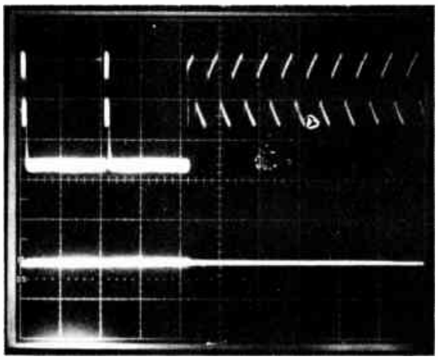
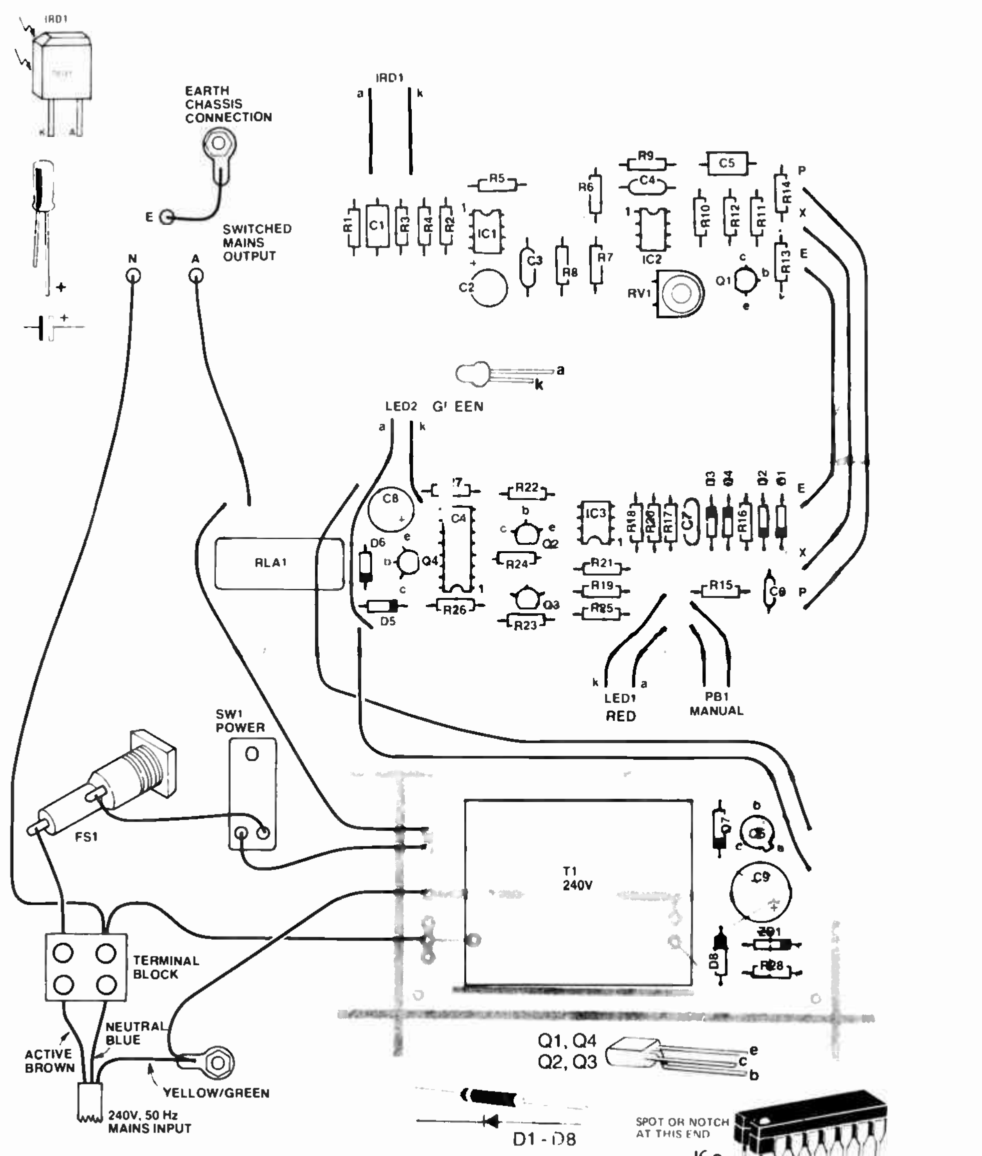


Figure 2. **Received waveform monitored across R1 on pc board ETI-599b. The transmitter was positioned 250 mm from the receiver diode. Vertical scale 20 mV/div. dc coupled; timebase 5 ms/div. for first four divisions then 50 μs/div. for rest of sweep. The bottom trace is 0 V. Signal voltage across R1 will vary greatly with the distance between the transmitter and receiver units.**



Component overlays and wiring diagram for receiver.

Construction — receiver

The receiver is built on three separate pc boards — preamplifier and active filter (ETI-599b), detector and relay (ETI-599c), and a regulated power supply (ETI-599d). It is all housed in a metal box measuring 150 x 70 x 175 mm with an overhanging lid. The front panel holds the two LEDs, power switch, fuse and infrared opto-diode. The 240 V mains socket for the switched output mounts on the rear panel alongside the mains lead. All mains wiring is kept well away from the low voltage circuitry and we used a cardboard partition just in case.

It doesn't matter which pc board you assemble first. Assemble all the boards, being careful with the polarity of the electrolytic capacitors and the orientation of ICs and transistors. The two frequency determining capacitors in the active filter, C3 and C4, should be styroseal or mica types for good temperature stability.

With the boards assembled, attach flying leads to each for later interwiring. Plastic insulated, 240 Vac rated wire, at least 32 x 0.2 mm, should be used for all mains wiring.

The case for the receiver may be drilled next, if you haven't obtained a predrilled one. Refer to our internal photograph for positioning of the boards and external components. Layout is not critical, but the mains wiring should be kept separated from the rest of the circuitry.

We mounted the preamp/filter board (ETI-599b) immediately behind the front panel. Behind this we mounted the detector/relay board (ETI-599c), with the power supply board (ETI-599d) at the rear. Each board is mounted using four bolts at each corner, the boards being spaced off the chassis using 12 - 15 mm long brass or fibre spacers.

Now the interwiring may be completed. As suggested earlier, use 32 x 0.2 mm plastic insulated hookup wire for all mains wiring.

Install the heavy cardboard protective partition last. It may be bolted or glued in place.

The infrared detector diode is fixed behind a hole in the front panel. We mounted ours on a small piece of vero board glued edge-on to the rear of the front panel. A small piece of filter plastic is then slid in front of the diode and glued in place. This is not essential but does improve the appearance. If you use a piece of filter plastic make sure it is the correct type which will pass infrared. We used 'Kodak Wratten 89c' but any similar type will do.

The infrared detecting diode, BPW50, is a flat package made from what appears to be black plastic. In actual fact, the package is made from a filter material which passes infrared and absorbs visible light — this is why it appears black. If you look at the top edge you will notice a chamfer on the corner of one of the faces. This is the *non-sensitive* face and should be positioned *inwards.*

When the receiver has been constructed, check the mains wiring VERY CAREFULLY and ensure the earth connection is firmly attached to the chassis. Make sure the input active goes to the output active, input neutral to output neutral. Plug a lamp or some other mains appliance into the switched outlet and switch the unit on. Adjust the receiver trimpot RV1 so that LED1 is off and check the functional operation of the unit by pressing the 'manual' button briefly. As this pushbutton is pressed LED1 should light and the relay should change state, making or breaking the power to the load. When the manual switch is released, LED 1 will go out but the relay should not change state.

Setting up

With the receiver unit operating by itself, adjust the trimpot RV1 (sensitivity) so that LED1 lights up, then back the control off slightly until LED1 just goes out. Take a deep breath, cross your fingers and aim the transmitter at the receiver from a close range. Press the 'operate' button and if all is well, LED1 on the receiver unit will light and the relay will change state. Release the operate button, wait a second or so, and press it again. The relay should revert to its original state.

When you are satisfied the system is operating correctly you can adjust the transmit frequency for maximum sensitivity, or range. Adjust the trimpot RV1 in the transmitter (frequency) while operating the transmitter at increasing distances from the receiver. You should be able to obtain reliable operation at a range of about 10 metres maximum. Do this adjustment with care, making sure you aim the transmitter directly at the receiver.

Have fun with your controller! ●

ETI-599 RECEIVER

Resistors .... all ½W, 5%

R1, 8, 9	15k
R2, R3	18k
R4, 10, 12, 15	10k
R5	330k
R6, R7	68k
R11	470R
R13	560k
R14, 18, 23	4k7
R16	1M
R17	2M7
R19	120k
R20	820R
R21	220k
R22, R24	47k
R25, 27, 28	1k
R26	6k8
RV1	10k min. flat-mounting trimpot

Capacitors

C1, C5	1n greencap
C2	100u, 16 V electro.
C3, C4	330p styroseal or mica
C6	22n greencap
C7	100n greencap
C8	100u, 16 V electro.
C9	470u, 25 V electro.

Semiconductors

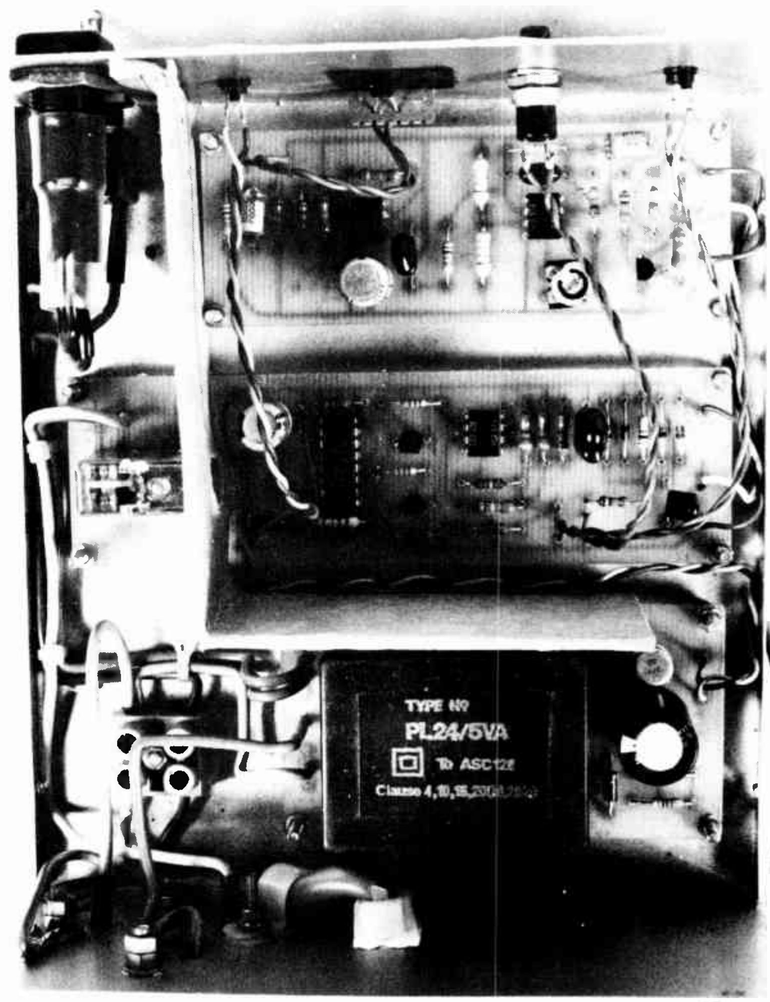
IRD1	BPW50 infra-red photodiode
LED1	TIL220R red LED
LED2	TIL220G green LED
D1 to D4	1N914
D5 to D8	1N4001
ZD1	12V, 400 mW zener
Q1 to Q4	BC547, BC107 etc
IC1 to IC3	CA3140
IC4	4027

Miscellaneous

PB1	SPST min. momentary push button
SW1	SPST toggle switch, 240 Vac rated
RL1	12V, pc board relay with DPDT 240 Vac/5 A contacts (Takamisawa type VB 12STAN or Pye 265/12/G2V)
T1	12-0-12 V, 5 A pc mount transformer, Ferguson type PL24/5VA or sim.

Panel-mount fuse holder and 5 A fuse to suit; mains cord; cable clamp; terminal block; panel mount three-pin mains socket; LED filter material — Kodak Wratten 89C or similar (small piece); metal box and lid 160 x 180 x 70 mm; stick-on rubber feet; three pc boards ETI-599b, c and d; wire, nuts, bolts etc.

Internal view of the receiver unit. The cardboard 'shield' separates the 240 Vac wiring.



Masthead amp for UHF TV

If your UHF TV signal is not quite up to scratch and you don't want to add more aerial hardware, this project is for you.

Phil Wait

WHEN INSTALLING a UHF TV antenna system it is often difficult to predict *up front* just how good a picture you're going to get, whether you'll have noise (snow) problems, etc. Undoubtedly, situations will arise where, having installed the antenna and feedline, the picture is found to be acceptable, but contains some snow. Alternatively, having erected a large expensive antenna array and installed expensive, top-quality coax, the picture is 'out of the mud' but not acceptable on anything but a short-term basis. Either way, erecting more hardware may not be as good a solution as attempting to boost the signal at or near the antenna with a suitable booster amplifier. That's where this project comes in.

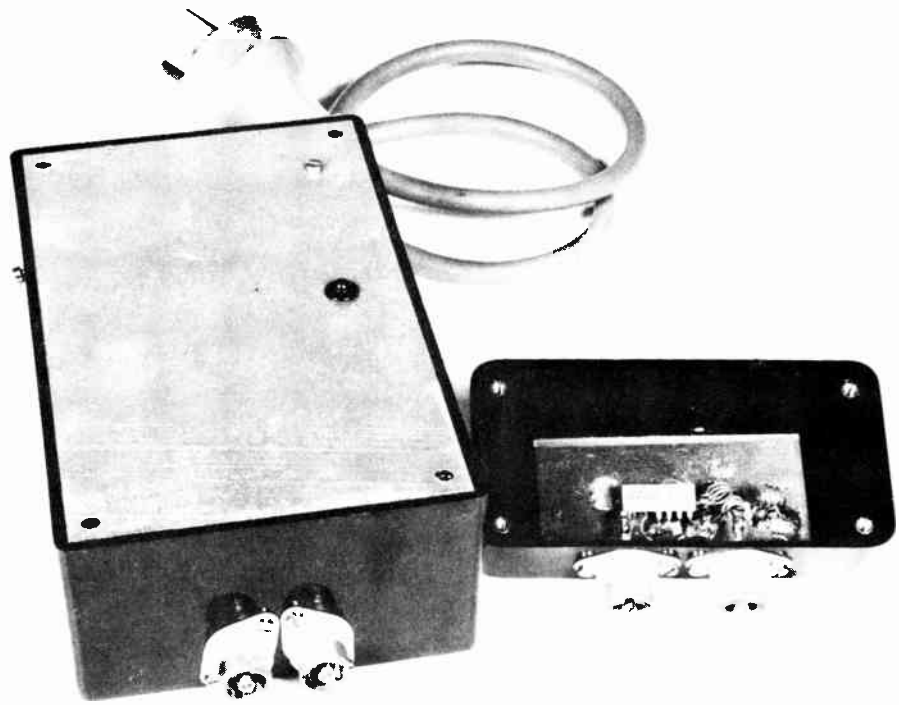
In other situations, long runs of feeder cable may be necessary. Traditionally, 300 ohm open-wire feedline is regarded as 'low loss'. It's not so at UHF. Coax performs better 'upstairs' and suffers less from the effects of weather and picks up less unwanted interference. However, a very long run may have as much as 5 to 7 dB loss, sometimes more. This not only attenuates the signal before it reaches the TV front end, but seriously degrades the tuner's noise figure — and you lose both ways. Again, that's where this project comes in.

The ETI-729 UHF TV Masthead Amplifier covers the UHF TV bands IV and V, extending from 526 MHz to 814 MHz. It provides nearly 18 dB of gain and has a noise figure typically around 6 dB.

Heart of the amplifier is a recently-released Philips wideband hybrid amplifier, the OM350. It is a two-stage amplifier built on a thin-film substrate and encapsulated in a 5-pin, in-line package having a resin-coated body. It is part of a range of five VHF/UHF wideband amplifiers made by Philips, which include the OM345, OM360, OM361 and OM370. We have published a short-form data sheet on the OM350 elsewhere in this article.

Construction

The amplifier is housed inside a small plastic box which is contained within a larger plastic box for weather proofing, the latter being attached to the antenna mast.

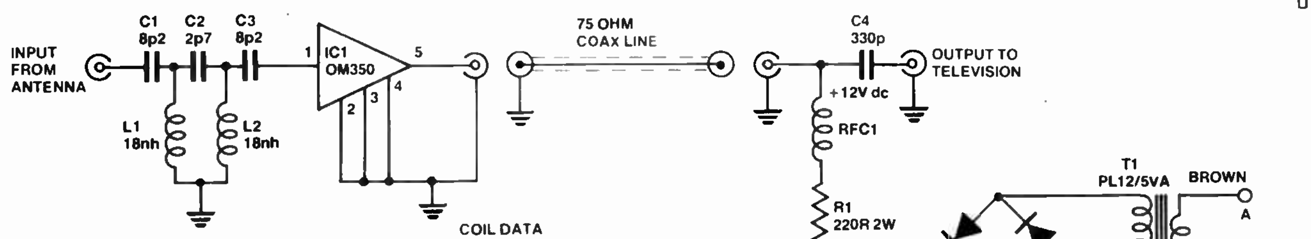


Unlike most of our projects, the amplifier does not use a pc board, but rather the components are wired to each other directly and mounted above a flat copper earth plane. This construction is quite easy and gives good results up to quite high frequencies, avoiding the cost of Teflon pc board and specialised components. In fact, our first attempt at making this amplifier used printed inductors for the high pass network and microstrip terminations. Probably owing to the pc board characteristics and the Q of the printed inductors, this was not successful, as the gain dropped off dramatically above 600 MHz.

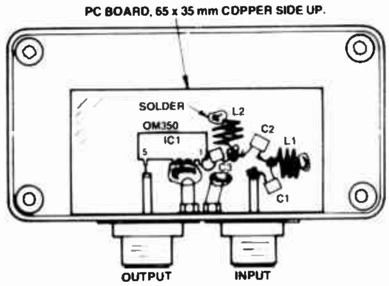
Follow the drawing and photograph of the amplifier very carefully. All earth connections from the coax sockets, the IC and the filter inductors are made directly to the copper ground plane. All the components have absolutely *minimum* or no lead length and you will find a pair of tweezers may help to hold the components while soldering.

Start by mounting the coax sockets about 30 mm apart on the side of the box, with their bolt holes in line with each other. Place two solder lugs under the two innermost mounting bolts for the coax sockets, and to these solder a piece of pc board, copper side up as the

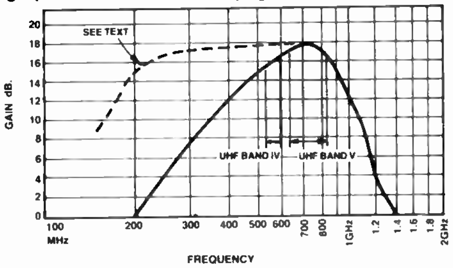
Internal view of the power supply. Note the pc board is double-sided.



Circuit diagram of the masthead amplifier and power supply.



Construction drawing. Compare this to the photograph at the bottom of the page.



Measured bandpass and gain characteristics of the amplifier. You can alter the response to that shown by the dotted line by adding one turn to L1 and L2.

earth plane. Its exact size is relatively unimportant, so long as it fits in the box. Wire all the components as shown. The three earthed leads on the IC are bent down slightly and soldered onto the earth plane while the output lead is bent up to the output socket, and the input lead solders to the high pass filter.

Be careful not to overheat the coax sockets as the Belling and Lee types used are easily melted.

Drill a small hole (about 3 mm) near the coax sockets to allow ventilation in the box to avoid condensation build-up. Fix the lid in place with Silastic rubber.

Weatherproofing

The amplifier box is contained in a larger box, which is attached to the antenna mast with a U-bolt. Drill clearance holes for the coax plugs so they can be passed through the bottom of the larger box to the amplifier. After mounting the box on the mast and connecting the coax cables, seal the lid with Silastic rubber.

The power supply

The power supply is located near the TV set and housed in its own plastic box. Commence construction by mounting all the components on the pc board, noting that C4 and RFC1 are soldered on the top side of the board. Again, use

HOW IT WORKS — ETI 729

The masthead amplifier is based on one of the Philips range of wideband hybrid integrated circuits. The OM350 features 18 dB gain from 40 MHz to 860 MHz with a noise figure of around 6 dB. Input and output impedances are 75 ohm, allowing the IC to be directly connected in line without impedance matching.

As the output of the chip is open collector the dc power is fed along the output signal path (in our case, the centre of the coax), making the IC ideal for masthead operation.

The signal from the antenna is applied to the input of IC1 via a high pass filter network with a cutoff frequency of about 400 MHz. As this amplifier will be used on antennas designed only to receive UHF transmissions it is desirable to prevent strong HF or VHF stations from being amplified and fed to the TV set. If so, some receivers may be prone to intermodulation, causing interference patterns on the screen.

The high pass filter comprises C1, C2, C3, L1 and L2.

The amplified signal is fed down the coaxial cable to the power unit mounted close to the television receiver. The signal passes through a blocking capacitor, C4, and is fed to the receiver's antenna input. The dc power is applied to the line on the amplifier side of C4 through an RF choke to prevent the signal being shunted by the power supply circuitry.

The power supply consists of a full-wave rectifier producing about 16 V filtered dc which is dropped to about 12 volts by R1. A LED indicates when the unit is switched on.

ETI-729 UHF TV MASTHEAD AMP

Resistors
R1 .... 220R, 2W
R2 .... 680R, ½W

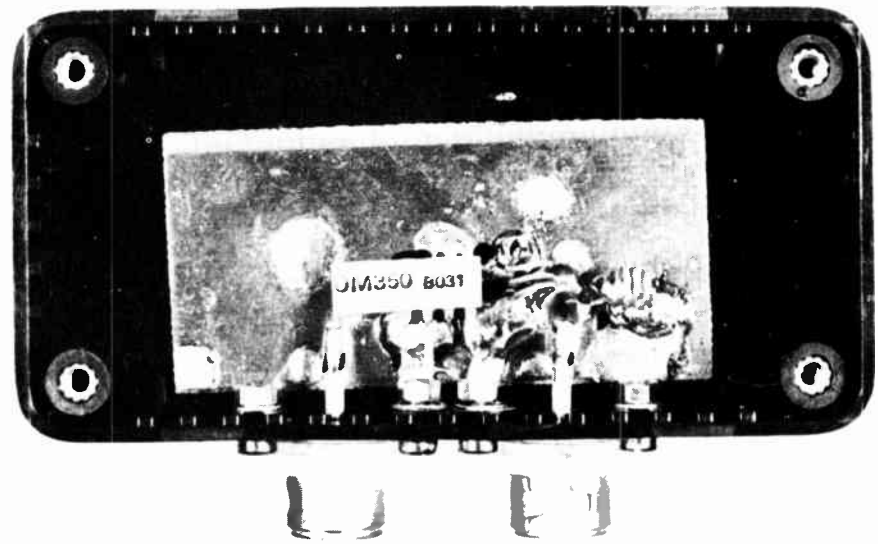
Capacitors
C1, C3 .... 8p2 ceramic (NPO)
C2 .... 2p7 ceramic (NPO)
C4 .... 330p ceramic (NPO)
C5 .... 470u/25 V electro.

Semiconductors
D1 to D4 .... 1N4001 or similar
LED1 .... TIL220R red LED
IC1 .... OM350 Philips wideband RF amp

Miscellaneous
ETI-729 pc board; four Belling-Lee coax sockets; four solder lugs; RF choke (see text); Ferguson PL12/5 VA transformer or similar; 240 Vac power cable and plug; plastic box — 100 x 50 x 25 mm (for amp); plastic box — 195 x 110 x 60 mm (weather protector housing); plastic box — 160 x 95 x 50 mm (power supply); 22 swg tinned copper wire, etc.

Price estimate **$28 - $34**

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.

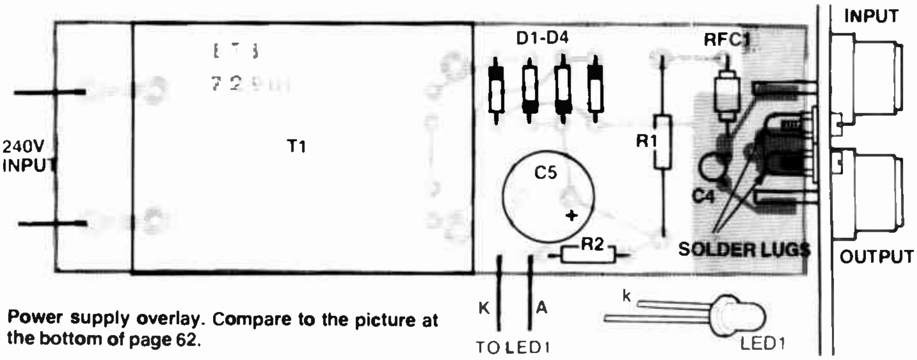


Internal view of the amplifier. A piece of pc board serves as an earth plane.

as short leads as possible. The value of the RF choke is not critical though you should use one which is physically small. We used a commonly available 10 uH choke, though any value above 500 nH should be OK. Mount the two coax sockets at one end of the box exactly 18 mm apart, as shown, again using two solder lugs on the two inside bolts as we did on the amplifier box.

The pc board is supported with one standoff near the transformer and by the connections to the coax sockets at the opposite end. Again, be careful not to melt the coax sockets with too much heat. The 240 Vac power cable terminates directly onto the pc board as we have used a pc mounting transformer. The earth lead (green/yellow) should be firmly soldered onto the two earth lugs at the coax sockets. Leave plenty of slack in this lead so if the cable is pulled from the unit the earth is the last to break off.

Finally, you will have to assemble a patch cord with a coax plug on either end to run from the power supply to the TV set. Use a good-quality coax for this as, although it is short, performance can be seriously degraded if you use a lossy cable ahead of the amplifier. ●



Power supply overlay. Compare to the picture at the bottom of page 62.

OM 350

HYBRID INTEGRATED CIRCUIT VHF/UHF WIDEBAND AMPLIFIER

Two-stage wide-band amplifier in hybrid integrated circuit technique on a thin-film substrate, intended for RATV and MATV applications.

dc supply voltage	V_B	=	12 V ± 10%
Frequency range	f		40 to 860 MHz
Source and load (characteristic) impedance	$R_S = R_L = Z_0$	=	75 Ω
Transducer gain	$G_{tr} = \|s_{21}\|^2$	typ	18 dB
Flatness of frequency response	$\pm\Delta\|s_{21}\|^2$	typ.	1 dB
Output voltage at 60 dB intermodulation distortion (DIN 45004, 3-tone)	$V_{o(rms)}$	typ.	100 dBμV
Noise figure	F	typ	6 dB
Operating ambient temperature	T_{amb}		−20 to +70 C

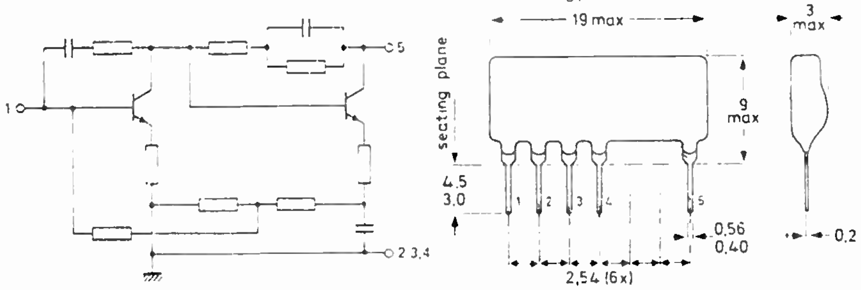
ENCAPSULATION 5-pin, in-line, resin-coated body

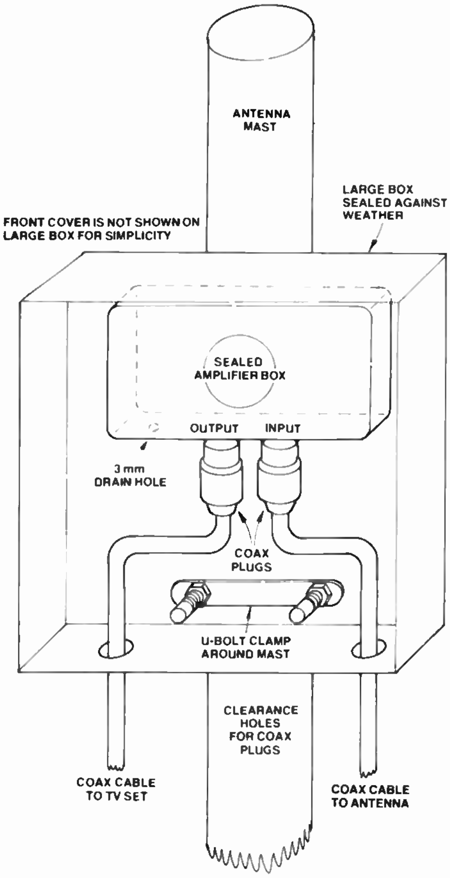
Terminal connections

1 = input 2,3,4 = common 5 = output/supply(+)

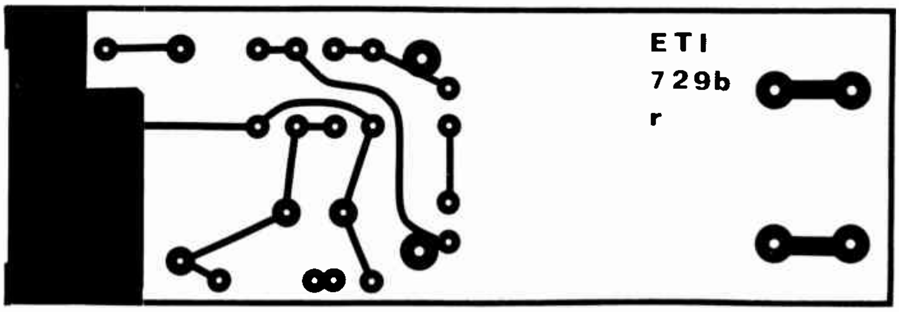
Hand soldering

Maximum contact time for a soldering-iron temperature of 260 C up to the seating plane is 5 s





ABOVE: Suggestion for mounting the amplifier in a weatherproof housing.



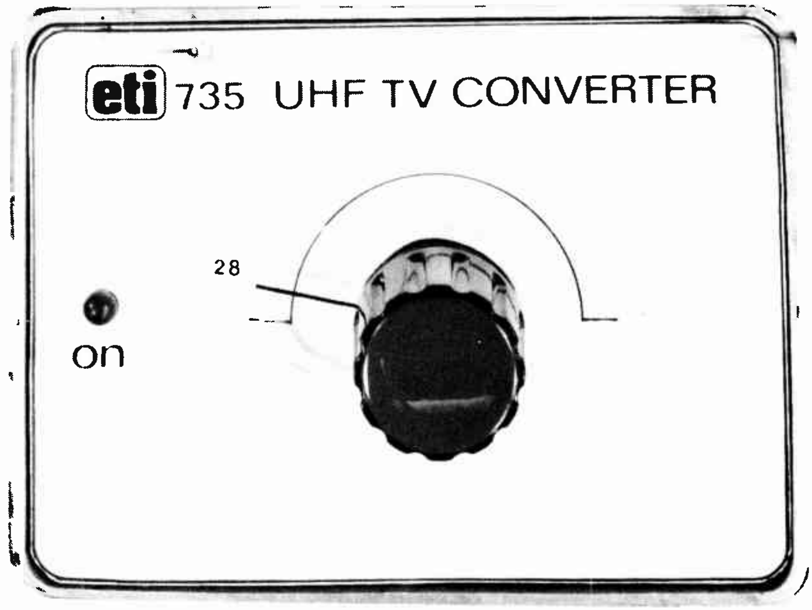
RIGHT: Printed circuit artwork, full size.

UHF to VHF TV converter

This project will convert TV station transmissions in the UHF band down to unoccupied channels in the VHF TV band. If your present TV set does not have a UHF tuner and you want to watch programmes on UHF, this project is for you.

Phil Wait

SINCE THE introduction of UHF TV services — first the translator services re-radiating the VHF station signals on UHF channels and then the multi-cultural service on channel 28 — the number of stations and service areas has grown at quite a rapid rate. It's no wonder that we have received many calls and letters from readers asking for projects to solve problems they had in trying to explore what the new services offered. We published an antenna design in March '81 (reprinted in this book on page 71) and a masthead amplifier in April '81 (also reprinted here, see page 62). These projects cater for those who own a TV receiver with a UHF tuner already built in. The biggest demand is probably for a UHF or VHF TV converter. We trust this project satisfies that demand.



Front panel view of the tuneable version of our UHF converter. Note there are two versions: tuneable and single channel.

Design philosophy

The predominant design requirement for this project was *simple construction* and a *minimum of alignment*. We judged that most constructors tackling a project such as this would not be familiar with UHF circuit techniques. Consequently, the design had to be simple, yet provide good performance — at least as good as the front end of UHF TV tuners used in modern domestic TV sets. We feel those aims have been achieved.

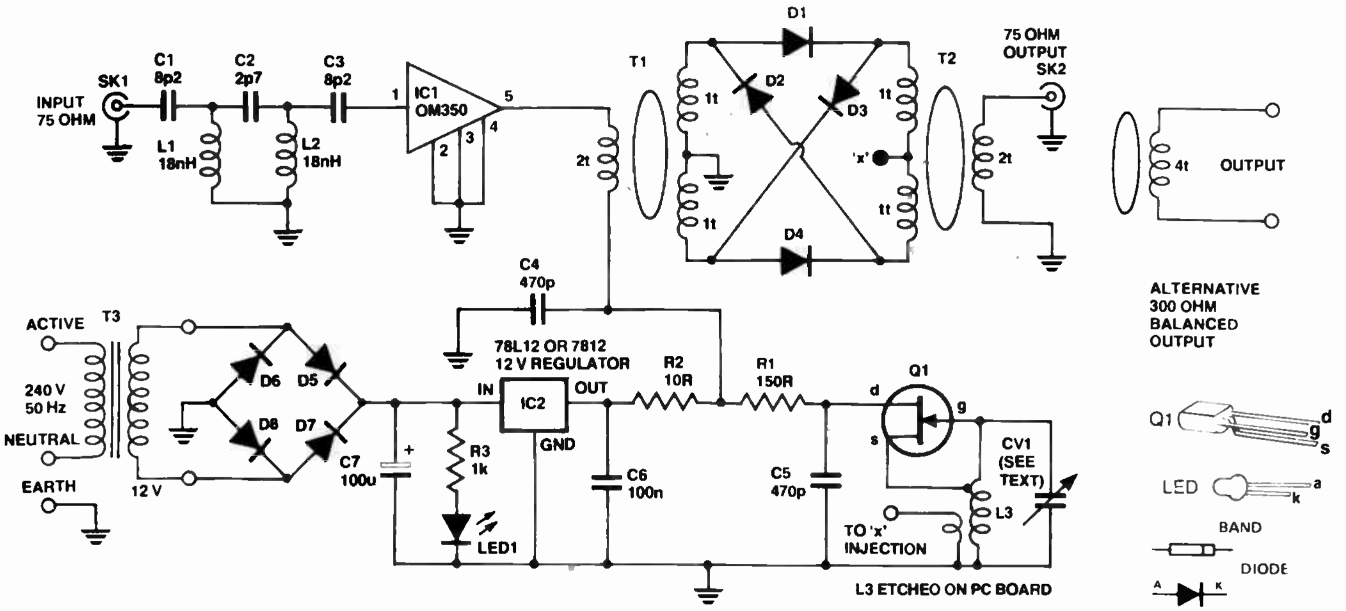
To reduce the requirement of alignment, there is only one adjustment — setting the local oscillator. That isn't even necessary in the tuneable version!

Before proceeding, we should explain that this project can be built in two versions: the *single channel* version and the *tuneable* version. Each has its advantages. If you only have a single UHF channel available in your area, and it's likely to remain that way for some time, then the single channel converter is the one you want. If you have several UHF channels available, then you can either make several single channel converters and set them up for the different channels, switching between converters, or you can make the tuneable version. If you only have one channel available currently and make a single channel converter, and then more channels become available later, the single channel converter is readily modified to the tuneable version.

The circuit arrangement is fairly conventional. An RF stage employing an OM350 hybrid wideband IC provides some 17-18 dB of gain before signal is applied to the mixer. A two-stage high-pass filter employed between the antenna and the RF amp input provides over 20 dB of attenuation to prevent crossmodulation problems from the high-powered VHF TV signals and other transmissions below 450 MHz. For the mixer, we chose to use a ring-diode balanced mixer circuit, employing wideband input and output matching transformers. This type of mixer provides low noise operation with good crossmodulation performance. In addition, the wideband input and output transformers do away with the necessity of having tuned circuits which require alignment. The ability to choose any convenient output channel is another advantage.

The local oscillator employs a FET in the familiar Hartley circuit. A parallel-tuned circuit is connected between the gate of the FET and common (ground). The drain is bypassed at the operating frequency and the source is tapped up to the tuned circuit's inductance to provide positive feedback. The tuned circuit inductance (L3) is realised by a length of track on the pc board and a small, low-value trimmer provides the tuning capacitance (CV1). Injection to the LO port of the mixer is provided by inductive coupling from L3 and a short length of 50 ohm stripline.

The pc board is double-sided to provide a groundplane area for the UHF circuitry. Output to the VHF TV receiver input can be either 75 ohm unbalanced (via coax) or 300 ohm (via ribbon). A regulated power supply is provided on board and the converter may be powered from a 12 Vac, 500 mA plugpack or a conventional trans-



HOW IT WORKS — ETI 735

The converter's format is quite conventional — an RF amplifier drives a mixer, local oscillator injection being provided by a variable frequency oscillator, the frequency of which is set by a small variable capacitor. A full-wave bridge rectifier followed by a three-terminal regulator provides regulated 12 Vdc to power the circuitry.

Signals from the antenna are fed to the input of the RF amplifier stage via a two-stage high-pass filter consisting of L1, L2 and C1, C2, C3. This filter attenuates strong signals in the VHF band (below 300 MHz) from overloading the converter and possibly causing crossmodulation problems. The UHF signals are amplified by IC1, a hybrid wideband amplifier chip which provides a gain of about 18 dB over a bandwidth extending from 40 MHz to 860 MHz. The input filter provides around 10 dB attenuation at 300 MHz, around 20 dB at 200 MHz, and more below that. The gain of the amplifier stage is around 15-16 dB across UHF Band IV and around 17-18 dB across UHF Band V. The gain falls off rapidly above 900 MHz. Noise figure is in the region of 6-7 dB, which is quite a bit better than many commercial UHF TV tuners!

The input and output impedances of the OM350 RF amp IC are quoted as 75 ohms, which is convenient.

The output of the RF amplifier is coupled into the mixer via the primary winding of T1.

The mixer employs four Shottky hot-carrier diodes (D1 to D4) in a double-balanced ring mixer circuit. The input and output transformers, T1 and T2 respectively, are wideband types, providing input and output impedance matching. No alignment is necessary — which is one of the reasons we used this type of mixer. The local oscillator injection is applied at point 'x' (the LO port). This type of mixer provides good conversion efficiency, few spurious outputs and has good strong signal performance so that problems with overload and crossmodulation are minimised.

The local oscillator employs a junction FET, Q1, in a Hartley oscillator circuit. This circuit is simple and reliable. The tuned circuit consists of CV1 and L3. The latter is a length of track on the pc board, a 'printed inductor'. Q1 is operated in the common drain mode, positive feedback being obtained by tapping the source across L3. The oscillator can be tuned over a range from about 250 MHz to a little above 600 MHz. Injection to the LO port of the mixer is obtained by inductive coupling. A short length of track adjacent to the 'earthy' end of L3 couples a small amount of energy from the oscillator. This is coupled to point 'x' via a short length of stripline running across the pc board.

The mixing process combines the signals amplified by IC1 and the signal provided by the local oscillator to produce a whole range of 'products' at the output. The principal products are the sum and difference of the input and local oscillator frequencies.

Say the input frequency we want to receive is 526 MHz (lower edge of channel 28). This will be amplified by IC1, along with all the other frequencies passed by the input filter, and applied to the input of the mixer. If we set the local oscillator to 470 MHz, the mixer output will be:

526 − 470 MHz = 56 MHz

This is VHF TV channel 1. If we tune the TV receiver to channel 1, we will be able to receive UHF channel 28. However, the sum of the input and local oscillator frequencies will also result from the mixing process:

526 + 470 MHz = 996 MHz

But the TV receiver will not respond to such a high frequency. A signal from UHF channel 50 (694-701 MHz) may appear at the output too:

694 − 470 MHz = 224 MHz

But that's outside the range of the VHF TV receiver. If we set the TV receiver to channel 6 (174-181 MHz), we will be able to receive channel 50 by setting the converter's local oscillator to 520 MHz.

Reception of a UHF station can also be obtained with this converter design by tuning the local oscillator above the channel frequency. For example, to receive channel 28, which occupies 526-533 MHz, assuming we have the TV receiver set on channel 1, the converter local oscillator should be set to 589 MHz:

589 − 533 MHz = 56 MHz.

But, if there is a signal 56 MHz above the local oscillator frequency (otherwise known as the 'image' frequency), i.e: 589 + 56 MHz = 645 MHz (UHF channel 43), it will be received equally well — and you'll have terrible interference if there's a station on that channel! With this converter, and the current arrangement of channel allocations, it is best to tune in a station with the oscillator set on the low frequency side of the desired channel. In addition, it is best to use channel 1 (or an adjacent unused channel) to receive UHF stations in Band IV (520-580 MHz) and an unused channel between 5A and 11 to receive UHF stations in Band V.

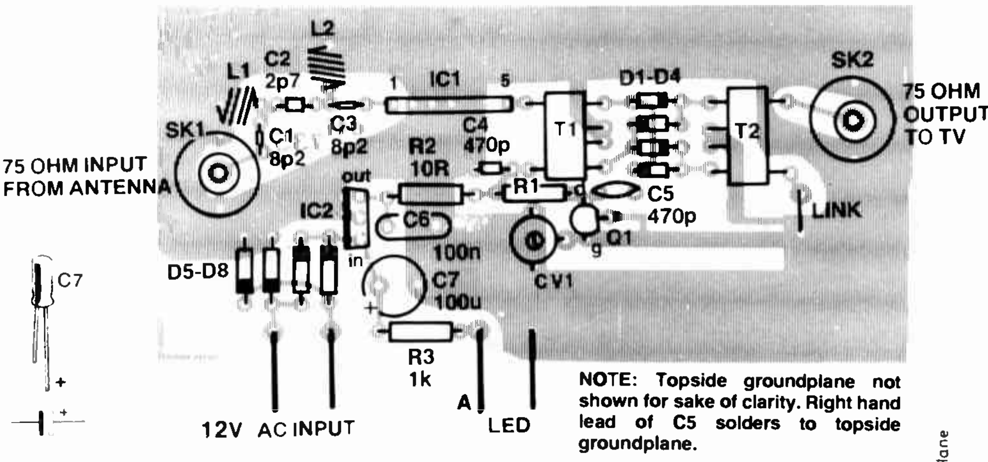
Power is provided by a full-wave bridge rectifier involving diodes D5 to D8, input being derived from a 12 Vac (nominal) source. An indicator LED (LED1) is driven from the output of the rectifier. Capacitor C7 is the rectifier smoothing capacitor. A three-terminal regulator, IC2, employing either a 78L12 or 7812, provides a regulated 12 Vdc supply for the RF amp, IC1, and the oscillator FET, Q1. The regulated supply ensures good oscillator stability. Capacitor C6 bypasses the output of the regulator, IC2, and prevents it bursting into HF oscillation. Resistor R2 prevents interaction between IC1 and IC2 at low frequencies, and C4 provides an RF bypass for the supply rail to IC1, which goes to the output pin (pin 5) via the primary of T1.

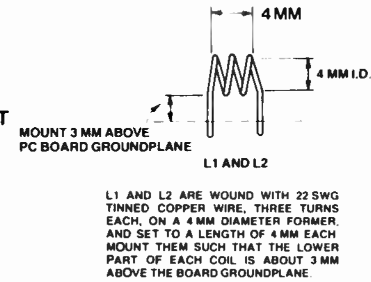
RF bypassing for the drain of Q1 is achieved by C5, and the power supply rail is decoupled via R1.

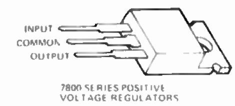
The output impedance of the mixer can be matched to an unbalanced 75 ohm load or to a balanced 300 ohm load by having a different secondary wound on T2. The impedance transformation ratio provided between the primary of T1 and the secondary of T2 will depend on the square of the ratio of their turns. With two turns on the primary of T1 and two turns on the secondary of T2, the impedance transformation will be 1:1. In this instance, one side of the secondary of T2 is grounded to provide an unbalanced output to match coax cable. If the secondary of T2 is wound with four turns, the output impedance will be given by:

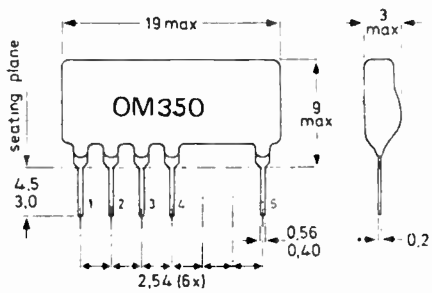
$$75(4/2)^2 = 75 \times 4 = 300 \text{ ohms}$$

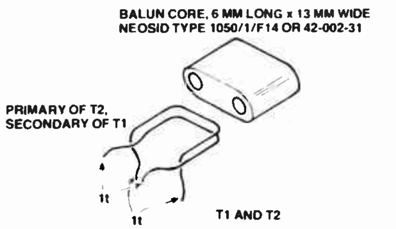
Thus, four turns on the secondary of T2 will provide a balanced match to 300 ohms.

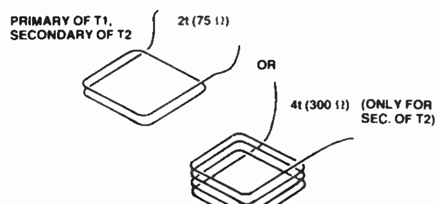












former. Overall gain is around 12 dB and the noise figure is around 6-7 dB. This sort of performance is more than adequate for normal service reception of UHF transmissions.

No doubt some readers are curious as to why we didn't design a tuner employing voltage tuned varicaps to tune the local oscillator and/or RF tuned circuits. Firstly, suitable varicaps having the required characteristics for these frequencies were not readily available. We did experiment with a few types that were available, as well as with some common high frequency silicon diodes, but results were very poor owing to the low Q and high losses of the components. Hence, we opted for the circuit design described here.

Construction — single channel version

We shall describe the construction of the single channel version first. The tuneable version is actually just a modification of the single channel version.

The converter is constructed on a double-sided pc board having a fibreglass substrate. A phenolic substrate board will not work in this application. The top side is predominantly copper, which serves as a groundplane, small areas being etched away where components pass through from the top to the bottom side tracks. The complete converter fits on to the one pc board, including the rectifier and power supply regulator components.

Construction is best commenced by mounting all the minor components. Leave the input and output sockets, coils and mixer transformers until later. All components should be mounted with the *absolute minimum lead length*. Press them hard down on the board. However, the input high pass filter coils, L1 and L2, are mounted about 3 mm above the board, to avoid the groundplane dampening their Q.

A number of components are soldered on both the top and the bottom sides of the board. These are: the anodes of D6 and D8 (in the rectifier), one lead of C4, plus the earth stake, the centre-tap connection of T1, the earth end of the output link (for 75 ohm output) and the earth ends of L1 and L2.

The OM350 RF amplifier IC must be seated hard down on the board, as should Q1 and the mixer diodes D1 to D4. Watch the orientation of the semiconductors and the rectifier filter capacitor, C7. Note that the OM350 can only be inserted one way, but the local oscillator FET, Q1, has its source lead — the centre one — offset from the others. This lead must be bent over so that the FET can be inserted the right way round. This is necessary to give the correct length of track on the board for the source feedback tap on L3 — which is a printed circuit inductor.

Take care when soldering CV1 in place as conducted heat can distort the body of the component, ruining it.

Having mounted the minor com- ▶

PARTS LIST — ETI 735

Resistors	all ½W, 5%
R1	150R
R2	10R
R3	1k
Capacitors	
C1, C3	8p2 ceramic NPO
C2	2p7 ceramic NPO
C4, C5	470p ceramic
C6	100n greencap
C7	100u/16 V electrolytic
CV1 (see text)	2-18p miniature film trimmer OR 2-15p miniature air trimmer with 4.8 mm (3/16") shaft.
Semiconductors	
D1-D4	5082-2800 (four-off) or matched set of 5082-2804 Hewlett Packard hot carrier diodes
D5-D8	1N4001, 1N4002 etc or similar
Q1	2N5245 FET (no substitutes)
IC1	OM350 Philips wideband amp IC
IC2	78L12 or 7812, 12 V three-terminal regulator.
LED1	TIL220R or any suitable LED.
Miscellaneous	
SK1, SK2	Belling & Lee pc-mount coax sockets
L1, L2	see text and diagrams
T1, T2	see text and diagrams
T3	12 Vac, 500 mA plugpack

ETI-735 pc board (double-sided, fibreglass necessary); pc board stakes; tinned copper wire; hookup wire; vernier drive (for tuneable version); 6.5 mm to 4.8 mm shaft reducer (for tuneable version); box to suit.

ponents, the next step is to wind the coils L1 and L2, and the mixer transformers T1 and T2. Winding details are given in the diagrams on page 67. Note that T2 can be wound in two different ways, depending on whether you choose to have a 75 ohm unbalanced output (coax) or 300 ohm balanced output (ribbon). If you choose a 300 ohm balanced output, the small link near the output socket is left out and the ends of the secondary of T2 connect direct to a length of 300 ohm ribbon, soldered on the underside of the pc board.

The converter may be mounted in any convenient box — but don't put the pc board close to a panel. Use 12 mm (or longer) standoffs to keep it away from the box panels, which may affect performance. To avoid unnecessary terminations, the input and output cables should be taken directly through the lid of the box you use and terminated directly on the pc board. This is why we have used pc-mounted coax sockets.

You can mount a small transformer in the box to power the converter, or you can use a plugpack. The transformer or plugpack should have an output of 12 Vac, rated at about 500 mA. Transformers and plugpacks with this rating are cheap and quite common. While the converter doesn't draw anything like 200 mA, the rectifier output must be several volts above the three-terminal regulator's output voltage. As less than full load is drawn from the transformer or plugpack, its output will be high enough to meet this requirement.

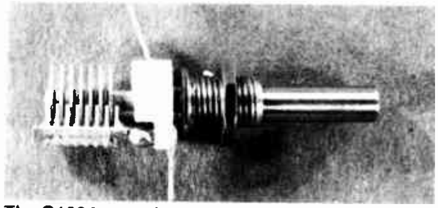
If you choose to use a plugpack, mount a suitable insulated two-pin socket on the box housing the converter. Dick Smith stores stock a suitable ac plugpack, catalogue number M-9555, while Ferguson market a plugpack designed to power doorbells, model PPB 12/500.

Construction — tuneable version

The tuneable version just requires a modification to the single channel version. To construct the tuneable version, commence by constructing the converter as per the instructions just described, but leave out the trimmer capacitor CV1 (not needed) and Q1 (which must be inserted later).

A small, low value variable capacitor is added to the local oscillator, replacing the trimmer CV1, and a vernier drive and dial added.

For the variable capacitor, we chose an American-made Johnson type with a ceramic base, measuring about 12 x 14 mm, with a threaded spindle and nut mounting. The shaft has the variable plates attached and the mounting spindle also serves as the moving plates connection. This is a common form of construction for small, single-gang variable capacitors for those readers who are not familiar with the beasts. The type we chose to use in the prototype has the moving plates and the fixed plates each milled out of a brass block, which provides excellent mechanical and electrical stability. These capacitors are available in different values and we would recommend you use one with a maximum capacitance of 15 pF. The exact one we wanted was not available when we constructed the prototype so we used one with a maximum capacitance of 20 pF and cut down the fixed plates to obtain the required value. This is visible in the close-up photographs. We purchased ours from General Electronic Services Pty Ltd of 99 Alexander St, Crows Nest NSW 2065, but several kit and components suppliers also stock them (see Shoparound, page 128). David Reid Electronics (in Sydney and Melbourne) stock a small variable capacitor, type C1604, that is suitable for this project. It is somewhat smaller



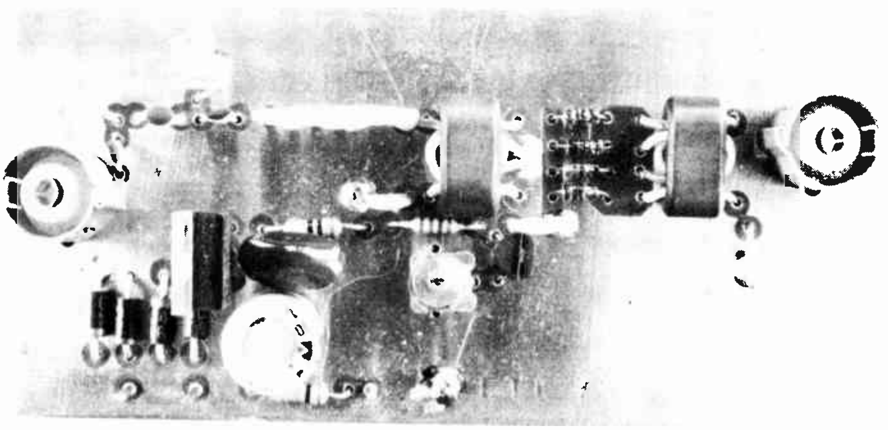
The C1604 capacitor.

than the one shown in the prototype, measuring 9 mm square around the base and standing about 17 mm high above the base of the spindle. It comes in three values of 20 pF, 14 pF and 8.5 pF maximum capacitance. The 14 pF model is the one to use here; it costs around $7.

Each capacitor requires a 6 mm hole to be drilled in the pc board for the spindle. This is drilled through the pc board adjacent to the end of the local oscillator inductor strip (L3), the hole centre being spaced about 9 or 10 mm from the pad at the very end of L3. The capacitor from David Reid Electronics (C1604) could be placed a little closer if you wish. Whichever capacitor you use, it must clear adjacent components. The main requirement is to place the solder tag for the fixed plates connection above the pc board hole for the gate of the local oscillator FET, Q1.

When securing the variable capacitor to the pc board, make sure the nut gets a good grip so that the shaft and spindle are well connected to the groundplanes on the top and bottom of the board. Ensure that the areas of copper on the board surrounding the spindle hole are clean and bright before installing the capacitor.

With the capacitor installed, Q1 needs attention. The drain lead goes in the original hole (see the overlay), but the source lead now goes in the hole where the gate lead went on the single channel version (again, refer to the overlay). Now, pass a short length of tinned copper wire through the hole in the pad on the very end of the local oscillator inductor strip (L3), up to the lug connecting to the fixed plates on the variable capacitor. Solder the wire to the board, then bend the lug on the capacitor down towards the board and solder the free end of the wire to the lug. Take the gate lead of Q1, bend it towards the capacitor lug and solder it in



The completed single-channel converter. Topside of the board is largely copper with 'let-outs' where components pass through. Input is on the left, output at right.

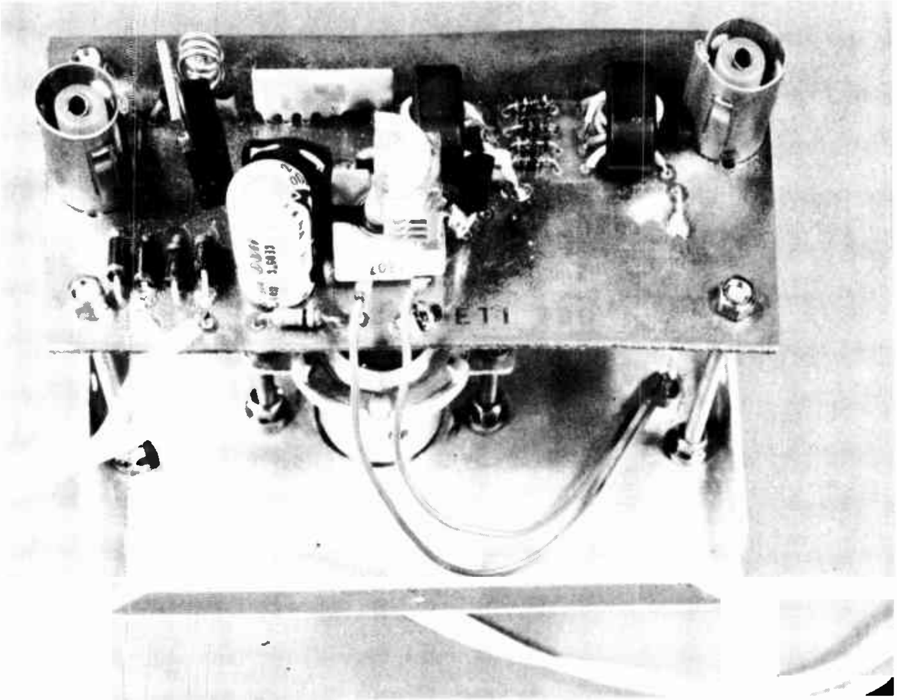
place. The one thing to remember here is to *keep all leads as short as possible*. The accompanying close-up photograph shows how we did it.

The converter may now be mounted in a box, so that the vernier drive and dial can be installed. The vernier drive we used is a Jackson dual-ratio type having a 2:1 and a 6:1 action. This is designed to couple to a 6 mm (¼") diameter shaft. The Johnson capacitor specified has a 4.8 mm (3/16") diameter shaft, while the C1604 capacitor from David Reid Electronics has a 4 mm diameter shaft. You will need an appropriate split-tube shaft reducer to slip over the capacitor's shaft, depending on which particular type you are using.

We mounted our tuner in a small Horwood box, type 34/6/D. This consists of an aluminium extrusion 100 mm wide by 75 mm high and 75 mm deep with a panel in each end secured by self-tapping screws. The converter and dial mechanism are secured to one end panel and the RF input/output and power supply cables are passed through holes in the other. Drilling details to mount the converter and dial mechanism are given in the drawings below. The pc board is secured to the front panel by four 38 mm long (1½") 6 B.A. bolts, while the vernier dial drive mechanism is mounted using two 25 mm long (1") 6 B.A. bolts. All six bolts have countersunk heads to permit the front panel transfer (such as Scotchcal) to sit flat on the panel. General construction is visible from the photographs here. The best way to go about the mechanical assembly is as follows: first, carefully mark out and drill the front panel as per our detail drawing. Secure all six bolts to the panel using washers under each nut. Thread another nut on each bolt. Slip the vernier drive over its two mounting bolts and position the two nuts such that the mounting lugs of the drive are about 15 mm from the panel. Secure the drive mechanism with two more nuts and washers, making sure the drive shaft passes through the panel at a right angle otherwise your dial pointer will not move parallel to the front panel.

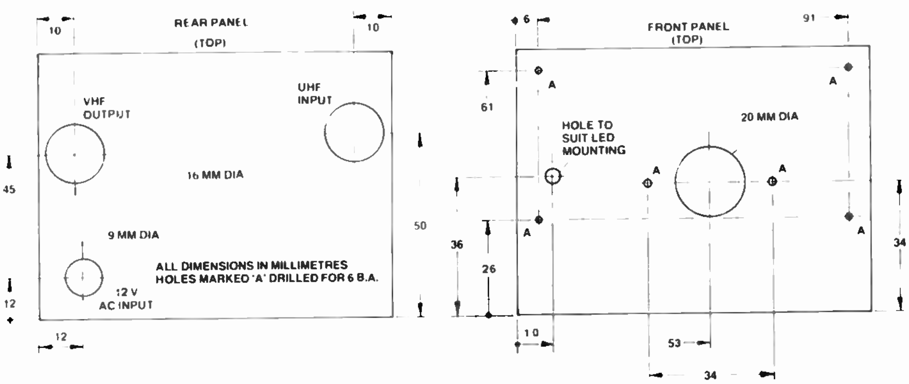
Now, slip the shaft reducer over the shaft of the variable capacitor. Assemble the pc board onto the mounting bolts and position the nuts on each bolt so that the board is about 32 or 33 mm from the panel. The capacitor shaft should line up with the drive coupling. Don't secure the board yet. Tighten the grub screws on the drive coupling to secure the capacitor shaft. Now you can secure the board with four more nuts.

Before you assemble the dial pointer mechanism to the vernier drive, fix the indicator LED in place and then attach the panel artwork. We used a Scotchcal panel, but only general markings are shown, as the exact channel positions (or frequency markings) will depend on which VHF channel you select as the converter's output. With the panel artwork in place you can assemble the dial pointer mechanism to the vernier drive. ▶



The completed tuneable version showing how we mounted the board and dial mechanism.

Close-up of the FET and tuning capacitor in the tuneable converter, showing where the capacitor is mounted and how the FET's gate lead is bent over to the capacitor's lug. The source lead now goes in the original gate hole.



Panel drilling details for the Horwood box in which we housed the tuneable converter.

We cut a piece of 3 mm thick perspex to shape and put a line on it with black ink.

The rear panel of the box has three holes drilled in it, two to pass the input and output cables and one, which is grommeted, to pass the power supply input lead. Pass the ac supply lead (length of figure-8 flex) through the grommeted hole and the input and output cables through the appropriate holes and then assemble the rear panel to the case. Wire up the ac supply to the pc board and you're ready to roll!

Setting up

Setting up the single-channel version is quite simple. We presume you already have an antenna (ETI-728 page 71.) Install a short jumper cable from the converter's output to the TV receiver's input. Attach the ac power source to the converter (plugpack or what-have-you), plug in your UHF antenna and switch on.

You will need to select an appropriate unused channel on your TV receiver. For UHF stations in Band IV (channels 28 to 34), VHF channel 1, or an adjacent unused channel, can be used. For Band V UHF stations (channels 38 to 63), select one of the higher VHF channels, such as channel 6 or 8.

First ensure your antenna is pointing in the right direction. Then, using an insulated alignment tool, adjust CV1 for best reception on the UHF channel you want to receive. Start with CV1 set at maximum capacitance so that the local oscillator frequency is tuned *upwards*. It is possible to tune Band IV stations by setting the local oscillator above the channel of interest, but this is not recommended as it may be possible to experience interference from stations on the 'image' frequency. For example, say you have chosen VHF channel 1 (56 MHz) as the converter output frequency. You can receive UHF channel 28 by setting the local oscillator to 470 MHz (526 - 56 MHz). You can also receive channel 28 by setting the local oscillator to 589 MHz. However, a station on 645 MHz (channel 43) may be received equally well. This channel is not occupied at the moment, though.

Setting up the tuneable version is very similar. First, set the dial to the lowest frequency (capacitor plates fully meshed). Attach the antenna and jumper cables and the ac power input from the plugpack, and power up. For the tuneable version, one of the higher frequency VHF channels should be selected on your TV receiver. If you want to go right up to UHF channel 63, you'll have to use VHF channel 11, as the converter's local oscillator in the tuneable version does not go above 600 MHz as it does in the single channel version.

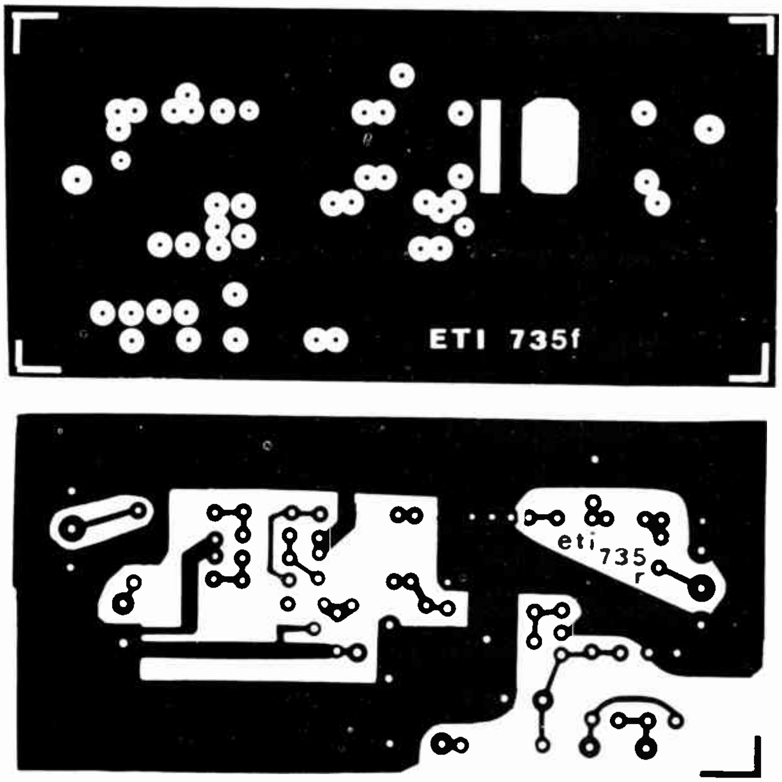
With everything set up, rotate the dial until you obtain good reception of the station of interest. Dial positions of channels can be noted on the panel with a Chinagraph pencil and the channel number put on later with rub-down lettering such as Letraset.

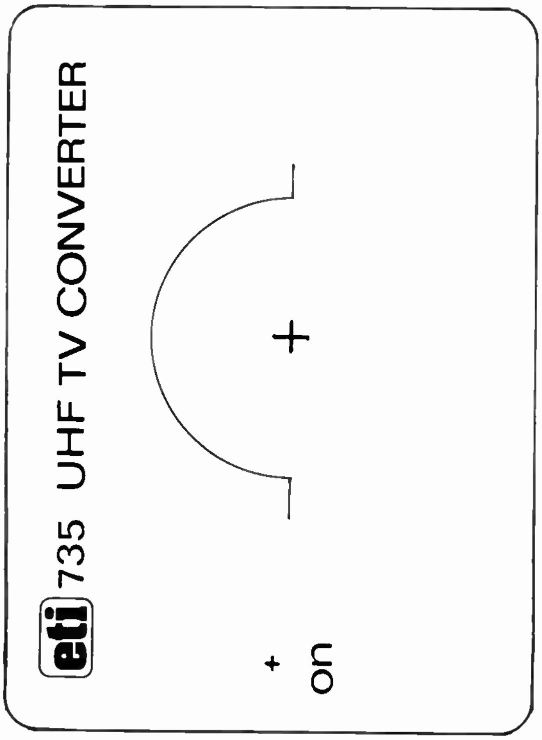
If you find you need to improve reception, experiment with the position and direction of the antenna. If necessary, further improvement can be obtained by using a masthead amplifier, such as our ETI-729.

Amateur TV use

The converter is eminently suited to amateur TV applications in the 420-450 MHz (70 cm) amateur band. Two 'channels' are used: 425-432 MHz (vision carrier on 426.25 MHz) and 443-450 MHz (vision carrier on 444.25 MHz). The local oscillator range in this converter is more than adequate to cover these two frequency bands, set to either the 'high side' or the 'low side'. However, the input high-pass filter will require some modification. This is simple — squeeze both coils until they're just under 3 mm long! This will bring up the gain around 400 MHz and still provide a reasonable roll-off below 250 MHz to attenuate the strong VHF TV station signals that may bring crossmodulation problems. ●

Full-size artwork for the front and rear sides of the pc board. Take care to place them the right way round and align them when exposing the resist.





Full-size artwork of the front panel for the tuneable converter.

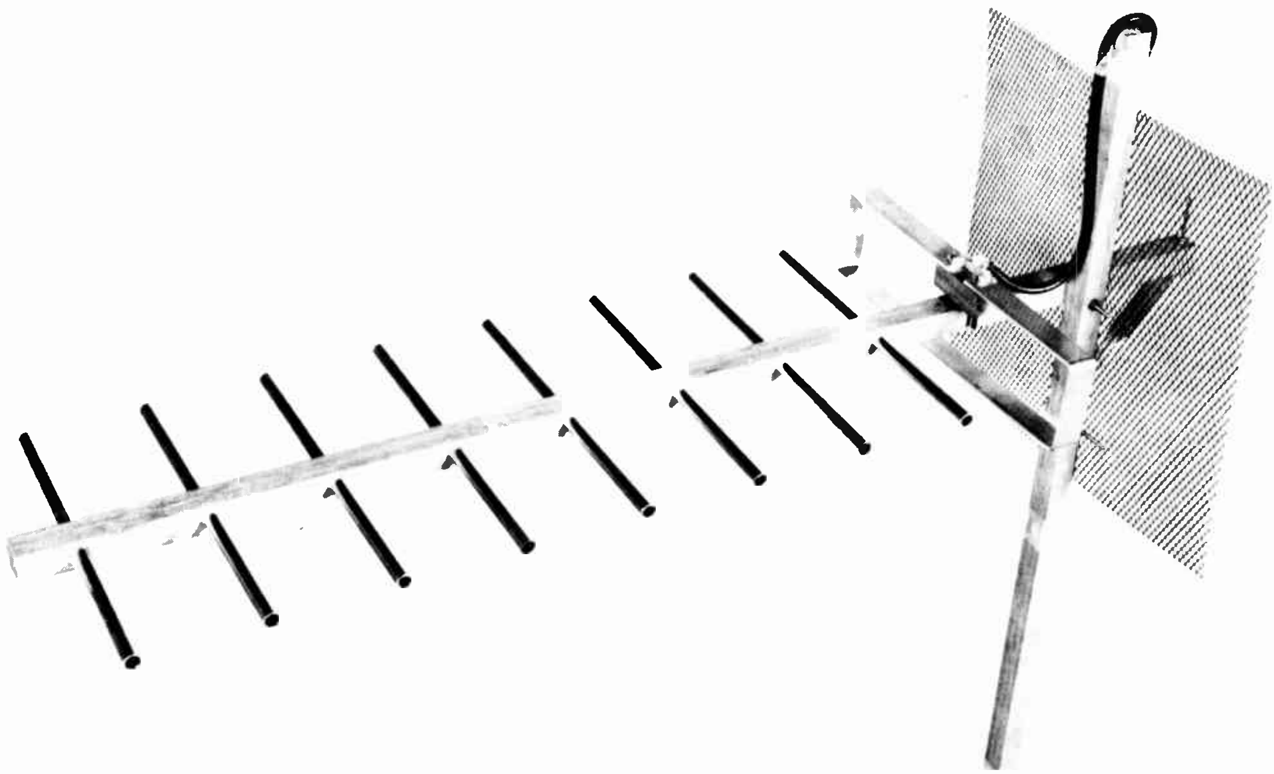
UHF TV has arrived ! — build yourself an antenna

This simple UHF antenna, from an idea provided by a reader, James Gerassimon of Penrith, NSW, proved to provide performance superior to some commercially available models.

NOW THAT 'ethnic' TV broadcasting is well under way on channel 28, and UHF repeater services for the existing VHF channels have sprung up, the time has come to exploit the advantages UHF TV offers. But first, you'll need a good antenna — assuming your TV receiver incorporates a UHF tuner! If you've bought a 'down converter' (or are thinking of doing so), then this antenna should help get you 'on the air'.

Available ready-built UHF TV antennas range in price from $20 to $100, and then there's the installation cost if you're not going to do it yourself. This antenna cost us well under $10 in material. The single most expensive item will be the coax between the antenna and TV receiver and the cost of that will entirely depend on how long a run of cable you'll need for your installation.

The design is a fairly straightforward yagi type and features simple construction, rather than optimised performance — which is nonetheless very good. James Gerassimon's original model employed 'all metal' construction, whereas we opted for a wooden boom to simplify construction yet again. General construction is obvious from the photographs.



To make this antenna you'll need two metres of 10 mm dia. aluminium tube, one metre of 25 x 3 mm aluminium strip, a 300 mm square of Multimesh, one metre or more of 19 x 19 mm dressed western red cedar, plus some nuts and bolts. We bought the lot for about $7!

Construction

James glued each of his director elements to a small square of perspex, which he then secured to his boom — consisting of a length of 19 x 19 mm aluminium box-section tubing — using glue. All his elements were made from 12 mm wide by 3 mm thick aluminium strip.

We made our antenna using a wooden boom cut from a length of 19 mm square, dressed western red cedar. The elements are 10 mm diameter aluminium tubing, the folded dipole we made from 25 mm wide by 3 mm thick aluminium strip and for the reflector we used 'Multimesh' expanded aluminium.

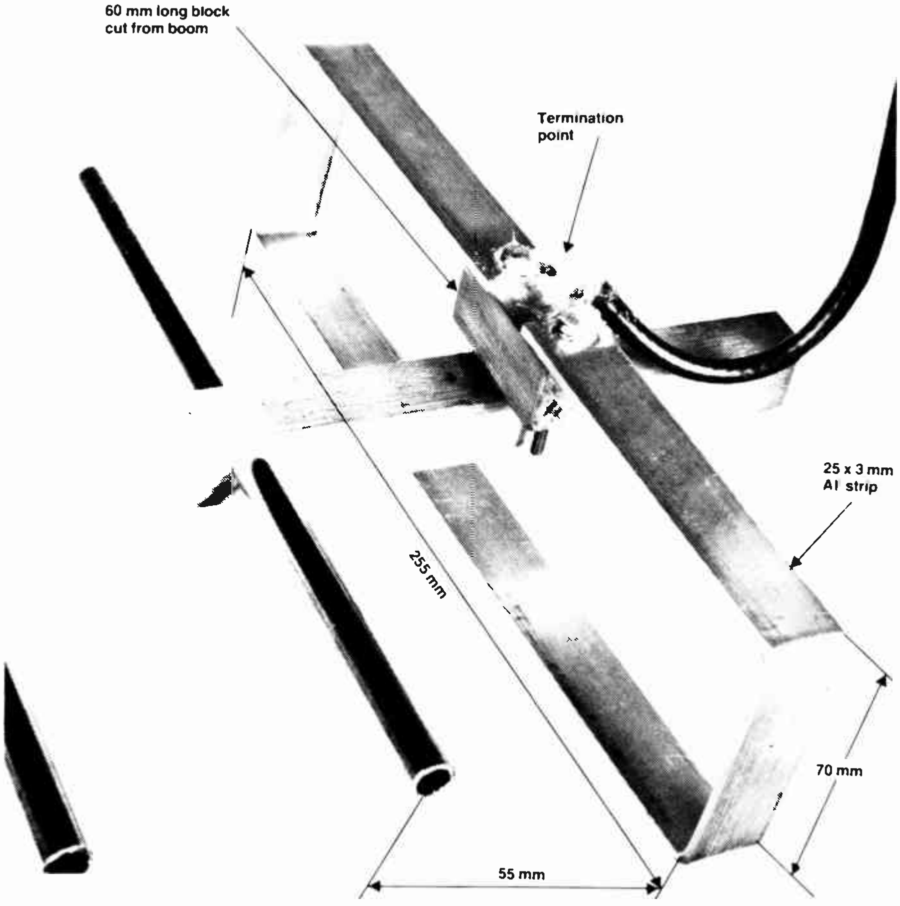
All dimensions are overprinted on the two photographs showing general construction and dipole construction.

Commence construction by cutting the boom to length. Measure the positions of all the holes and mark them clearly before drilling. The holes for the directors should be drilled using a 3/8-inch diameter drill bit. This is slightly smaller than the diameter of the directors (about 9.5 mm) and allows them to be force-fitted. When the drilling is finished, the directors can be fitted, tapping them into place with a wooden mallet or 'soft' hammer so as not to damage the tubing. So that you can centre them accurately, find the centre of each and run a mark around the tubing 10 mm either side of the centre mark. Tap the elements into place until these marks are visible either side of the boom.

The folded dipole was constructed from a 700 mm length of 25 mm by 3 mm aluminium strip. This was cut and bent to the dimensions shown in the folded dipole construction photograph. As the bandwidth of the antenna is quite broad, accuracy of measurement and cutting need not be too stringent; you've got about ±2-3 mm to play with.

The reflector consists of a 300 mm square piece of 'Multimesh' expanded aluminium, obtainable from hardware stores. This we mounted on the *rear* of the wooden mast section, as you can see in the photograph.

The termination part of the dipole is bolted to a 60 mm length of the 19 mm square cedar using two 4 BA bolts. Put a star washer and solder lug under the head of each. The boom and this block of wood should be coated before final assembly in a clear outdoor lacquer/ preservative (such as 'Estapol') to protect the wood. Glue the dipole in place when everything is dry.



Construction of folded dipole.

The boom is bolted to the wooden mast section and a brace, made from a piece of the 25 x 3 mm aluminium strip. is used to support it rigidly. A 90° twist in the brace is necessary — see the photograph of the rear of the antenna. The reflector is assembled in position before the brace is attached. You'll have to cut holes in the mesh where the boom and the brace pass through it, which is easily done using a pair of sidecutters. Note that the hole for the boom is *not* in the centre of the mesh.

With the antenna assembled, the next step is to terminate the coaxial cable. Note that 300 ohm ribbon is *rarely* used on UHF installations as its loss is generally greater than coax at these frequencies and it deteriorates rather rapidly due to the weather. No attempt was made to provide a balanced-to-unbalanced connection for the coax — few commercial UHF antennas do and we've ignored it also; performance seems unaffected. Once the coax is terminated to the dipole feedpoint connections, apply a liberal amount of a suitable sealant, such as 'Silastic', to prevent water getting into the cable's insulation.

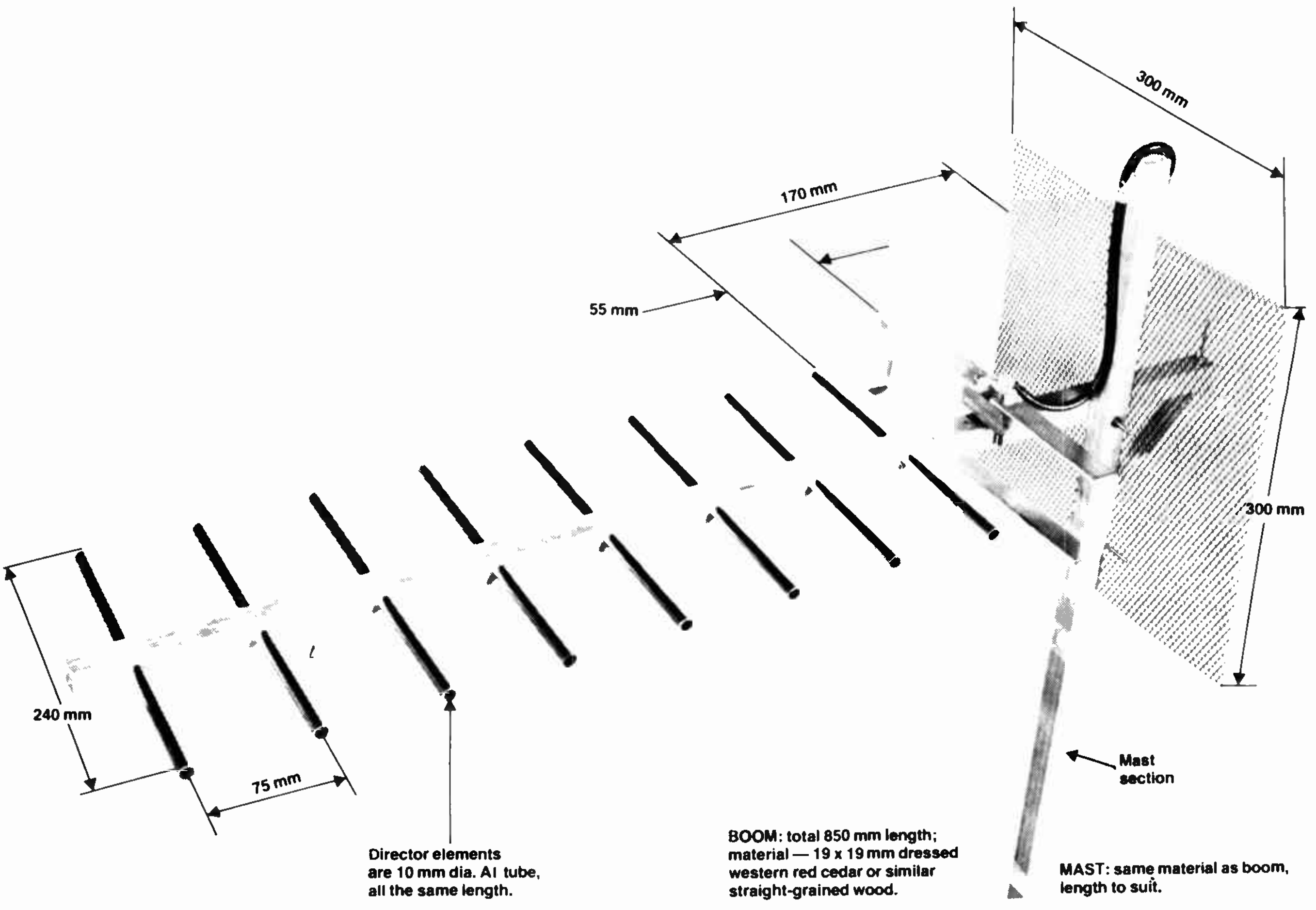
You can give the antenna a test run, but remember that UHF is not as tolerant as VHF and you should mount it pretty well where you intend it to finish up.

Results

We decided to give our antenna a *good* tryout, from a site at Annangrove, northwest of Sydney and some 55 km as the crow flies from the transmitter. 'Normal' reception without this antenna could be described as "... well, there might be something there, but ..." on both channel 0 and 28. This antenna brought up a colour picture with just a smidgin of noise. No ghosting was evident. Shortly after installation, a violent summer storm passed through the area, which the antenna survived without damage.

James Gerassimon compared his antenna to a commercial model costing about $20. The latter antenna provided a weak, distorted picture, but with colour. His homemade antenna provided a considerably better picture, according to the details he supplied.

Good luck with yours! ●



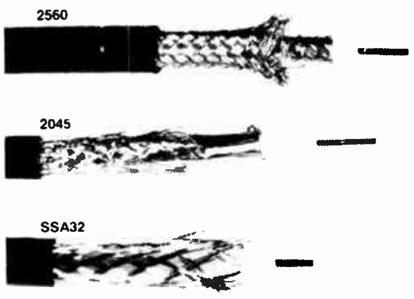
General construction. Note that a metal mast may be used instead of the wooden one.

INSTALLATION HINTS

You have to be a lot more careful when installing UHF TV antennas as UHF propagation is much more 'line of sight' than VHF. Also, UHF waves are absorbed and reflected by tiles, guttering etc. to a much greater extent than VHF.

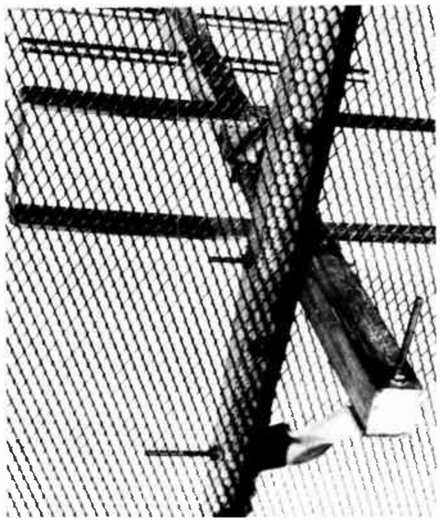
CABLE

Success will depend on the feedline chosen — choose a good quality, low loss coaxial cable from a reputable manufacturer. We don't recommend 300 ohm ribbon — neither do commercial manufacturers, it just doesn't work at UHF. Our antenna and the majority of commercial models are designed to feed 75 ohm cable. Use coaxial cables such as good quality RG59/U (from a variety of manufacturers), SSA32 (locally made by Hills) or 2045, 2560 and 2402 from Electrocraft. Those types having a foil shield and a braid over it, together with a 'foam' or 'fluted' dielectric are preferred as they will have the lowest loss and hence the best performance. Use as direct a route as possible when installing the cable to keep the cable length as short as possible, to minimise the loss.



MOUNTING

Mount the antenna as high as possible and with a clear view toward the transmitter sight. Close obstructions, such as trees, other buildings etc. can adversely affect the signal so a little planning can go a long way towards getting a good result. Do not mount your UHF antenna too close to your VHF TV antenna. Separate the two by 1½ to two metres, at least, with the UHF antenna higher than the VHF antenna.



Rear view showing support strap for the rear of the boom. The picture was taken when the reflector mesh was only thumb-tacked to the mast. It has since been more securely fixed with screws.

High impedance instrument probe features 100 MHz bandwidth

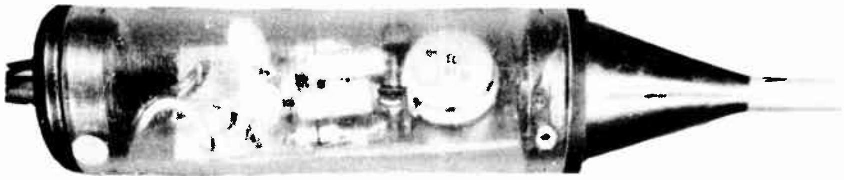
This probe will allow you to make CRO or frequency meter/timer measurements on high impedance circuits with waveforms having rise times as fast as three or four nanoseconds. Cost is well below commercial equivalents.

Jonathan Scott

MOST READERS would be aware that, when taking a measurement on electronic circuitry, the input impedance of the measuring instrument must be much greater than the impedance of the circuit to which it is attached, otherwise the accuracy of the measurement suffers. The input impedance of the majority of oscilloscopes is generally 1M with a parallel capacitance of between 20 pF and 40 pF. For a wide variety of applications this is perfectly adequate and will suffice for measurements of frequencies up to 5 MHz or so. The input impedance of the CRO falls with increasing frequency owing to the falling reactance of the input capacitance. For example, a capacitance of 30 pF — which may be made up of direct input capacitance plus cable capacitance — has a reactance of only 500 ohms at 10 MHz. The input capacitance also affects the rise time of the input — that is, the speed at which a 'step' input will rise from the 10% amplitude value to the 90% amplitude value.

The input impedance of an oscilloscope can be effectively raised, and the capacitance decreased, by using a 'step-down' probe. For example, a 'x10' probe will generally have an input impedance of 10M and a parallel capacitance of between 5 pF and 15 pF. While this improves the input impedance there are two trade-offs. Firstly, unless elaborate (and expensive) compensation is employed, the rise time is degraded, and secondly, maximum sensitivity is decreased by a factor of ten. As Murphy's law would have it, your CRO will run out of grunt just when you need it most.

Taking the situation with digital counter/timers, we find similar problems. Those that operate beyond 30 MHz or 50 MHz generally employ a prescaler with an input impedance of 50 ohms — which is perfectly all right if you're working on low impedance circuits and/or with high signal levels. But there are those occasions when you need a high impedance input and a fast (high frequency) rise time. As with the CRO, this is where your counter/timer runs out of grunt.



It's times like these you need . . . the ETI-156 instrument probe. This project is a x1 active instrument probe using a special buffer IC with an input impedance of typically 100 000 megohms! — that's 10^{11} ohms — a very low input capacitance of around four to five picofarads, a fast rise time (around three nanoseconds) and a bandwidth of 100 MHz. Output impedance is around 50 ohms and the device is capable of driving capacitive loads up to several thousand picofarads. Thus it is eminently suited for use with high speed, wide bandwidth oscilloscopes and digital frequency meter/timers at frequencies up to 100 MHz. Output impedance is close to 50 ohms and it is thus suited to drive both high impedance instrument inputs and low impedance inputs (which are generally 50 ohms).

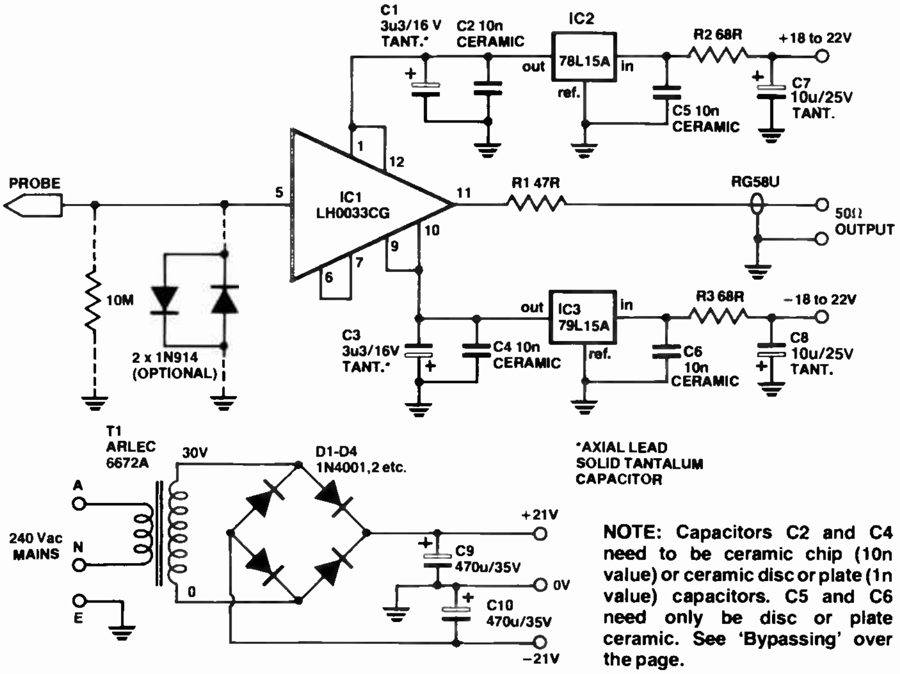
Design

It's all done inside a special IC — an LH0033CG from National Semiconductors. This is described as a 'fast buffer amplifier'. (It has a companion designated LH0063, described as a 'damn fast buffer amplifier'!). The LH0033 is a direct-coupled FET-input voltage follower/buffer (gain ≈ 1) designed to provide high current drive at frequencies from dc to over 100 MHz. It will provide ±10 mA into 1k loads (±100 mA peak) at slew rates up to 1500 V/µs, and the chip exhibits excellent phase linearity up to 20 MHz. No offset voltage adjustment is required as the unit is constructed using specially selected FETs and is laser-trimmed during construction. Input is directly to the gate of a junction FET, operated as a source follower, driving a complementary output pair of bipolar transistors.

Regulated plus and minus supplies of 15 V each provide power to the IC. Low-power three-terminal regulators are

SPECIFICATIONS ETI-156 HIGH IMPEDANCE INSTRUMENT PROBE

Input impedance		10^9 to 10^{11} ohms (depends on construction)
Input capacitance		about 5 pF (depends on construction)
Maximum permissible input voltage		
	*Hi-z load	±15 V
	*50 Ω load	±10 V
Output impedance		50 to 55 Ω
Bandwidth		100 MHz
Rise time		better than 3.5 ns
Gain	*Hi-z load	0.98
	*50 Ω load	0.49



NOTE: Capacitors C2 and C4 need to be ceramic chip (10n value) or ceramic disc or plate (1n value) capacitors. C5 and C6 need only be disc or plate ceramic. See 'Bypassing' over the page.

used to keep the unit compact. An external unregulated supply of between 18 and 22 volts at around 50 mA is required to power the probe.

The supply pins on the IC need to be well bypassed over a wide frequency range so that the IC can maintain its characteristics, and the construction has been specially arranged to achieve this. Axial lead solid tantalum capacitors are used to bypass the IC's supply pins at the lower frequencies, while low inductance ceramic capacitors are employed as bypasses for the higher frequencies. A double-sided fibreglass pc board is used to preserve the high frequency response and the high input impedance, and the layout is arranged

SPECIFICATIONS LH0033

Absolute maximum ratings

Supply voltage	±40 V
Max. power dissipation	1.5 W
Input voltage	same as supplies
Continuous output current	±100 mA
Peak output current	±250 mA

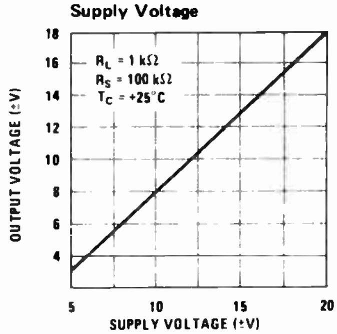
dc characteristics (LH0033C/LH0033CG) — typical

Output offset voltage	12 mV
Voltage gain	0.98
Input impedance	10^{11} ohms
Output impedance	6 ohms
Output voltage swing	±13 V
(V_s = ±5 V)	(6 V p-p)
Supply current	21 mA
(V_s = ±15 V)	
Power consumption	630 mW
(V_s = ±15 V)	

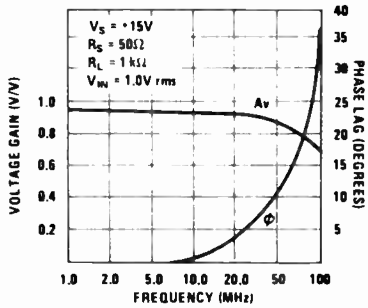
ac characteristics (LH0033C/LH0033CG) — typical

Slew rate (V_{in} = ±10 V)	1400 V/µs
Bandwidth (V_{in} = 1 V_{rms})	100 MHz
Phase non-linearity (1 - 20 MHz)	2°
Rise time (ΔV_{in} = 0.5 V)	3.2 ns
Propagation delay (ΔV_{in} = 0.5 V)	1.5 ns
Harmonic distortion (f›1kHz)	‹0.1%

LH0033 Output Voltage vs Supply Voltage



LH0033 Frequency Response

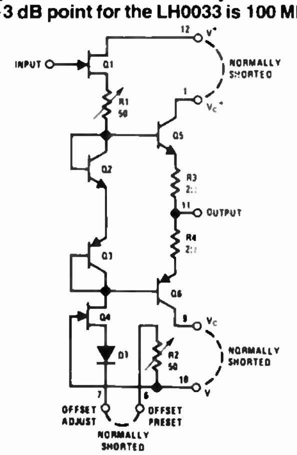


NOTE: Unless otherwise specified, these figures apply for +15 V applied to pins 1 and 12, −15 V to pins 9 and 10, and pin 6 shorted to pin 7. Specifications apply over temperature range between −25°C and +85°C; typical values shown are for a temperature of 25 °C.

HOW IT WORKS ETI-156

This instrument probe employs a wideband hybrid voltage follower/buffer IC, the LH0033, with very close to unity gain, that features a very high input impedance and a low output impedance. It requires regulated, well-bypassed supply rails. Two three-terminal low power regulators provide plus-and-minus 15 V supplies from an unregulated input.

The internal circuit of the LH0033 is shown below. Basically, it consists of a FET input stage (Q1), operated as a source follower. The other FET, Q4, provides a constant current source for the source bias of Q1, while Q2 and Q3 are connected as diodes and provide bias for the bases of Q5 and Q6. Resistors R1 and R2 are laser trimmed in manufacture so that the IC meets the offset voltage specification. As Q1 has a constant current source load, the input impedance at the gate of Q1 is very high indeed and the distortion of the stage is very low. The output of the source follower drives a complementary pair output stage, Q5-Q6. Thus the IC will have a very high input impedance, a very low output impedance and a gain very close to unity. With appropriate construction employed for the internal devices, the bandwidth over which the device will operate can be made very wide indeed. The −3 dB point for the LH0033 is 100 MHz.



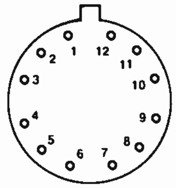
As the device is direct-coupled, dc levels will be maintained between input and output.

Bypassing requirements for the IC's supply leads are explained elsewhere in the article.

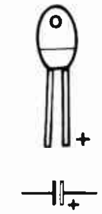
To provide regulated plus-and-minus 15 V rails for the IC, two three-terminal regulators are employed, a 78L15A for the positive rail and a 79L15A for the negative rail. These can supply up to 100 mA and have a very low output impedance up to several hundred kilohertz, which is exploited for low frequency bypassing. Each supply rail requires an unregulated input of between 18 V and 22 V. Decoupling of the supply leads is provided by R2/C7 on the positive rail and R3/C8 on the negative rail. The input terminal of each regulator is bypassed to prevent instability.

As the input voltage is limited to a maximum equal to the supply rails (high impedance load), input protection may be added in applications where only low level signals are being examined. As shown in the main circuit, this protection consists of two 1N914 diodes connected back-to-back in parallel with a 10M resistor across the input. Signals above 1 V peak-to-peak will be clipped, preventing any damage to the IC. If very fast rise time signals are to be examined then better protection for the IC can be obtained by using hot-carrier diodes such as the HP 5082-2800 instead of the 1N914s.

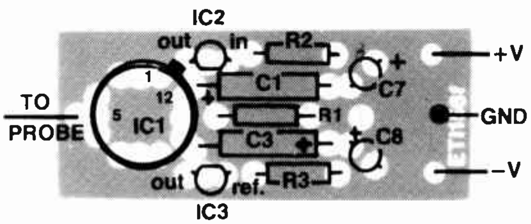
COMPONENT OVERLAY, TOP OF BOARD



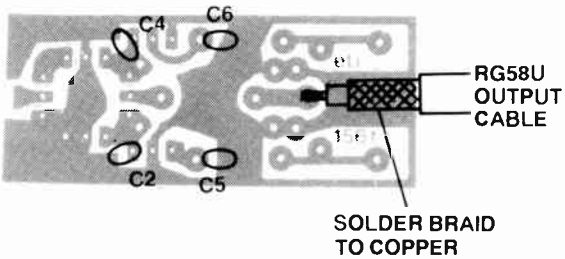
LH0033CG
top view

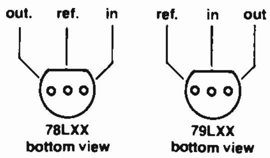


TANTALUM CAPS.

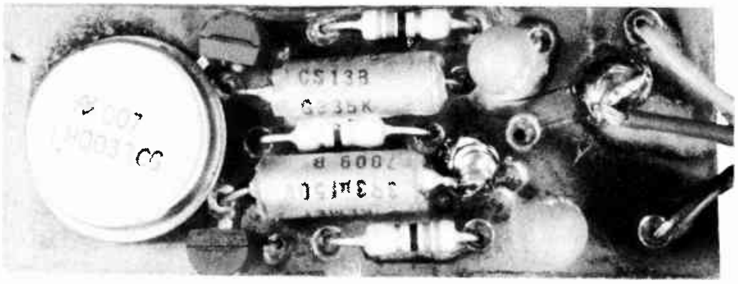


COMPONENT OVERLAY, BOTTOM OF BOARD





IC2, IC3 PINOUTS



The completed pc board, prior to assembly in the probe housing (pcb pattern is on page 116).

PARTS LIST — ETI 156

Resistors all ½W, 5%
R1 .... 47R
R2, R3 .... 68R

Capacitors
C1, C3 .... 3u3/16 V solid tant. axial leads, or
C2, 4, 5, 6 .... 10n ceramic block caps.
C7, C8 .... 10u/25 V tant.
C9, C10 .... 470u/35 V electros (if required)

Semiconductors
IC1 .... LH0033CG
IC2 .... 78L15A
IC3 .... 79L15A
D1 - D4 .... 1N4001, 2, etc. (if required)

Miscellaneous
ETI-156 pc board (double-sided fibreglass); RG58U coax cable and BNC plug; T1 — (if required) Arlec 6672A 240 V to 30 V transformer or similar; optional 10M/½W 5% resistor and 2 x 1N914 diodes; wire; probe housing — Jabel type PH3T or similar.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$48 - $55

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

to permit direct connection to the probe tip and provide low input capacitance.

However, the presence of the pc board substrate will degrade the input impedance, surprisingly enough, and you can drill out the area of board immediately beneath pin 5 of the IC and solder the pin directly to the probe tip. For those who wish to go 'all the way' (as Frank Sinatra sings), the plastic insulation of the probe tip can be replaced with a similar piece of Teflon — if you can afford it and have access to a lathe.

The maximum input voltage permissible, when driving a high impedance load, is plus or minus 15 volts. When driving a 50 ohm load, maximum input voltage permissible is only plus or minus 10 volts (limited by maximum output current). No input protection has been included. However, if you are only working with circuits where voltages are no greater than about 1 V peak-to-peak, protection can be added by putting two diodes back-to-back in parallel with the input, along with a 10M resistor. The maximum input voltage figures include any dc voltages present, *plus* the superimposed signal voltage.

At this stage it is only fair to tell you that the LH0033CG is an expensive device (by comparison) at around $30 or so apiece over the counter. But — compare the total cost of this probe to a similar commercially-made type and you won't catch your breath a second time!

Construction

The project is constructed on a small double-sided fibreglass pc board *with components mounted on both sides of the board.* Commence by soldering in place the components that go on the top side of the board, leaving IC1 until last. Note that the positive leads of both C3 and C8 are soldered to the groundplane areas on both the top and the bottom sides of the board. Take care with the orientation of the tantalum capacitors, as well as IC2 and IC3. Having done that, solder C2, C4, C5 and C6 to the bottom side of the board. Now you can install IC1. Watch the orientation — the tag on the can points toward the 'out' pin of IC2. You will have to juggle the legs a little. Push the can as far down on the board as you're able; its base should sit no more than 3 mm from the board.

Now that you have everything in place, *check it all.* It seems pretty simple, but Murphy's law will ensure that the simplest things have the highest stuff-up rates!

All's well? — now you attach the output coax cable to the underside of the board, plus the dc input and ground (0 V) wires. *But* — before you do, slip the output end piece of the probe case over the cable and supply wires, push it down about 150 mm or so and then slip the case of the probe case down the wires. This saves slipping them over the other end of the whole business and sliding them all the way to the probe.

The probe tip can be attached and

soldered in place last of all. Now you can screw it all together and attach the appropriate plugs to the other end of the cable and supply wires.

With the construction completed, you can power up and try it out. Note that the transformer suggested in our power supply is but one of many suitable types. Any transformer that will deliver at least 26 Vac at a load of about 50 mA will suffice. Alternatively, any dual-polarity dc supply having an output between 18 and 22 volts at 250 mA will power the probe.

Notes

When using the probe to drive a 50 ohm load, the pulse response can be improved if you wish by a simple modification. Apply a fast rise time square wave to the input and observe the output on a wideband (50 MHz to 100 MHz) CRO. The rise time can be optimised by paralleling small-value ceramic capacitors across R1 — tack them in place on the underside of the board.

Always take care that you don't exceed the input voltage limitation; LH0033s are expensive. ●

BYPASSING

SUPPLY LEAD BYPASSING is important in order that the LH0033 can operate correctly over the full bandwidth from dc to 100 MHz. To ensure this, the bypassing has been specially arranged and the techniques employed are probably unfamiliar to many readers.

The output circuit signal return path for the IC is via the ground and the two supply rails. Any significant impedance in series with this path (or paths) will subtract signal from the output load. Thus, the supply rail bypassing has to present an impedance which is a *fraction* (like one-tenth or better) that of the minimum output load impedance. Here, the minimum output load is about 100 ohms (R1 + 50 ohms instrument input impedance) and the supply bypassing impedance should ideally be less than 10 ohms across the frequency range.

The bypassing on each supply rail to the IC leads here takes advantage of the characteristics of three separate components to cover three sections of the frequency range.

From dc to around 100 kHz, each three-terminal regulator (IC2, IC3) has an output impedance well below one ohm, rising to four or five ohms at 1 MHz, as shown in Figure 1. The two tantalum capacitors, C1 and C3, then take over.

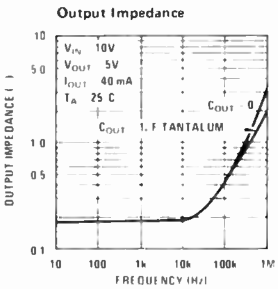


Figure 1. **Output impedance characteristic of a three-terminal regulator.**

Solid tantalum capacitors have a characteristic impedance that falls with frequency according to its value, which then 'flattens out' in the region around 500 kHz — 1 MHz, rising to a few ohms around 10 MHz, as can be seen in Figure 2. Thus, C1 and C3 serve as effective bypasses across the range from around 100 kHz to around 10 MHz. Axial lead tantalum capacitors were chosen as their construction exhibits the slowest impedance rise following the minimum impedance value.

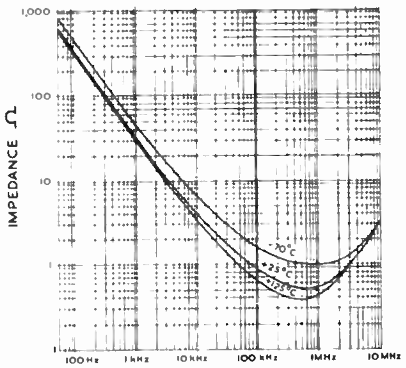


Figure 2. **Impedance characteristic of axial lead solid tantalum capacitors.**

To provide bypassing over the decade from 10 MHz to 100 MHz, capacitors C2

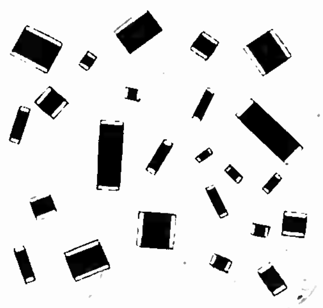


Figure 3. **Ceramic chip capacitors — shown about actual size. They have no leads, just plated end pads for connections.**

and C4 have been specially chosen and positioned on the pc board. For the prototype, 'chip' ceramic capacitors were used. These tiny, 'naked' chips of ceramic with a capacitor embedded in them are probably the most effective bypass capacitors made. The leads and physical construction of all capacitors form an inductance which is effectively in series with the capacitance of the component. The combined effect forms a series resonant circuit, the frequency of which (that is, the self-resonant frequency of the component) is mainly dependent on the length of the connecting leads, the particular construction of the capacitor and the way in which it is mounted. Ceramic chip capacitors, being a tiny block with connecting pads or surfaces on each end, have extremely low values of series inductance and thus very high self-resonant frequencies — see Figure 4. Now, any value of chip capacitor between 1n and 10n can be used for C2 and C4. The self-resonant frequency of a 1n chip capacitor is somewhat above 100 MHz (as per Figure 4), but that of a 10n chip is between 40 MHz and 50 MHz. Now, this isn't a problem, for the chip's impedance falls with frequency as usual until near the self-resonant frequency where it falls rapidly, reaching a minimum at the self-resonant frequency. Above that frequency its impedance rises again, but is still low enough for effective bypassing.

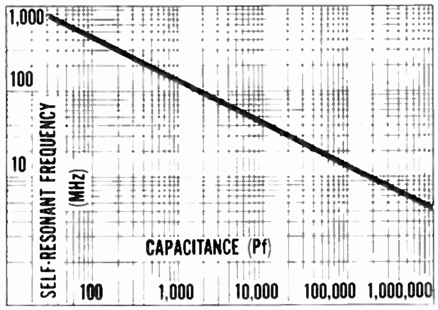


Figure 4. **The self-resonant frequency versus capacitance of a typical ceramic chip capacitor.**

Ordinary ceramic disc and plate capacitors behave in much the same way. The self-resonant frequency of a typical 5 mm diameter disc or 5 mm square plate capacitor depends on the lead length, as shown in Figure 5. Thus, you could use 470 pF or 1000 pF (1n) capacitors of this type for C2 and C4, provided you installed them on the underside of the board with *absolute minimum lead length*. More information on this subject can be obtained from "Self Resonance in Capacitors" by Roger Harrison, ETI March 1978, page 80.

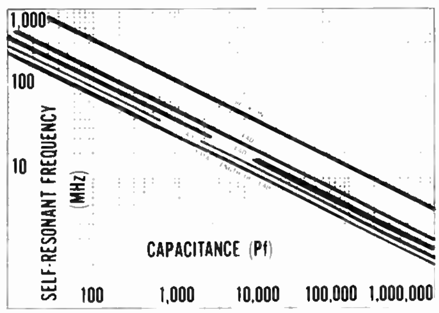


Figure 5. **The self-resonant frequency versus capacitance of a typical 5 mm disc or plate ceramic capacitor with differing lead lengths (from lower curve, up — 25 mm lead length, 22 mm, 13 mm, 6 mm and none).**

An 'intelligent' battery charger

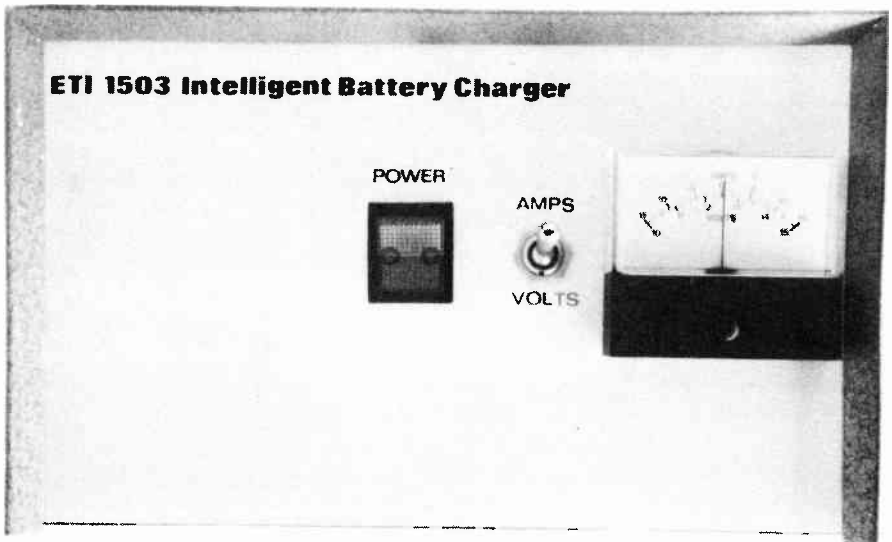
This is no ordinary battery charger. If you run a house alarm system, an amateur repeater or any electronic system with a 12 V battery 'back up' supply, this charger will keep that battery in a healthy state. It has other uses, too.

Jonathan Scott

IT IS PERHAPS too little known a fact that lead-acid batteries are not happy if left fully charged or discharged. They need to be used to stay in good condition. This is not, as a rule, a difficult situation when the battery is in a car, say, because it is called upon to run clocks or parking lights and to start the engine, and is charged when the engine is running. Some cars even arrange for the battery to be discharged to some extent when the engine is running and the lights are on (a mechanism into which we will not go just now). However, sad is the battery used as a burglar alarm power back-up system where it is continuously topped up, awaiting the moment when the mains fails. The battery fails too often before the mains supply!

As well as avoiding that situation, this charger maintains the 'spare' battery you keep in the garage for when that blighter of a P-plate driver son of yours borrows the Kingswood and leaves the lights on in the garage. Perhaps you charge it periodically at present, but the poor battery does not do any of the work that is necessary for its health and well-being.

Many amateur radio repeaters, popular on the VHF and UHF amateur bands for mobile operation with low power transceivers, employ (or should!) a battery back-up system. When a mains failure occurs the battery may be called upon to supply a pretty arduous load, cycling from a relatively low current in the listening mode to much higher currents when transmitting. To provide an operating time anywhere near the battery's rated capacity, the battery must be in 'good' condition. 'Float' or trickle charging will not ensure that.



The completed project was housed in an inexpensive yet attractive metal case, dressed up with a Scotchcal front panel label. A Scotchcal label could be used for the meter scale; however, University Graham Instruments will be supplying ready-made scales for these meters.

It is to overcome this sort of problem that we have designed this 'intelligent' battery charger.

This device monitors the state of charge and waits dormant until the battery is beginning to get flat. When it is low, but not in the deep discharge region, it turns itself on and charges the battery until it is full, whereupon it goes to sleep again until the battery is near exhausted, and so on. This has the disadvantage that there is an element of luck as to how charged the battery will be at any moment, but it is quite likely to be enough to start a car, for example, or to ring an alarm bell for quite a period. And it will be *just the same* in three months time.

In the burglar alarm back-up application this unit is ideal. It can also be used in conjunction with a load, such as the ETI-147 (Oct. 1980), to 'recycle' a battery to restore lost capacity, or perform tests on a battery in a simulated load situation (how long will it run parking lights?). These last two are the original applications for which it was designed.

Although we have not specifically included it in the circuit, it is a good idea to have a small load on the battery when it is connected to the charger. We have provided terminals on the unit from which to draw power, as we expect the unit will be powering an alarm system or similar. If it is used to keep a spare battery healthy we recommend that a load such as a 180 R, 1 W resistor or a one-watt light globe be connected across the terminals to give a constant but small current drain.

Before we get into the construction,

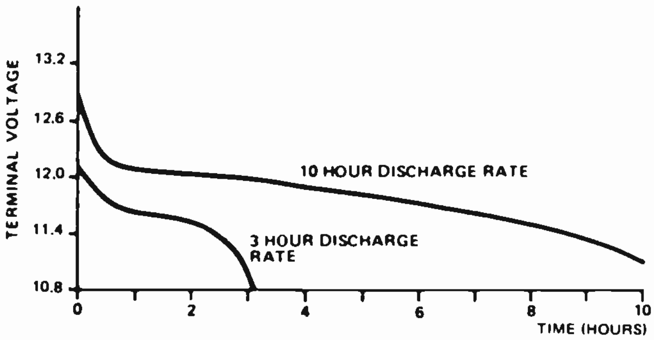


Figure 1. **Typical discharge characteristics of a 12 V (nominal) lead-acid battery.**

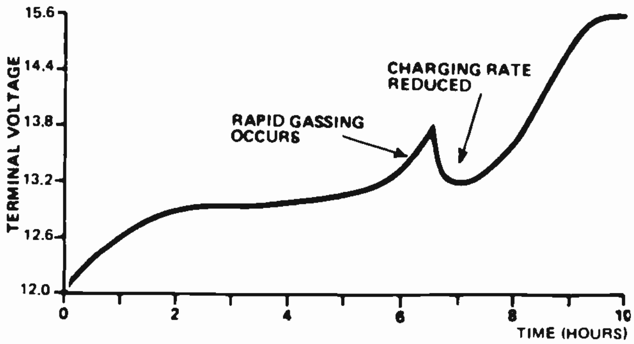


Figure 2. **Charging characteristics of a 12 V (nominal) lead-acid battery. The 'kink' in the curve near six hours is explained in the text.**

let's take a look at the characteristics of lead-acid batteries to gain an understanding of what happens when you discharge and charge them.

Lead-acid batteries

The fully-charged, no-load terminal voltage of a lead-acid cell is between 2.3-2.4 volts. This drops under load to about 2.0-2.2 volts. When discharged, the cell voltage is typically 1.85 volts. The amp-hour capacity is determined from a 10-hour discharge rate. The current required to discharge the battery to its end-point voltage of 1.85 V/cell is multiplied by this time; e.g: a 40 AH battery will provide four amps for 10 hours before requiring recharge. Note however that the amp-hour capacity varies with the discharge current. The same battery discharged at a rate of 10 amps will not last four hours; on the other hand if it is discharged at 1 amp it will last somewhat longer than 40 hours. The typical discharge characteristics of a (nominal) 12 V battery are shown in Figure 1.

The ideal initial charging current for the fully discharged battery (cell voltage under 2.0 V) should be about 20 amps per 100 amp-hours of capacity (i.e: 8 amps for a 40 AH battery). Once the electrolyte begins to gas rapidly, the terminal voltage will be around 13.8 volts and rising rapidly. At this point, the charging current should be reduced to somewhere between 4-8 amps per 100 AH until charging is complete.

At the end of charging, terminal voltage may rise to about 15.6 volts or more, but this decreases slowly after the charger is removed, the terminal voltage then usually reading around 14.0 to 14.4 volts (see Figure 2).

This project may be used with batteries having rated capacities from 4 AH to 100 AH, providing it is set up for the battery in use, according to the set-up procedure given at the end of the article.

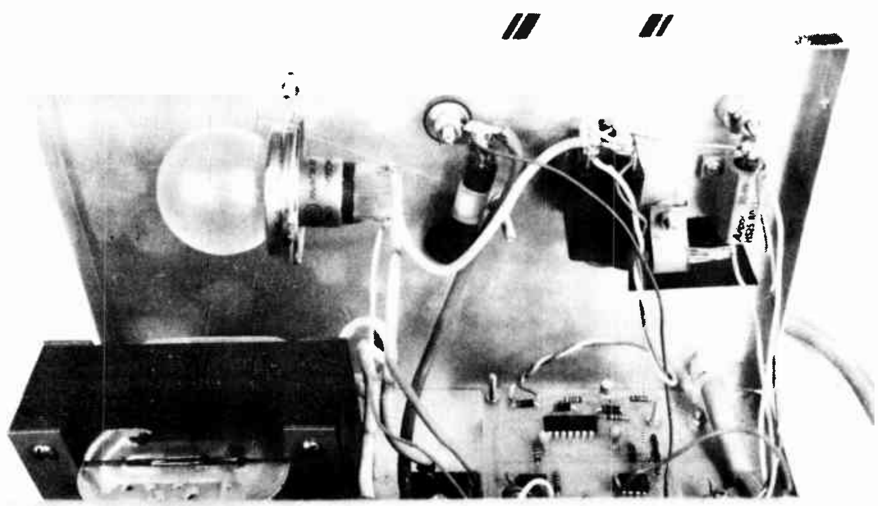
Construction

The component layout is not critical with this project, so there is no need to adhere strictly to the details which follow, provided you know roughly what you are about. The only constraint is that quite a lot of power (60-odd watts) is dissipated by the circuit as a whole and so the design needs to be fairly open and well ventilated.

We used a 'K&W' model C1066 box which allows plenty of room and has good ventilation slots in the sides and top. The first step in the construction is to set the major components out inside the box where you will want them and check that there is enough 'room to move' and that wiring will be easy. Mark the positions for mounting holes with a soft lead pencil, then remove the bits and pieces and drill the holes. We used a 6 V headlight globe from Volkswagen for LP1, which we mounted by soldering some 18-gauge tinned copper wire to the metallic collar and forming bolt holes in the ends of the wire. This held it most satisfactorily about 10 mm from the rear panel of the case, just below a set of vent slots.

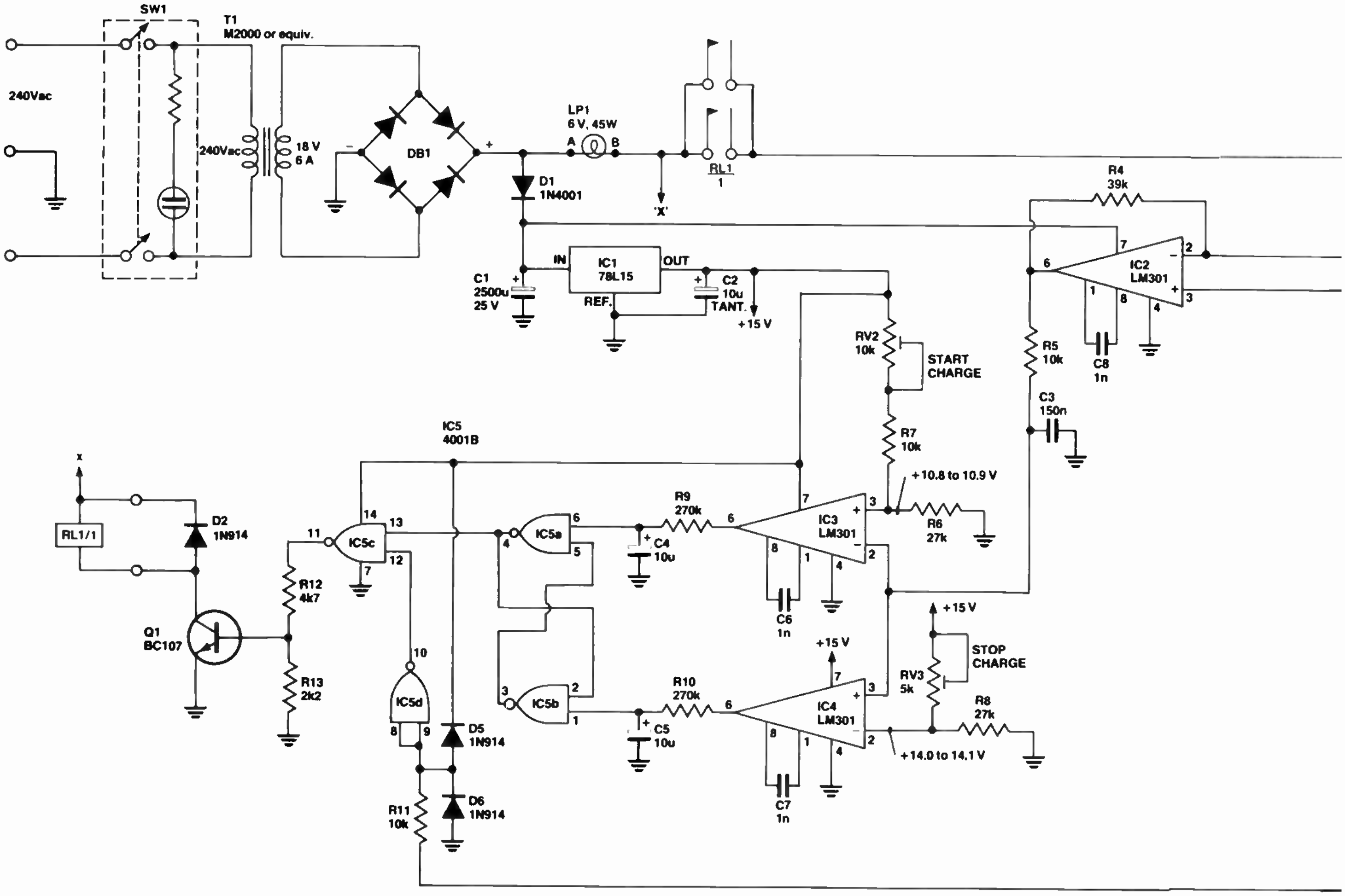
Next fit the components to the pc board as shown in the overlay, starting with the resistors and capacitors and finishing with the ICs. Take care to observe the correct polarity with the electrolytic capacitors, diodes and ICs. Attach adequate lengths of hookup wire, where applicable, to the pc board.

Next, fit and interconnect the various components in the box. The metal-clad power resistor, R1, will be carrying up to 15 A or so at maximum and thus should be connected to the battery and the output terminals by short lengths of the heaviest cable possible. We used 6 mm-thick automotive starter-type ▶



View of the rear panel showing how we mounted the various major components. Note the 45 W lamp 'ballast'. The relay was glued in place between the two output terminals. The Arcol metal-clad resistor is mounted as close as possible to the positive output terminal.

Project 1503



HOW IT WORKS — ETI-1503

The overall function of the device is as follows: when the open-circuit potential of the battery falls to below about 10.8 volts the charger turns on, charging the battery until the potential rises to about 14 volts, whereupon it turns off the charging current and waits dormant until the cycle repeats.

Let us start by considering the conditions when a normal, partially charged battery is connected and the unit is dormant. IC2 in conjunction with R1 and the surrounding components are connected to determine the open-circuit voltage potential of the battery even though it may have a load drawing power. IC1's output is equal to the terminal voltage of the battery minus about 4 times the voltage across R1, times the reduction fraction of RV1; mathematically it is:

$$V_{out} = V_{battery\ terminal} - \frac{39k}{10k} \times V_{across\ R1} \times K$$

where K is the fraction between 0 and 1 determined by RV1

When a load current is drawn from the battery a voltage = $I_{load} \times R1$ is dropped across R1. With respect to the voltage at the junction of R1 and the battery (the reference for IC2) this potential is negative. By choosing K to be the correct value, which is:

$$K = \text{Internal Resistance of battery} \times \frac{1}{3.9} \times \frac{1}{R1}$$

$$V_{out} = V_{battery\ terminal} + I_{load} \times IR_{battery} = V_{open\ circuit}$$

Since K cannot, of course, exceed a value of one, the circuit will handle batteries with internal resistances up to 3.9 times R1, or about 85 milliohms. This should be adequate for all car batteries, but doubling R4 to, say, 82k, will enable batteries with up to 180 milliohms internal resistance to be used, and so on.

Having ascertained the function of IC2, let us now consider the action of the rest of the circuit. IC3 and IC4 act as comparators. The output of IC3 goes high when the battery open-circuit voltage falls to below 10.8 volts. This level is set by RV2, which compensates for offsets and component tolerances. The output of IC4 goes high when the open-circuit battery voltage rises to above 14 volts. This is set by RV3. These levels correspond to a battery at the ends of its healthy charge/discharge curve.

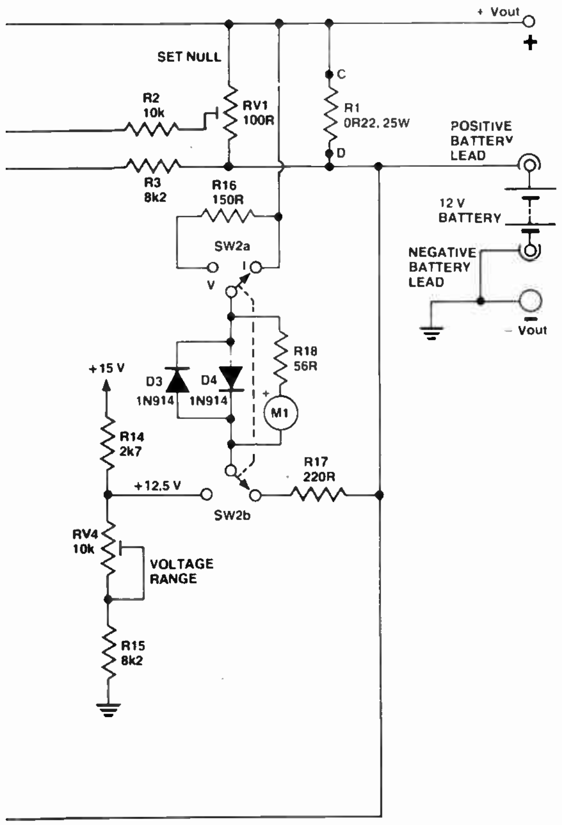
IC5 performs the logic necessary to control the relay. The first two gates (IC5a, IC5b) are coupled as a flip-flop. When the device is idle, the output of IC5a is high and the flip-flop is in the 'discharge' condition. The relay is held off by IC5c. If the battery is very flat, or if the wires are short-circuited, or the battery connected in reverse, IC5d holds the relay off irrespective of the flip-flop condition. When the battery is connected and is only normally discharged, and when the flip-flop is in the charge condition, IC5c turns Q1 on and the relay pulls in connecting the battery to the unregulated supply, again via R1 (permitting actual V_{out} to be measured) and via the light globe, which effectively regulates the current. (More on this in a moment).

IC1 simply provides a voltage reference of about 15 volts, as well as a regulated supply for IC3, IC4 and IC5. The meter and surrounding components provide a convenient 15-0-15 amp current meter and a 10-15 volt suppressed zero voltmeter, which reads the voltage delivered to the load.

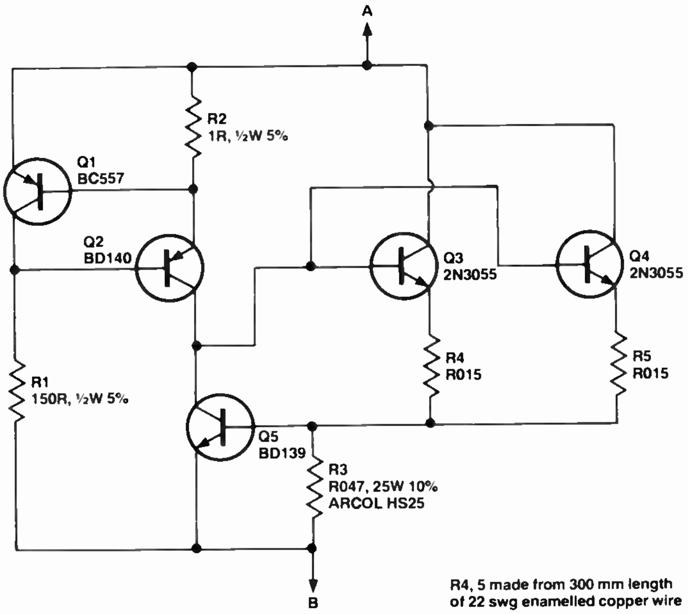
When the battery open-circuit potential falls to below the preset limit (10.8 V), IC3 toggles the flip-flop and RL1 pulls in. The charge current flows until the output of IC4 goes high, toggling the flip-flop back to the original state and turning the relay off. While charging, the current is effectively regulated by LP1 (a 6 V, 45 W light globe). The globe exhibits a characteristic of $I \alpha V^2$, which tends to hold the current at around 5-6 A after it warms up. Initial charging current will be higher. This method of current regulation is by far the cheapest, and causes no RFI, etc. In case anyone should experience trouble getting such a globe, such as might be the case if you do not have a Volkswagen parts place nearby (many old VWs have 6 V headlights), we have included a circuit which can be substituted. It is at once clear how much nicer is the globe approach!

LIGHT GLOBE SUBSTITUTE

Transistors Q1 and Q2 form a current source, feeding about 600 mA out of the collector of Q2. This turns on Q3 and Q4 until 0.6 volts is dropped across the R047 resistor, R3. At this point, Q5 turns on and removes the excess drive current from Q3/4, regulating the current in this fashion. The two R015 resistors, formed by about 300 mm of 22 swg each, ensure that Q3 and Q4 share the load roughly equally. Q3 and Q4 must be mounted on a suitable heatsink.



The circuit is fairly straightforward. The M-2000 transformer (T1) is rated to deliver 6 A at 18 V. However, it will deliver more than twice the output current for short periods, without distress, and we've taken advantage of that. The secondary voltage loads down somewhat, but that's been taken into account. Note that the relay has its contacts paralleled.



Circuit of the light globe substitute.

cables, which ran to the bolt-on battery terminals, rather than the alligator clips usually found on battery chargers and jumper leads. This minimised resistance and hence voltage drop with heavy load currents. The voltage sensing circuitry expects a low resistance path to the battery, so this arrangement is by far the best.

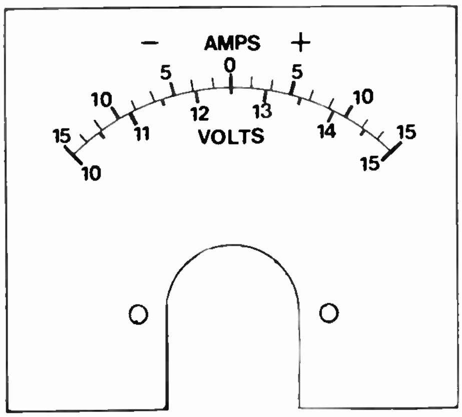
The leads connecting transformer, diode bridge, lamp and output terminals need to be fairly heavy, but not so heavy as the battery leads — ordinary automotive hookup wire (32 x 0.2 mm) or 1.5 mm tinned copper wire in spaghetti is quite adequate.

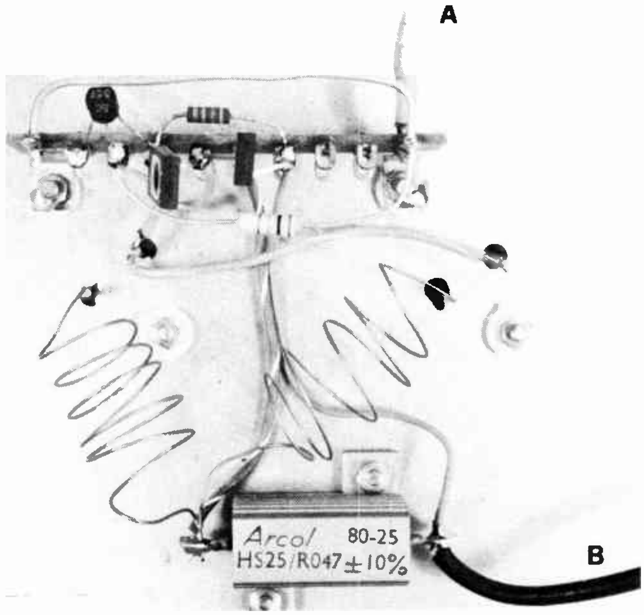
Follow the interconnection diagram to complete the circuit. If you like, a large and chunky bezel can be fitted to an appropriate part of the front panel so that it is illuminated by the globe when the unit is charging.

We felt this to be a little superfluous as light streams out of the ventilation slots!

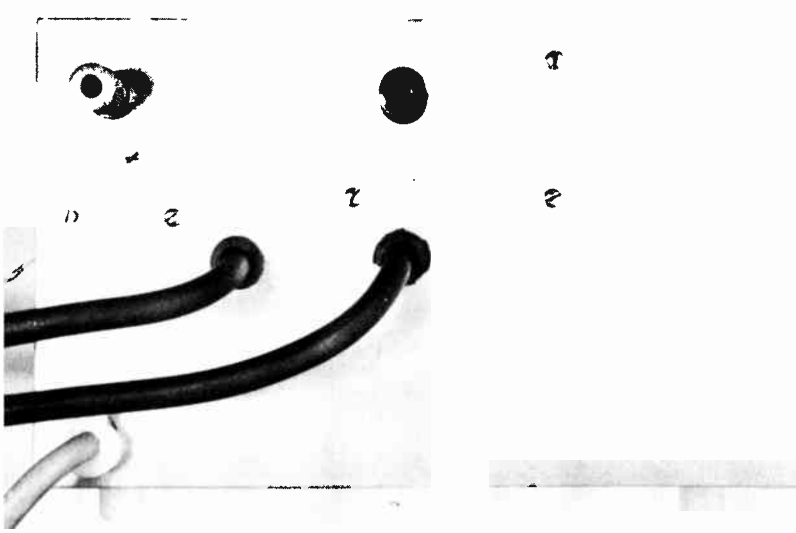
The mains wiring should be installed ▶

Full-scale artwork for the TD-66 1-0-1 mA meter. University Graham Instruments will be supplying meters for this project with this scale fitted.

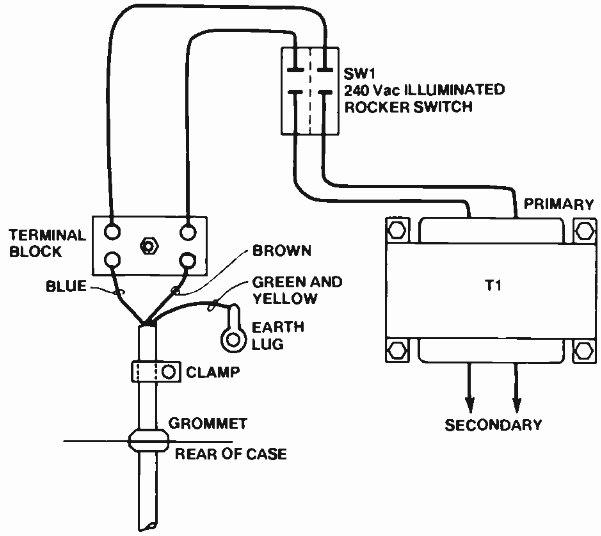




Construction of the light globe substitute circuit. Layout is not critical.



View of the rear panel (exciting, isn't it!), showing the mains cable entry and the two battery cables. The output terminals to supply equipment running off the batteries are at the top, positive on the left, negative on the right.



Mains cable wiring. Be sure to sleeve all exposed connections for your own protection.

with care, the mains input lead being physically 'shielded' from the pc board by a cardboard 'screen'.

For those people with no access to a VW dealer or other source of suitable 6 V globes, we have provided a tested current regulator circuit. We constructed ours using a tag strip which bolted neatly on to the power transistor collector connections (see pic, p. 41). This is a last resort, as it is more costly and less easy to install than a simple lamp, and demands some sort of careful heatsinking. We built ours on a separate small sheet of 1 mm thick aluminium, though there is no reason why you should not use a panel of the box if physically convenient. We mounted two pre-drilled heatsinks to the transistors to dissipate most of the heat. Be sure to fit the 2N3055s carefully, removing burrs which might puncture the insulating washers and using adequate thermal compound. The value of the two R015 resistors (R4, R5) is not critical, though care should be taken to ensure that they are equal in value as their function is to make the two transistors share the load. We made them with about 300 mm of 22 swg enamelled wire each.

Setting up

Once construction is completed, the unit may be set up for correct operation after you have carried out a *thorough* wiring check.

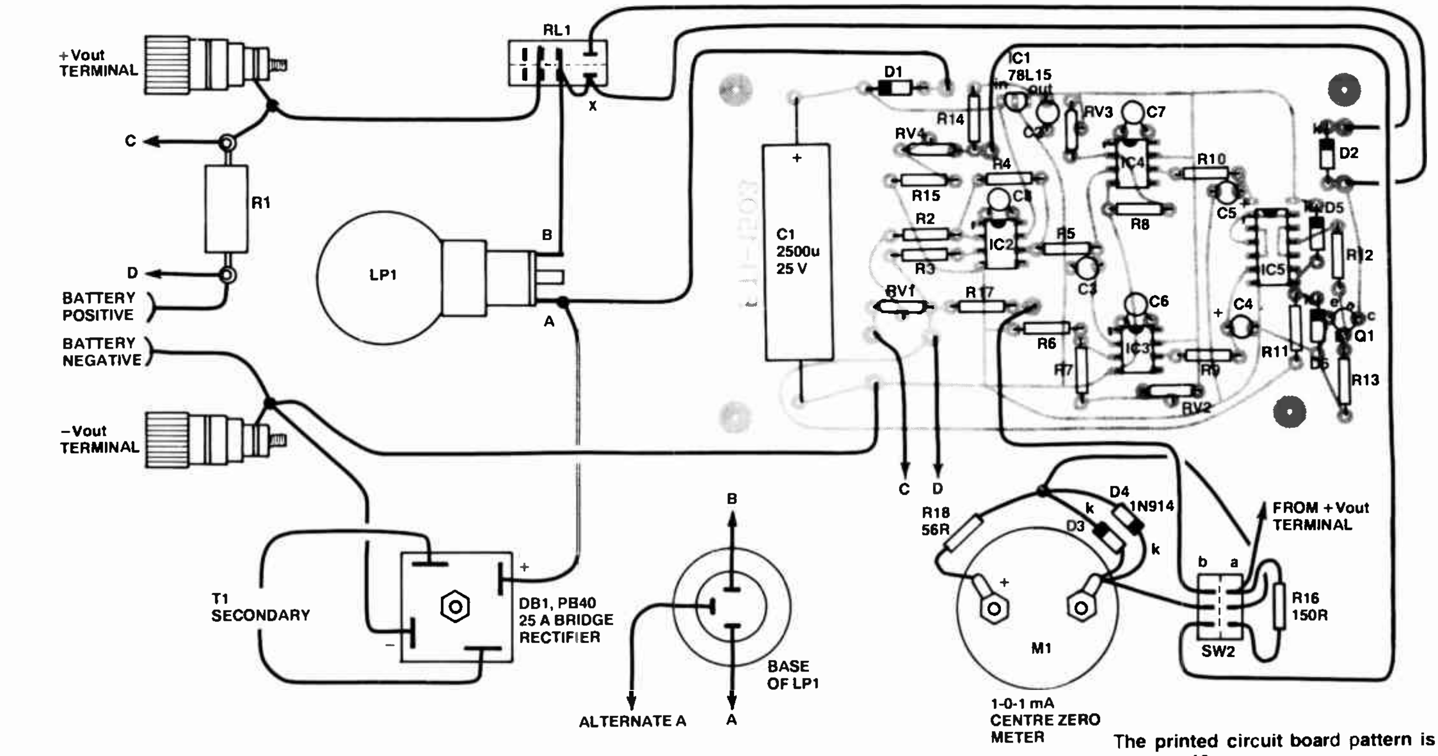
Fit a battery which is not very flat and turn the unit on. It may come on in the charge mode or it may be dormant, depending on the actual battery terminal voltage. To set the charger up you will need a multimeter with a sensitivity of at least 20k/volt.

First, operate the meter switch so that the meter reads volts (V). Connect your multimeter across the output terminals on the rear of the case, set it to read volts, and adjust RV4 so that the front panel meter reads the same voltage as the multimeter. Once RV4 has been adjusted, connect your multimeter (still on the same range) between pin 2 of IC4 (multimeter positive lead) and 0 V (black output terminal). Adjust RV3 so that your multimeter reads 14.0 to 14.1 volts here. This adjusts the point where the charger turns off ('STOP CHARGE'). Next, connect your multimeter between pin 3 of IC3 (multimeter positive lead) and 0 V, and adjust RV2 to obtain about 10.8 to 10.9 volts here. This sets the point where the charger turns on ('START CHARGE').

Finally, the unit needs to be adjusted to compensate for the internal resistance of the battery. This adjustment is simple, but will need to be done for each different battery with which the unit is used. If the unit is charging initially it may be best to toggle it off for convenience. This is most easily accomplished by momentarily connecting the positive end of C5 to the 15 V supply ('out' pin of IC1). Next, connect a load of a few amps to the charger's output terminals, either via a switch or flying leads so that you can connect and disconnect it. Then adjust RV1 so that no change in voltage occurs on the output of IC2 (pin 6) when the load is connected or disconnected. This should not be done with a flat battery — i.e: if the unit goes to charge mode at initial switch-on, let it charge for a few hours before completing the calibration.

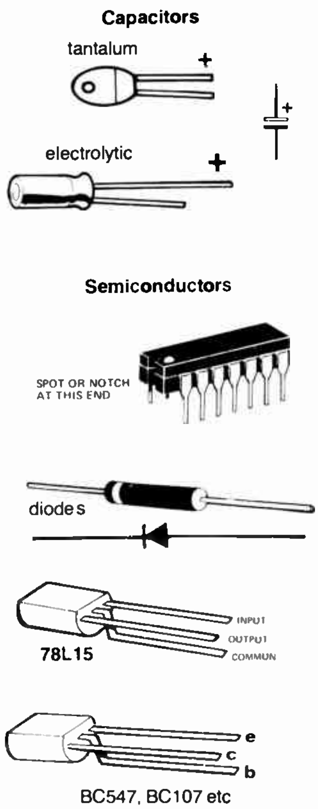
Strictly speaking, the recalibration of RV1 does not need to be redone for any new battery connected, especially if the battery is just going to be left alone and is not intended for back-up work, such as a burglar alarm battery. The internal positive lead resistance will be roughly similar for similar capacity batteries, so this can be neglected if you are only leaving the battery on for a short while, as might be the case if you transfer the car battery onto the charger for a day or a few days. However, RV1 should be recalibrated if the installation is to be considered permanent or if the batteries are very different in capacity.

The charger was designed to be used with batteries having a capacity up to 100 AH. The smallest capacity car batteries generally available are rated at around 32 AH. They will perform quite happily when used with this charger, though the charging current is greater than optimum. For batteries having a capacity lower than 40 AH, the charging current may be conveniently reduced if you wish by using the lower wattage filament in the globe specified for LP1. Connect the 'A' lead from the bridge rectifier positive terminal to the alternative filament connection as shown in the LP1 Base Lead diagram with the overlay and wiring diagram. ●



The printed circuit board pattern is on page 40.

COMPONENT PINOUTS



PARTS LIST — ETI-1503

Resistors all ½W, 5% unless noted

- R1 .... R022, 25 W (Arcol, metal clad type)
- R2,R5,R7,R11 ..... 10k
- R3,R15 .... 8k2
- R4 .... 39k
- R6, R8 .... 27k
- R9,R10 .... 270k
- R12 .... 4k7
- R13 .... 2k2
- R14 .... 2k7
- R16 .... 150R
- R17 .... 220R
- R18 .... 56R

Capacitors

- C1 .... 2500u/25 V electro.
- C2,C4,C5 .... 10u/16 V tantalum or RBLL
- C3 .... 150n
- C6,C7,C8 .... 1n ceramic

Semiconductors

- D1 .... 1N4001 or similar
- D2-D6 .... 1N914 or similar
- DB1 .... 25A bridge rectifier
- IC1 .... 78L15 3-terminal regulator
- IC2,IC3,IC4 .... LM301
- IC5 4001
- Q1 .... BC107, BC547 etc

Miscellaneous

- RV1 .... 100R trimpot
- RV2, RV4 .... 10k trimpot
- RV3 .... 5k trimpot
- M1 .... 1-0-1 mA centre-zero panel meter
- RL1 .... 12 V SPST relay with 10 A contacts or DPST with 5 A contacts.
- LP1 .... 6V, 45 W or 50 W Volkswagen headlamp globe
- T1 .... 240 V to 17-18 V transformer, 6 A secondary (i.e: DSE M-2000)
- SW1 .... Rocker switch, 240 Vac rated with neon illumination.
- SW2 .... Spring-return action DPDT toggle switch

Case — 255 x 160 x 160 mm or similar (e.g: K&W Series C1066); ETI-1503 pc board; wire; mains cable clamp, mains lead and plug; battery cables and clamps; one red and one black heavy duty terminals.

Supplementary parts — substitute for LP1

- Q1 .... BC557 etc.
- Q2 .... BD140
- Q3,Q4 .... 2N3055
- Q5 .... BD139
- R1 .... 1R, 1 W
- R2 .... 150R, ½W
- R3 .... R047, 25 W (Arcol, metal clad type)
- R4,R5 .... see text.

Transistor insulated mounting components, heatsinks, nuts, bolts, etc.

Price estimate

We estimate that the cost of purchasing all the components for this project will be in the range:

$78 - $86

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel (if used) supplied etc — whether bought as separate components or made up as a kit.

These two slot car controllers will put more zap in their zip

Jonathan Scott

A spare $15 and an idle Saturday afternoon led Jonathan and a few 'assistants' into the labyrinthine maze of the world of slot cars. Your basic slot car set is so basic that Jonathan thought the application of a few engineering and physics degrees, computers, components, electricity and trials would help. These two projects are the result!

WELL, let's not beat about the bush. Slot cars are fun. The genesis of this project was the purchase of a cheap set and the realisation that there was much room for improvement in the whole thing, especially the 'electronics'. Since then, we have built several controllers, purchased an alarming length of track, bought and modified too many controllers and cars, and generally had a load of fun! Here are the fruits of the labours, both in the form of electronic projects and in some discussion of what you can do to get the best performance from even a cheap set of slot cars.

Shortly after the infection set in, the author's household was to be found in a huddle with a couple of computer programmers, another engineer and a couple of PR people. A list was made of all the things that anybody could possibly want out of a given car set, and all the things that could possibly be desired in a controller. Argument ensued. The fearless editor of this magazine would argue for cost effectiveness; another for a no-holds-barred approach. Thursday nights were set aside for the various parties to meet and report ... After preliminary models of controller had been made and *thoroughly* evaluated, it was conceded that all the aims could not be realised in the one type of controller. Hence, two lines were followed and we have the ETI-824 Slot Car Power Supply and the ETI-825 Slot Car Controller. We also have a lot of tips for optimising your set itself, and we trust that these are sufficient to turn a couple or three $15 sets into a first-class slot car racing set-up.

We also present several suggested layouts, and suitable constructs and axioms for the optimisation of your own layouts.

In the course of this research use has been made of calculators, programmable calculators, desktop computers, plotters, engineering degrees, physics degrees, computer science degrees, a mound of components a lot of paper and a *hell* of a lot of electricity — so be warned that one can get pretty involved. Closet racers, prepare for exposure!

If you are not sure that you are a fanatic, the ETI-824 is probably what you require. It is relatively simple to construct, cheap, and easy to get going. It is basically a replacement for whatever you are using to power your set now. It offers operation from ac or dc, car battery, model train transformer, doorbell transformer or a range of typical project transformers or power supplies. It gives independent protected supplies for each lane, adjustable for most car set types available.

If you're after something really exciting, then the ETI-825 is *it*. This is not a project for beginners. It gives independent, protected supplies for each lane. It can operate in voltage and current modes. It has powered braking, controlled overshoot and fuel tank simulation. It has fault and fold warnings, does not load the hand controllers, and can handle a wide range of maximum torques on sets of 4.5 to 12 volt rating. If you are really enthusiastic or you have just blown $100 to $300 on a Scalextric set, this is the one for you.

Slot cars and tracks — a dissertation

In practice, the basic rheostat in series with the track (car) is not at all a bad compromise. For a given control setting the car accelerates fairly rapidly towards a final speed. This is because torque is proportional to current (in the permanent magnet motors used) and current is a maximum when the car is standing still; as the engine RPM increase so does the back emf, or rather the internal emf of the engine, which represents the mechanical power output in the mathematical model of the engine. As this rises, the voltage drop across the control resistance decreases, and so does the current, the torque and the acceleration. (Figure 1.) This gives a very car-like performance for a minimum of parts.

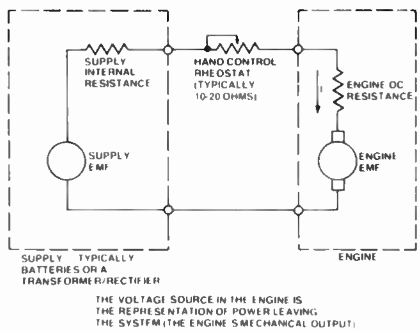


Figure 1. **Circuit model, slot car set.**

The final speed is fixed by the minimum dc path resistance, the available supply voltage and the amount of friction and other losses in the car. Overall performance includes cornering ability, which is affected by the car weighting and wheel

FUN!
FUN!
FUN!

type and condition. Attention to these factors will effectively 'tune' the car.

If you think you have a car set with one car better than the other, the chances are that checking the above things will reveal a silly fault in one car, and you will end up, after some tinkering, with two improved cars. Let us go through a typical tuning up of a small car, such as those in the $14-$15 sets. We will start at the car and end up at the controller.

Firstly, the wheels. It is important to check that these do not have some wobble or severe out-of-roundness. The tyres should be slightly rough, so that they grip, and fairly flat at the point of contact with the track, so that they do not bounce at all when the wheel rotates quickly. See that the tyre is fitted straight, if you have removable tyres, and that the wheels are squarely mounted on the axles.

Next it is worth opening the car up. Check that the axles and cogs are free of dust and carpet fluff. A very small touch of light machine oil on bearings and cogs is a good idea, though not entirely necessary. DON'T oil the tyres or any exposed bit of the car. See that the cogs mesh neatly and fairly silently. On an expensive car, such as Scalextric, these things should be in order already.

Now let's look at the brushes. These are, in our experience, the most vulnerable point in the car. Brush friction usually accounts for 90% of car performance problems. The brushes should be clean and dust free. There will be some unravelling of the braid. This is good. The ends of the brushes seem to benefit from a bit of 'combing'. This can be done with a small jeweller's screwdriver, a scriber or scalpel. About three to five millimetres of combed braid is nice. Finally, the shape of the brushes is important. There are several ways to bend the brush, and you should experiment to see which is better. We used the down-and-then-straight pattern. (See Figure 2.)

Next, the minimum rheostat resistance is important. Some controllers have such resistive leads that the series resistance never gets below an ohm or two. If you have a protected *voltage* source this is a disadvantage.

Finally, the supply potential is critical. If it is too high, the control becomes too critical and it is too hard to get just the right amount of power. It cannot be too low, of course, as you would not get anywhere near enough power to realise the maximum speed of which the car is capable without crashing — which takes out all the skill. As well, if the supply is not regulated, one car can interact with the other; the extreme of this is seen when one car suddenly 'shutting down' causes such a surge that the other spins off the track. (It can happen!)

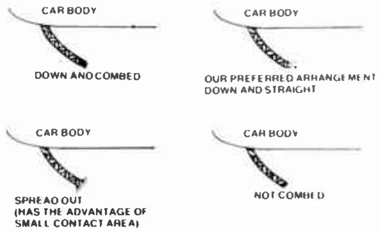
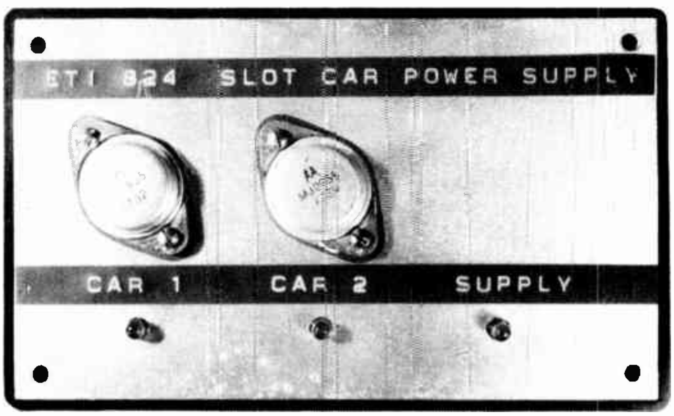


Figure 2. **Arrangements for the contact brushes.**

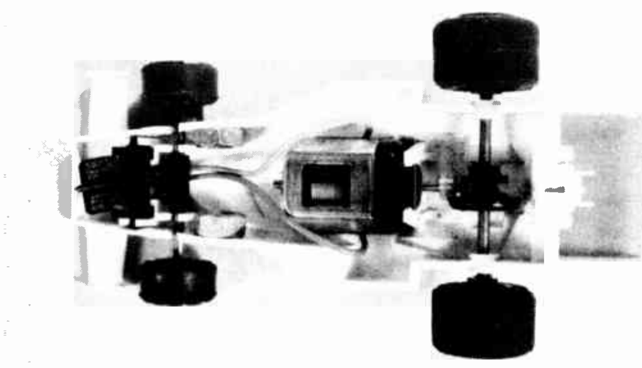
One further factor is worth discussing, with respect to the car: weighting. This is an area where you are going to have to experiment for yourselves. Most cars have spaces inside the plastic shells. Nuts or other pieces of metal can be secured in these spaces with a little Blutac, or similar poster adhesive, to add weight. Weight will reduce the acceleration for a given power, but it will increase wheel adhesion on the road. It will also change the handling, possibly making spinouts more likely, and reduce the period of time required between brush realignments. In our experience, a couple of 2 BA or similar nuts in a small car, near the middle and low down, are quite beneficial if you have adequate power, as with our controllers.

The 824 supply

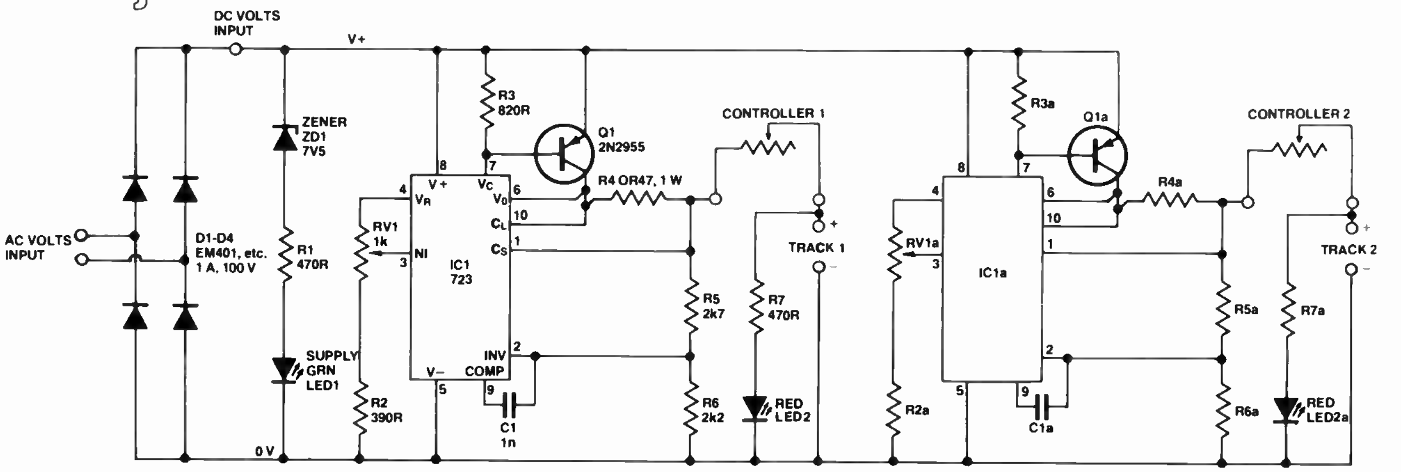
As we have said, all that is necessary to achieve quite adequate performance is a voltage supply for each car. It needs to be the right voltage, and each car should not interact via the supply with the others. The ETI-824 is this. It is versatile in that it will operate from whatever source of voltage you have available; it simply needs to deliver at least three volts more than the cars need (average) and to be able to supply the maximum current, typically ½ to 1 amp per car. ▶



Plain and simple, the ETI-824 slot car supply.



Example of how to weight a car with two nuts stuck under the body.



HOW IT WORKS — ETI 824

This is basically a crude series voltage regulator, based on the 723 variable regulator IC, that supplies power to the rheostat in the hand controller. The rheostat is in series with the motor in the car, via the track connections. The voltage supplied to the controller and car can be preset anywhere between about 3 V and about 12 V.

The circuit is designed to be powered from a variety of sources — bell transformer, car battery, plugpack, model train transformer or conventional 240 Vac to 15 V/1-2 A transformer — whatever is available. If the source is ac, such as that direct from a transformer secondary, the diode bridge rectifier formed by D1-D4 rectifies this, supplying unfiltered dc to the circuit. These four diodes may be deleted if the unit is run from a dc supply, or they may be left in, provided the dc supply you use exceeds the voltage required by the car by about four volts. Leaving D1-D4 in place has the advantage that the device can be run off ac at any time, and when running it off a dc supply it can be connected either way round as polarity doesn't matter and no possible damage can be occasioned by accidental reverse polarity connection.

To indicate that a supply of sufficient voltage is connected to the circuit, ZD1, R1 and LED1 make a simple indicator. When the supply voltage between the V+ and 0 V rails is high enough to overcome the zener voltage plus the voltage drop across LED1 and R1 at a current of a few milliamps, LED1 will light. You need to produce a minimum of about 10 V between the V+ and 0 V rails. Note that while this is sufficient for the IC regulator circuit to operate, it may not be enough for some slot car sets. For those that require 12 Vdc, at least 14 V between the V+ and 0 V rails will be required. An ac input of up to 24 Vac (RMS) may be used.

Following the rectifier and indicator sections of the circuit is the regulator, which consists of IC1, Q1 and associated components. Each lane in the slot car set should be supplied with a separate regulator circuit to ensure that one lane does not interfere with the operation of the other, especially in the event of a short circuit due to a crash or a fault, etc. Two regulator sections may be run from one rectifier section.

The 723, IC1, controls the base current of Q1 so as to deliver the required voltage to the hand controller, except when the external circuit (controller and car motor, via the track) attempts to draw current above about 1.2 A. In this case, the 723 reduces the voltage supplied to the external circuit to prevent possible damage.

The output voltage is set by RV1. By adjusting this preset control, the voltage delivered to the controller and external circuit may be varied anywhere between about 3 V and about 12 V maximum. This should be adjusted to suit the particular slot car set you are using by setting its position so as to deliver a suitable amount of acceleration to the car when the hand controller is set full on.

LED2 indicates that voltage is reaching the track. This is useful to check correct operation and for detecting shorts on the track.

The 825 controller

For superior performance, the controller can have several 'extras'. This is the ETI-825. Firstly, this gives you *fuel tank simulation*. This means that the control box has a meter which represents fuel in the car. A button 'refuels' the car, provided it is stationary. When it has petrol, you can go again. As the petrol is used up the car gets more acceleration, corresponding to the reduction in weight. The degree of the effect is presettable by a resistor (R107-R207 for the second car). It is rather exaggerated with the value given, but this is more fun. Of course, if you run out of fuel, the car slows down and finally coughs to a stop.

Next, the 825 offers *controlled overshoot*. If the output momentarily exceeds the level that your hand controller commands, the car responds more 'snappily'. This accelerates it a bit harder at first, corresponding to 'dropping the clutch', and brakes hard when it is slowing down corresponding to hard braking. You can even lock up, if you are too hasty!

The controller also informs you if it is folding, such as when the track is short-circuited. In the current mode, it warns of open circuit as well. It does not, in addition, load the hand controller rheostats, as they do not carry the car current. (In some sets the controller handsets get very warm.) It comes with an internal power supply as well. Both controllers are, of course, short-circuit protected.

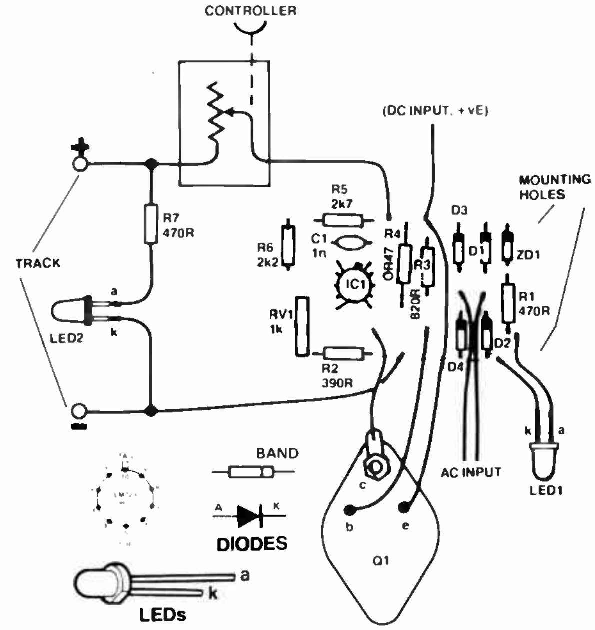
The two modes, current and voltage, each offer their own advantages. Current mode gives torque proportional to control depression, as torque is proportional to current. It has slower take-off and generally sloppier, though perhaps more realistic, operation. It is also more immune to bad contact in the track and brushes, if you are having trouble in that direction. Voltage mode, which we prefer, gives a very tight control, with snappy response from the car; perhaps less realistic, but more fun. It seems to demand more from the drivers, though performance is considerably superior. You can actually get a car to lock up and slide sideways out of a long straight into a corner, and accelerate out of the corner, the car's pin in the slot all the time, which is not a mean feat!

Having set forth the pros and cons, we will proceed into the construction of the two projects, and you may choose the one you feel is appropriate.

Construction ETI-824

Construction of the ETI-824 is relatively straightforward. You will require one pc board for each lane, though some components will not be required on all but the first board. If you have only two lanes, as is likely, you can follow our construction diagrams exactly. Further lanes will simply demand a larger box and a repeat of the wiring up of the first two boards, less ZD1, R1 and LED1.

The first step is to drill the box. We used a jiffy box, primarily because they are the cheapest form of conveniently workable container. If you want it to look particularly good, or it will have to withstand nasty knocks, a diecast aluminium or extruded type of box of sufficient size can be used, but is likely to



PARTS LIST—ETI-824

Resistors .... all ½W, unless noted

R1, R7	470R
R2	390R
R3	820R
R4	0R47, 1W
R5	2k7
R6	2k2
RV1	1k trimpot

Capacitors

C1	1n greencap

Semiconductors

D1-D4	1N4001, EM401, etc 1A, 100 V
ZD1	7V5, 1 W zener
LED1	TIL220G, green
LED2	TIL220R, red
IC1	723
Q1	MJ2955

Miscellaneous

ETI-824 pc board; jiffy box to suit; terminal block; transformer (if necessary); nuts, bolts, wire etc.

NOTE: The supply circuit is duplicated for the second track. Those components duplicated are designated Q1a, R4a, IC1a, C1a etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range.

$15—$18

Note that this is an **estimate** only and not a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used) etc — whether bought as separate components or made up as a kit

add 20-50% to the cost. Anyway, if you have our type of box, the front panel doubles as the heatsink.

Drill the 2N2955 mounting holes and the LED mounting holes first. The only other hardware preparation is the holes for the pc board mounting and the holes for the wires and the terminal block to which they lead.

After the drilling is done, assemble the boards. The first should have all components fitted. It is best to include D1 to D4 even if you have a dc supply, as the unit can then not be connected the wrong way around, and can still be used with ac later on if required. Only if the dc is too low to tolerate the diode drops should D1 to D4 be omitted — i.e : below 12 volts average. (Omitting the diodes will let it run on around 10 volts.) It should also be noted that the supply will have to be a bit higher if the car set is a 12 volt type — around 15 volts at least. An 18 Vac transformer is ideal in that situation. Fit all the components on the boards as shown in the overlay, starting with resistors and finishing with the IC. Take care with the IC orientation.

Once the boards are assembled, connect the flying leads as shown in the assembly diagram. The current-limiting resistors for the track LEDs are mounted behind the LEDs themselves, as part of the flying leads. We used an ordinary plastic terminal block as these are cheap and wires will probably not have to be connected and disconnected repeatedly, so that more 'flashy' terminals are not justified.

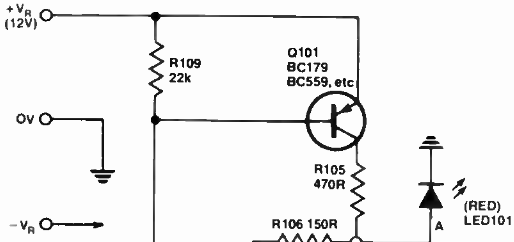
Once the assembly is complete, label the panel and connector appropriately. We used Dymo tape, again in the interests of cost. There is no reason why you should not use paint and Letraset on the panel before assembly, or do a custom job with model paint after assembly, if you should be that way inclined. (Shades of certain panel vans we have seen! Probably more appropriate if your cars are hotrod types.)

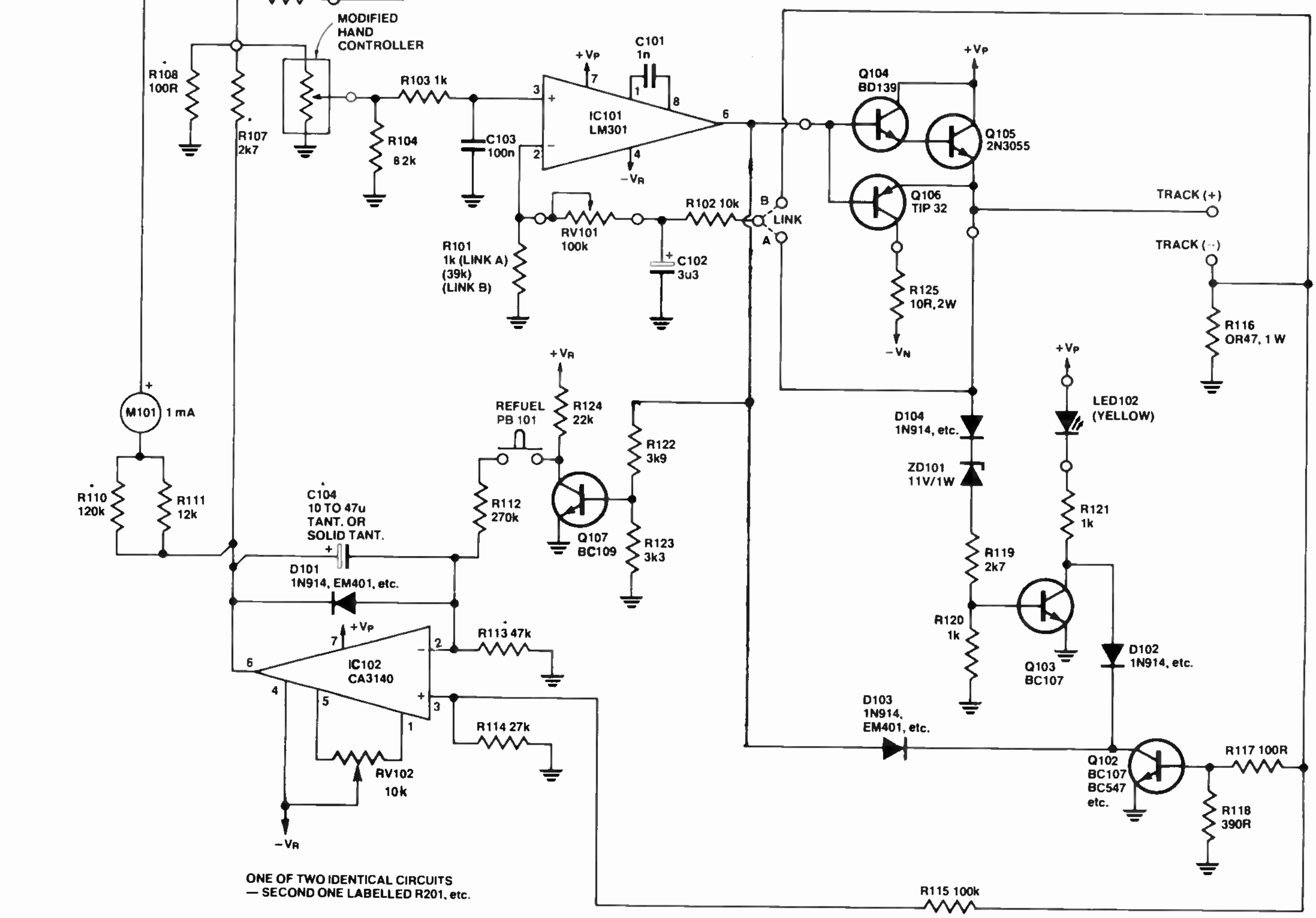
Construction ETI-825

Construction of this unit is fairly flexible and will depend somewhat upon how you plan to house the unit. We built two prototypes — one very compactly in an extruded aluminium case from Amtex and one in a large plastic case from Vero (distributed by Warburton and Franki). It is advisable to use a fairly spacious housing as this demands less careful layout and allows easy access for adjustment or debugging. The only requirement for the case is that if you are using our pc board the meters must be spaced horizontally by the required amount, as ▶

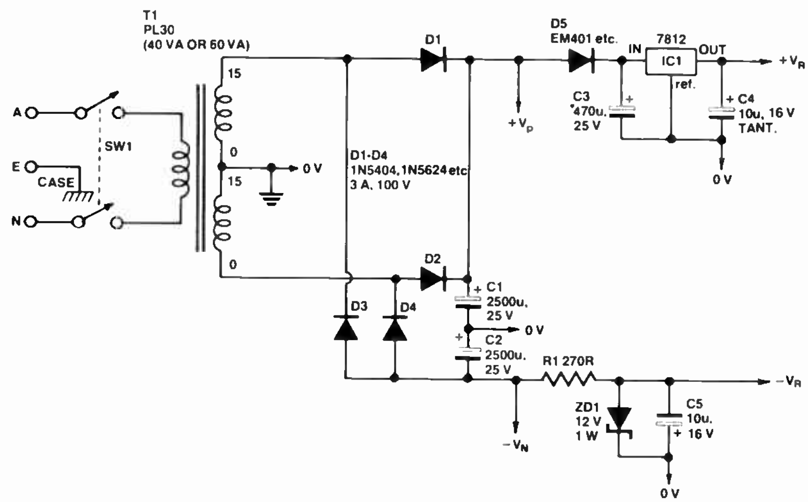
the board mounts on the meter terminals.

First step in the construction is to drill the case and panel. Note that the power supply transformer and rectifier-filter components are not included on the pc board and are mounted on the case in a convenient position. You will have to position these components so that they do not foul any other components, and drill the case to suit. The power supply components are mounted off-board for a number of reasons. Firstly, they are bulky and would add seriously to the pc board size and the space needed for it, and secondly, it means that a set of higher current capacity diodes and a higher VA-rating transformer may be used for powering more than two lanes. A PL30/40 VA transformer will power two lanes, a PL30/60 VA will power up to four lanes.





*ITEMS ASTERISKED MAY REQUIRE ALTERATION OF VALUE TO SUIT YOUR PARTICULAR REQUIREMENTS — SEE TEXT.



We found it convenient to mount the mains supply terminating block, cable clamp (or clamp-grommet), output terminals and presettable pots (RV101, RV201) on the rear panel of our box. We used ordinary potentiometers for RV101 and RV201, rather than preset types, cut the shafts short and cut a slot in the end of the shafts. To avoid fouling other components, mount the pots so that they are below the height of the transformer.

Next, prepare the front panel. Naturally, drill it first. Locate the meter holes carefully as the pc board determines their spacing (144 mm centre-to-

HOW IT WORKS — ETI-825

The unit comprises a power supply, a control section (involving IC101), a driver circuit (involving Q104, 5 and 6 and associated components), an overload protection and warning circuit (Q102, 3 etc), an 'electronic fuel tank' (Q101 plus IC102 and associated components) and a 'refuel' circuit (Q107 etc).

The circuit has two modes of operation — voltage and current. The mode to be employed is selected by means of a link on the pc board. In the voltage mode, the hand controller sets the voltage delivered to the track (and thus the slot car's motor). In the current mode the hand controller sets the current delivered to the car's motor via the track. In either mode, a potentiometer (RV101) sets the maximum value of the voltage or the current.

POWER SUPPLY

Transformer T1 has two 15V (RMS) secondaries, connected in series. There are two rectifier circuits — one to provide a positive supply rail, the other to provide a negative supply rail. The joining of the two secondaries provides a 0 V connection.

Diodes D1-D2 and capacitor C1 provide a nominal +21V supply rail (+V_P) while D1-D3 and C2 provide a nominal −21V supply rail (−V_N). From these two rails +12V and −12V regulated rails are derived. The +12V rail is achieved by IC1, a three-terminal positive supply regulator (a 7812 or 78L12). This rail is used as a reference for the hand controller and metering circuit. Capacitor C4 ensures high frequency stability for the three-terminal regulator and acts as a supply rail bypass. The −12V rail is derived by a simple zener circuit involving R1 and ZD1. C5 is a supply rail bypass. The negative rail is limited to 12 volts so that the maximum supply voltage limitation of the op-amps, which is about 36 volts, is not exceeded.

CONTROL SECTION

This centres on IC101. A certain current (which we will discuss in detail a little later) is passed through the hand controller resistance. This develops about 200 millivolts drop across it. Thus, when the hand controller is operated, a voltage ranging between 0 and 200 mV is applied to pin 3 of IC101, the precise voltage depending on how far the 'driver' has depressed the controller lever. Capacitor C103 smoothes out any variations — many hand controllers have momentary loss of contact between the wiper and the resistance as the wiper traverses the resistance element. You may need to vary the value of C103 according to how coarse the resistance variation happens to be in your controller. For the inexpensive controllers — which are really quite adequate despite the coarse variation they provide — a value of 470n to 1u (electro) is suitable.

Now, IC101 attempts to drive its output (pin 6) in such a fashion as to induce the same voltage on its inverting input (pin 2) as is on its non-inverting input (pin 3).

In the voltage mode, pin 2 of IC101 is connected via RV101, C102 and associated components to the positive track terminal so that the position of the wiper on the hand control resistance sets the output voltage. In the current mode, pin 2 of IC101 is connected to the end of the 'current sense' resistor (R116) so that current is defined by the position of the wiper on the hand controller resistance.

In either mode, RV101 — which is in series with the negative feedback path — in conjunction with R101, sets the maximum voltage or current delivered to the car's motor via the track. Capacitor C102 induces some 'overshoot' in the feedback which enhances acceleration and braking according to controller movement.

DRIVER

The driver circuit comprises Q104, Q105 and Q106 plus R125. Its function is merely to amplify the current delivered from the output of IC101.

Transistors Q104 and Q105 are connected as a Darlington pair which provides considerable current gain (the Beta of Q105 is multiplied by the Beta of Q104). The output of IC101 (pin 6) swings positive during acceleration (depressing the hand controller lever) and Q104-5 amplify the current, the emitter of Q105 being connected to the track positive terminal. Q106 is reverse biased during this time. During braking, pin 6 of IC101 can go negative (particularly if you 'drop' the hand controller lever). This reverses the voltage delivered to the track or reverses the current flow (depending on which mode you're employing). When this occurs, Q104 and Q105 are reverse biased and Q106 is forward biased — and it amplifies the negative excursions from pin 6 of IC101.

The function of R125 is to protect Q106 against momentary current overload.

PROTECTION

The protection circuit involves Q102, Q103 and associated components. If the voltage output to the track exceeds about 13 volts, ZD101 and D104 conduct, forward biasing the base of Q103. When Q103 turns on, it draws collector current via LED102 and R121. LED102 lights, providing warning of a fault. If the output current exceeds about 1.5 amps the current through R116 (which is in series to the supply to the track) induces a voltage drop across it of about 0.7 volts or so and this forward biases the base of Q102 via R117 and R118. Q102 thus turns on and it draws collector current via D102, R121 and LED102. However, the collector voltage of Q102 will be around a few hundred millivolts and the output of IC101 (pin 6) will be shunted to the 0 V rail via D103 and the collector-emitter junction of Q102.

Thus, you receive a warning of supply overload and the supply, track etc., is protected against overcurrent damage.

FUEL TANK

The 'fuel tank' is simulated by IC102 and associated components. This op-amp is connected as an integrater. A 'full' tank corresponds to 0 V on the output of IC102 (pin 6), an 'empty' tank to about 12 volts. As current flows through the load (car motor), and hence via R116, a voltage is dropped across R116. This voltage is integrated by IC102 which has an RC network (R113-C104) in the feedback loop. As more load current is drawn, pin 6 of IC102 rises towards 12 volts.

The meter, M1, indicates the output voltage of IC102 and is marked like a fuel guage. While the fuel tank is full or partially full, the current through M1 flows via the base of Q101, forward biasing it. Thus, Q101 is held on while this current flows. The collector current of Q101 flows via LED101 (the hand controller and associated resistors). LED101 lights, indicating you have fuel in the tank. When the fuel 'runs out', pin 6 of IC102 is at 12 volts and no current flows through M1 and thus the base of Q101 receives no bias and it turns off. LED101 extinguishes at this stage and no voltage is delivered to the hand controller. IC101 interprets this as if you have the controller set to the rest or off position and no power is supplied to the track. Your car stops . . .

The 'capacity' of the fuel tank is defined by the values of C104 and R113. The values shown give a 'full tank' of about 60 amp-seconds — which corresponds to about 30 rapid laps of a 2½ metre long track in 1/64th scale. The values of C104 and R113 may be varied to suit your taste, as indicated in the table on page 91.

While there is fuel, LED101 is on and its terminal voltage is about 1.7 volts. This voltage permits about 10 mA to flow through the resistance of the hand controller via R105. (Recall we have yet to see what its current is). In addition, R107 permits some current to flow into the controller— generally between 0 and 5 mA — from pin 6 of IC102. This current increases as fuel is 'used up', corresponding to the car getting lighter, and you get more acceleration at any particular hand controller setting as you 'use up' fuel. Resistor R107 defines how much more acceleration is obtained when the car is 'lighter'.

When the fuel runs out and Q101 turns off, the current delivered through R105 to the hand controller plummets and only the 5 mA flowing via R107 is available. This gives a 'soft' end, allowing you to limp to the pits — if you aren't too far away on the track.

The parallel combination of R108 and the hand controller should be around 15 ohms. If your controller has a high resistance, or you want to substitute a 1k wirewound pot, for example, R108 should be derived from the following formula:

$$R108 = \frac{1}{\left(\frac{1}{15} - \frac{1}{R_{controller}}\right)}$$

REFUEL CIRCUIT

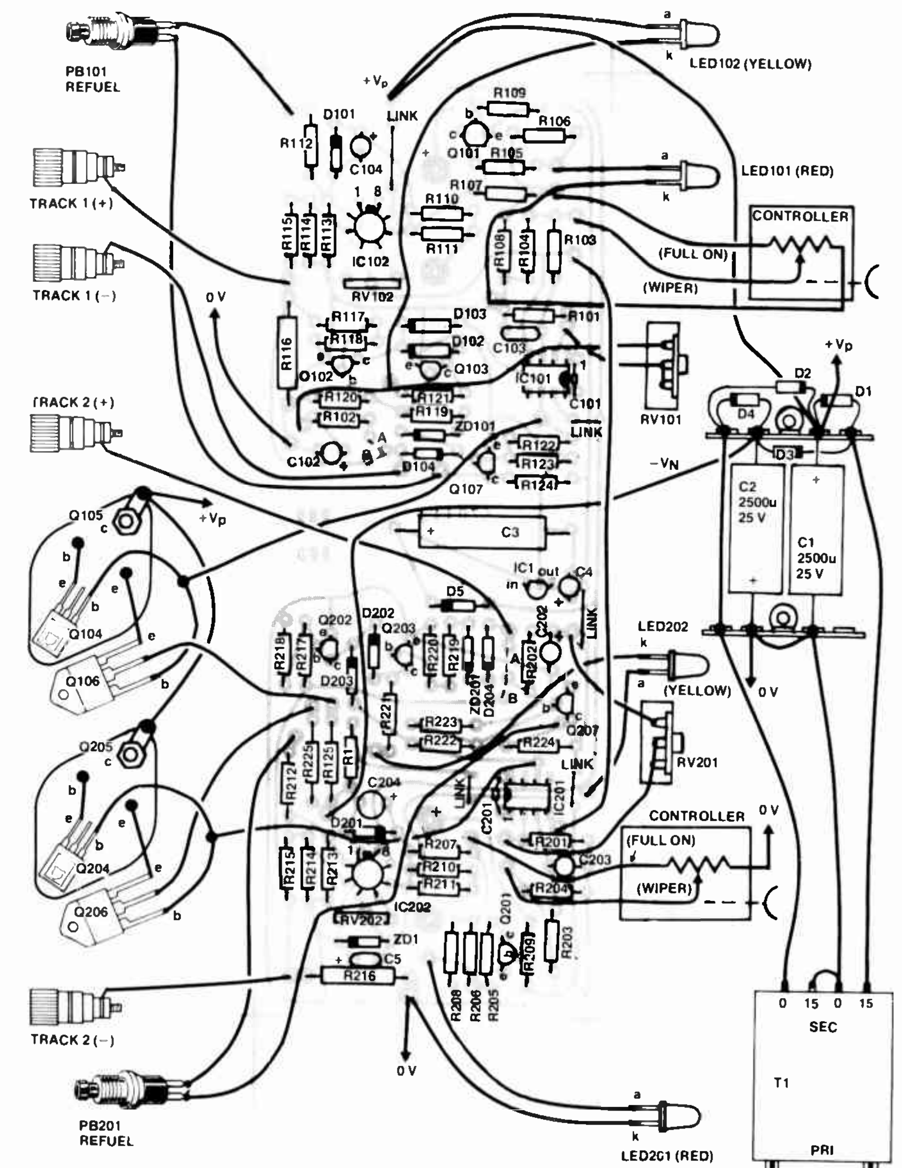
'Refuelling' is effected by PB101 and Q107. When the car motor is not drawing power, the output of IC101 (pin 6) is low (less than one volt) and thus Q107, which derives its base bias from pin 6 of IC101, is off. Pressing PB101 connects R112 to the +12 V rail via R124 and IC102 will discharge C104. The output of IC102 (pin 6) will drop to 0 V (which is the 'tank full' condition). Q101 will turn on again and current will be supplied to the hand controller circuit. When you power the car again, the voltage on pin 6 of IC101 will rise, the base of Q107 will be biased on and its collector will draw current via R124. Thus, if you try to 'top up' while the car is in motion, R112 will be virtually connected to the 0 V rail via the collector-emitter junction of Q107 and you won't be able to drive the output of IC102 low. In addition, if you attempt to drive the car while refuelling, the refuelling action will be stopped by the same means.

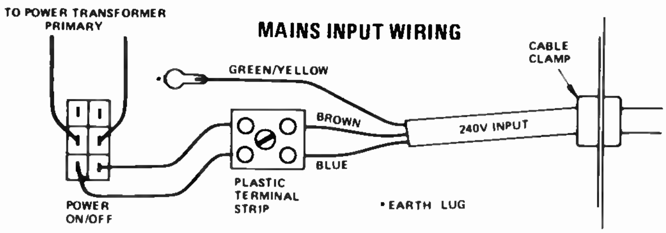
---

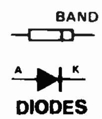
centre). For panel marking we used rub-down lettering on one panel (such as Letraset, Geotype, etc), put directly on the panel after cleaning it, and automotive 'touch-up' paint on the other. Both methods proved satisfactory. In the interests of giving a Spartan, vehicular look we put '?' symbols near the overload/fold warning LEDs and '!' symbols near the fuel warning LEDs, but words are OK if you need the controller to be self-explanatory.

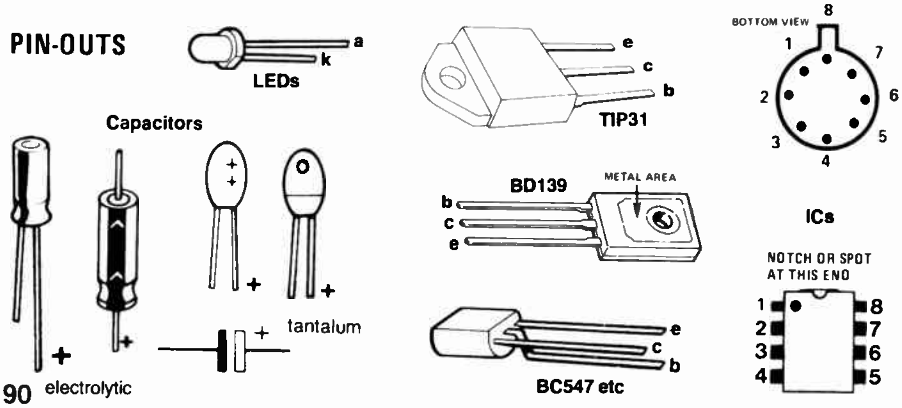
Apply a spray-on lacquer to protect the panel markings. With this job finished, fit the meters, LEDs, etc. Finally, drill the mounting holes for the power transistors, which are mounted off the board. These dissipate little heat so ▶

The pc board artwork for each project appears on page 40.









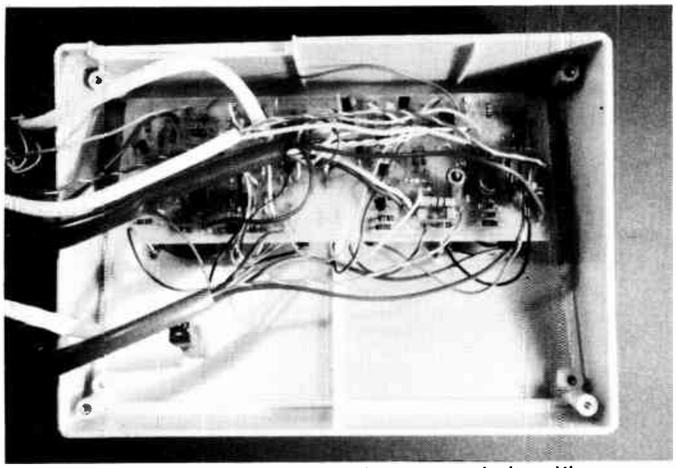
they merely need mechanical support.

The next step is to assemble the components to the pc board. As there are quite a few flying leads, it may pay to use pins for the termination of these to the pc board. Pay attention to all the usual details — orientation of tantalum and electrolytic capacitor, orientation of semiconductors, etc. Choose the components in Table 1 to suit your requirements, according to the instructions given with the Table. When all the components are soldered in place, fit the flying leads to the LEDs and pushbuttons which are mounted on the front panel, along with the meters. These can be secured and the pc board bolted to the meter terminals before the leads to the main case are fitted. Be sure that all flying leads are long enough to allow the box to be fitted together and dismantled without straining the connections. In the controller we assembled in the extruded aluminium case, very long wires were required as the panel has to be slid into position end-wise because it rides in a groove of the extrusion. Long leads can be kept neatly 'loomed' with plastic sleeving slipped over a bunch before one group of ends is terminated.

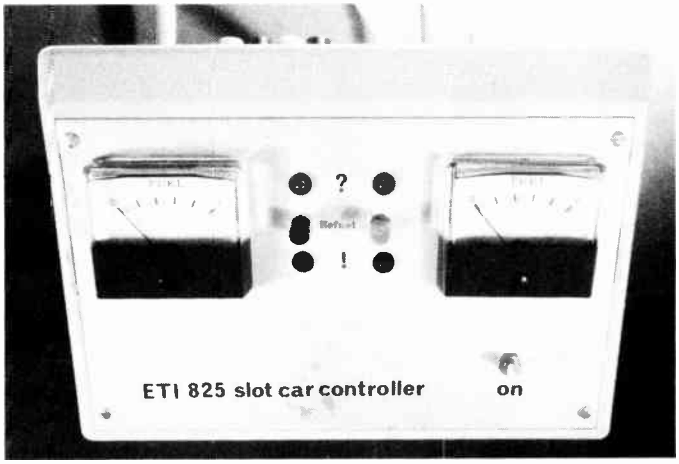
Assemble the transformer, power supply components and potentiometers in the case next and wire them up. Take particular care with the mains wiring. The rectifier components are supported on a tagstrip and we'll leave the wiring details to you for this one.

The final step before testing is to modify the handheld controllers from rheostats to true potentiometers. Open up the case of a controller. You will find that it consists of a short coil of resistance wire, wound on some sort of former, with a wiper contact which moves along the coil according to how far the thumb or finger control is depressed. When fully released, the wiper rests in a position where it does not touch the coil. There will be two wires coming from the hand controller — one leading to the wiper and one from an end of the resistance wire. It is neccesary to have a third contact, connected to the other end of the coil (the end without a connection). Remove the existing wires (some of these have considerable resistance themselves) and fit the two new wires, then the third. These run to the controller unit. Make sure you have plenty of length to play with. Now re-assemble the hand controller, being careful to tie off the wires in the same way the original two were secured.

You should now be ready for a test run.



Inside the ETI-825. The board mounts on the meter terminals and the power supply and other components mount in the cabinet base.



Full frontal view of the ETI-825 'control' panel.

TABLE 1. Component value variations.

Component	Nominal Value	Function	How to vary it
C104(C204)	10u	Sets fuel tank capacity, along with C104.	Increase its value to increase fuel tank capacity. E g: 20u gives double capacity. RANGE: 10 to 47u
R113(R213)	47k	Sets fuel tank capacity, along with C104	Increase its value to increase fuel tank capacity. RANGE: 10k to 100k
R110(R111)	120k in parallel with 12k.	Calibrates M1 for full scale deflection at 'full tank' status; allows other meter fsd values to be used.	Reduce R110 to increase reading. Choose R110/R111 to give value according to $11.4/I_{fsd}$. This should not need much adjustment if a 1 mA meter is used.
R107	2k7	Sets the variation of engine power remaining fraction of fuel.	Reducing R107 gives a greater gain in power as the fuel 'runs out' RANGE: 2k2 to 22k.
R108	100R	Sets the effective controller resistance to about 15 ohms.	Choose R108 such that R108 in parallel with the controller resistance gives a combined resistance of 15 ohms.

PARTS LIST—ETI-825

Resistors .... all ½W, 5% unless noted
R1 .... 270R
R101 .... 1k (link A), 39k (link B)
R102 .... 10k
R103,120,121 .... 1k
R104 .... 82k
R105 .... 470R
R106 .... 150R
R107 .... 2k7*
R108 .... 100R*
R109,124 .... 22k
R110 .... 120k*
R111 .... 12k
R112 .... 270k
R113 .... 47k*
R114 .... 27k
R115 .... 100k
R116 .... 0R47, 1W
R117 .... 100R
R118 .... 390R
R119 .... 2k7
R122 .... 3k9
R123 .... 3k3
R125 .... 10R, 2W
RV101 .... 100k lin. pot.
RV102 .... 10k

Capacitors
C1 .... 2500u/25 V electro.
C2 .... 2500u/25 V electro.
C3 .... 470u/25 V electro.
C4, C5 .... 10u/16 V tant.
C101 .... 1n greencap
C102 .... 3u3/10 V tant.
C103 .... 100n greencap
C104 .... 10 - 47 u/16 V tant. — preferably solid tant.

Semiconductors
D1-D4 .... 1N5404, 1N5624 etc (3A, 100V)
D5,D101,D103 .... 1N4001, EM401, (1A, 100V)
D102,D104 .... 1N914, 1N4148
ZD1 .... 12 V, 1 W zener
LED101 .... TIL220R, red
LED102 .... TIL220Y, yellow
Q101 .... BC179, BC559 etc
Q102,103 .... BC107,BC547 etc
Q104 .... BD139
Q105 .... 2N3055
Q106 .... TIP32
Q107 .... BC109,BC549
IC1 .... 78L12 or 7812
IC101 .... LM301
IC102 .... CA3140

Miscellaneous
T1 .... PL30/40 VA (or 60 VA), Ferguson (2 x 15 V, 1A)
SW1 .... SPST, 240 Vac rated toggle switch
M101 .... 1 mA meter, MU-45 or similar
PB101 .... momentary action pushbutton

ETI-825 pc board; case to suit; tagstrips; terminal block; mains cord and plug; clamp grommet; Scotchcal meter scales; nuts, bolts, wire etc.

NOTE: The controller circuit is duplicated for the second track and those parts marked R101, D101, C101, IC101 etc are duplicated, designated R201, D201, C201, IC201 etc for the second controller.

* Components marked with an asterisk may require alteration to suit your particular requirement (see text).

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range;

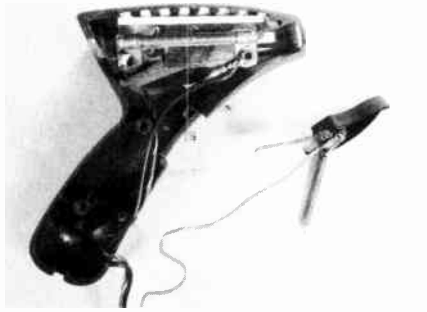
$60—$70

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.

Test run

Make up a simple circle of track. On powering up, the car should work to some degree. If not, stop and recheck. Once it works it is necessary to adjust the presets and so forth. RV102/202 should be adjusted to minimise 'fuel tank' circuit drift in the absence of power being delivered. (These are the integrator offset adjustments.) At this stage it is probably worth assembling the unit and giving it a serious workout. You may find that you want to increase the fuel tank capacity (C104), change from one mode to the other (links A and B) or that the control is rough or jittery. If this latter is the case, then your controller is probably one with *relatively few* turns of resistance wire. This is causing sharp changes in level, to which the electronics respond with excessive overshoot. The cure is to increase C103/203 to, say, 1 µF. This is especially prevalent with the cheap, 6 V operated sets. After you have had a while in the seat, remove the front panel and alter the appropriate components (marked with an asterisk) in order to produce the effects desired. To figure out what these are, consult Table 1.

A note should be included on the correct adjustment of the maximum torque presets, RV101/201. This is much a matter of preference. They should be ▶



Modified hand controller with connection to both ends of resistance wire.

adjusted so that the car does not get ridiculous amounts of power just prior to running out of fuel, but so that the car can just be crashed on full power with a full tank. It is probably also a good idea to set the two channels alike with a multimeter to ensure fairness. (Be sure to have equal amounts of fuel when doing this adjustment!)

The track

When it comes to track, there are three factors worth mentioning which may influence your choice if you have yet to purchase it, before we discuss actual layout. These factors are: range of pieces available, flexibility and width. If you are going to buy the cheap sets, and let's face it, that is the most cost-economical approach, you will have to accept that the track comes in fixed quantities, probably multiples of what it takes to make up one loop or a small figure-8. However, it is so cheap that you can get twelve 45° curves and four straights, not to mention two cars and controllers, and fences, etc, for under $15 in some places in Sydney (e.g.: Paddy's markets, etc). For $30, plus one of our controllers, you can get a really good set-up, and for $45 you get a really *fantastic* set. There is no denying that an expensive brand is better in that you can buy three radii of curvature (for funny bends or up to six lanes) and several lengths of straight, but at $150 or so for a basic figure-eight set, it is not a purchase to be taken lightly. Such sets also have the advantage that they have flexible track which can thus be banked on the curves, but they are on a larger scale and take up more room. The cheap stuff is usually about 102 mm (4") wide, but if you are lucky you can get it a bit wider, like 110 mm. This is a bit better, as the cars are less likely to interfere with each other on bends, and less likely to foul badly on fences.

In designing a layout, the main problem is not to find a shape which is particularly interesting, but one which is fair, or equal, for both lanes, as well as 'rational'. By rational we mean that the pieces of track fit together into a loop naturally and require no forcing. A layout which has to be pushed out a bit to meet up is not only unaesthetic to the perfectionist mind, but tends to rapidly separate in various places with a bit of use. If you are using the track pieces which come in the cheaper sets you are probably constrained to turn increments of 45°, and straight sections each equal to the centre radius of curvature of the curved sections. If, in addition, you want to use all or almost all of the track available, (and who doesn't?), you are probably constrained to some fixed ratio of curves-to-straights. Even if you are lucky enough to have a range of bits, it is quite challenging to sort out a fair and rational track using all the bits. And besides, who rushes out and gets that quarter straight every time he devises a nice-looking layout that doesn't quite meet up squarely?

Method

If you are not seriously interested in layout analysis and design, you may skip this paragraph; it deals with our mathematical method of thinking out a track set-up. First, let us define some terms. A 'construct' is any group of track sections. It does not necessarily meet up to form a closed loop, but is usually a familiar shape which can be found in common layouts. A rational construct is one which replaces a basic subsection of an oval of track — either a right angle, a single straight section, or a combination of these — and thus, geometrically, introduces an integral multiple (or in some sets of track, a simple rational fraction) of the basic radius of curvature into each axis.

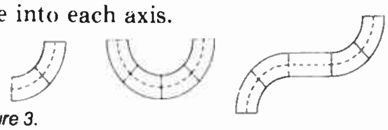


Figure 3.

To explain this, consider Figure 3. The right angle turn introduces a one-unit displacement down and one unit along. The U-bend introduces a two-unit shift down and no shift along. The S-bend introduces three down, and two along. These are all rational constructs in the system of track here — that is, one where straights are exactly one radius of curvature long, as is common. The constructs in Figure 4 are all equivalent to a right angle, and are thus rational.

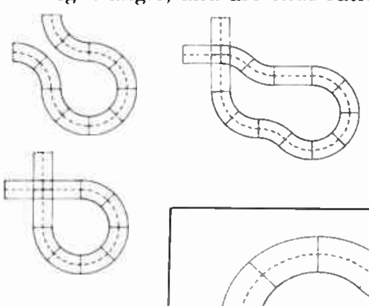


Figure 4.

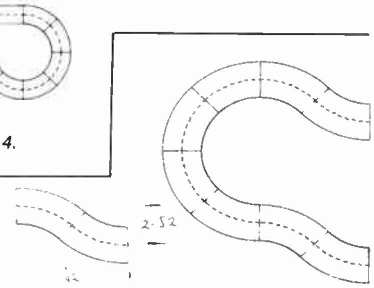


Figure 5.

The zig-zag in Figure 5 is irrational, as it has displacements of $\sqrt{2}$ and $2-\sqrt{2}$ respectively, but the construct next to it is rational, as the zig-zags clearly cancel out.

A layout is said to be *rational* if it fits together *exactly*. For this to happen, there must be no uncancelled irrational constructs. Some constructs favour one lane. For instance, in a plain 180° bend, the outside lane is longer, and thus you might expect it to take longer to negotiate. If there are fences it may be faster, as the car can bounce off them and thus use them to allow greater speed without accident.

Experiment will determine how each construct favours lanes. In our experience, a zig-zag favours the lane first on the outside, especially with fencing. Once you have an idea of each construct and how it favours lanes, you can assemble them into a fair layout. Even though a completely flat layout will inevitably have one lane longer on the outside, it can be made fair by judicious addition of constructs to favour the worse lane — such as zig-zags at the ends of long straights.

It is desirable to avoid bridges, because they are easier to disrupt in moments of excitement as well as harder to achieve with rigid track. It is also a pain to quickly recover a crashed car from the underpass. Flat layouts can be fair, with some thought and understanding of the constructs used.

Finally, let us mention cleaning. Unless rust is rife, abrasive things such as emery paper should be avoided. Cloth soaked with methylated spirit is best for removing crud. After cleaning, light application of machine oil or Vaseline (the latter collects more hair but is better for storage) will reduce crudding and prevent corrosion. The plating on the tracks is sufficient protection until it fails, so just wiping should be enough. Occasionally, the small metal flanges which make contact from track to track should be bent slightly to improve friction and contact.

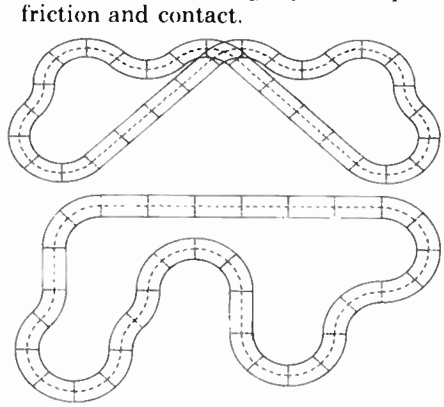
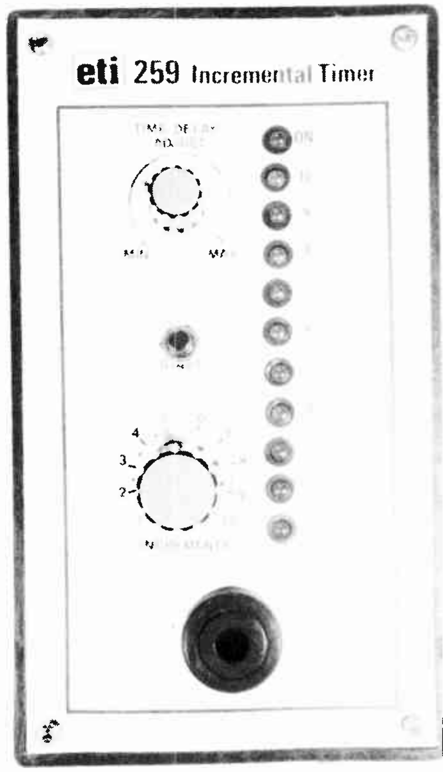


Figure 6.

If you are really getting into it, you can devise a catalogue of constructs. We developed a computer program for checking rationality and a layout plotting routine; we tender a couple of optimal layouts (Figure 6) which use all the track from two cheap figure-eight sets. The analysis and synthesis of track layouts becomes more complex when you have different and more varied pieces available — our examples are of the elementary type, as in cheaper sets. ●

Versatile, low cost 'incremental' timer

This timer is based on the popular LM3914 LED display driver IC, rather than a 'timer' IC, and provides period timing in preset increments — you choose the number of increments, up to a maximum of 10. The period between increments may be preset by a front panel control and a 'bar' of LEDs indicates 'where you are'. A switched 240 Vac output is provided along with audio indication of the end of timing.



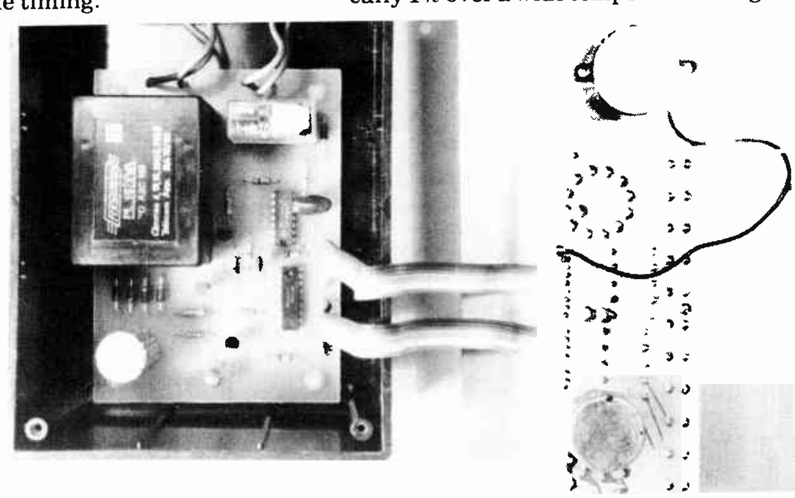
Graeme Teesdale

MANY ELECTRONIC timers published make use of a timing device, such as the ubiquitous 555 IC or UJTs like the 2N2646, to generate pulses at predetermined intervals which are used to operate a relay or alarm. Some employ digital counting techniques, using the mains frequency as a timing reference. This project employs an LM3914 LED display driver IC in an unusual way. The input is driven with a voltage that increases linearly with time. That is, the voltage increases equal amounts in equal periods of time.

The outputs of the LM3914 go 'active' in turn, lighting a LED, and further circuitry detects when a selected output goes active, setting off an audible alarm, tripping the relay circuit and resetting the timing.

At the one time, we obtain all the usual features included in many other timers, plus a 'bargraph' indication of how the timing period is progressing. This is very useful in the timing of many processes — particularly photographic processing, such as print development and resist development in the manufacture of pc boards. You can also coordinate a sequence of activities as the process continues, using the display to prompt you.

The total time, and thus the period between increments, may be varied by means of a potentiometer and the circuit has been arranged so that this provides about a 10:1 variation. The maximum period may be chosen by selecting the value of one capacitor. Accuracy is typically 1% over a wide temperature range.



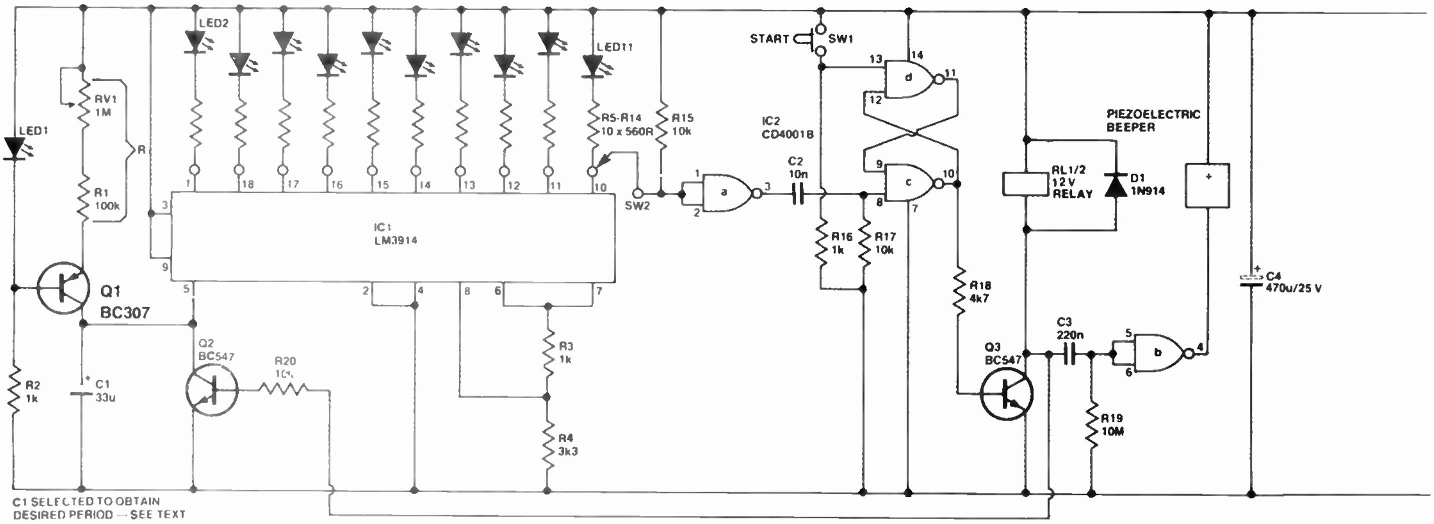
The inside story! As you can see, assembly is pretty straightforward.

Construction

Two pc boards are employed and the whole unit is housed in a standard 'jiffy' box measuring 196 x 113 x 60 mm. Although not absolutely essential, we recommend you use the pc boards designed for this project. The boards simplify construction and help ensure that there are few wiring errors. One board holds the power supply, relay and most of the electronics. This is the larger board, and is mounted in the bottom of the jiffy box. The other, smaller board holds all the display LEDs, the potentiometer, the increment selector switch, the START pushbutton and a few resistors. It is connected to the other board by two ribbon cables. This board is mounted to the front panel of the box via the securing nuts of the START button and the increment selector switch. The piezoelectric buzzer is separately mounted to the front panel.

Commence construction by drilling the box and front panel. The larger pc board (ETI-259a) should be used as a témplate to mark the hole positions for the four mounting bolts it requires. Also mark hole positions for the 240 Vac mains input cable. We strongly recommend you use a clamp-type grommet to secure the cable where it enters the box. Also mark out the hole positions for the 3-pin mains output socket. The terminal block may be bolted to the bottom of the case or glued ('liquid nails' will do).

The front panel artwork, obtainable from ETI, may be used as a template to mark out the hole centres▶



HOW IT WORKS — ETI 259

The LM3914 LED display driver is connected as a zero-to-5 V (full scale) voltmeter to display in the bargraph mode. Thus, each LED will turn on at increments of 0.5 V as the input rises from 0 to 5 V. The input to IC1 is driven by the voltage across capacitor C1. This is charged with a constant current so that the voltage across it will rise linearly with time. That is, the voltage across it will rise equal amounts in equal periods of time. Thus, as the voltage across C1 rises, the LEDs will light up one by one until the voltage reaches 5 V or until C1 is discharged.

A relay and alarm circuit is built around IC2 plus Q3 and associated components. SW2 selects at which 'increment' the relay and alarm are operated by selecting one of the outputs of IC1. When that output goes 'active' (when the LED lights) the alarm sounds, the relay drops out and the timer is reset by discharging C1. For example, if the third increment is selected (pin 17, IC1) then LEDs 2, 3 and 4 only will light, the alarm sounding when LED4 lights. C1 is then discharged at that time, resetting the timer ready for its next use.

Now, let's get down to individual circuit details. First, the constant current source that charges C1. Transistor Q1 plus LED1, R2, RV1, and R1 form the constant current source. Figure 1 shows the collector characteristics of a typical silicon transistor. This shows that, if you hold the base current constant, the collector current will remain substantially constant for a widely varying range of collector voltage. Figure 2 shows the general circuit of a 'constant current generator' using an npn transistor, as in our circuit. The voltage between the base and the emitter return (the +ve supply rail) is held fixed by a zener diode. Thus, the voltage (Ve) across the emitter resistor, Re, is fixed at a value equal to the zener voltage (Vz) minus the base-emitter voltage drop of the transistor (about 0.6 V for a silicon transistor). With a fixed voltage across Re, the current through it will be constant. Thus the emitter current of the transistor, and therefore the collector current, will be constant. The resistor supplying current to the zener is generally chosen so that the zener current is five to ten times the base current of the transistor.

When you charge a capacitor with a fixed current, the voltage across the capacitor will rise linearly with time. As we want to drive IC1 with a voltage that increases linearly with time in order to obtain equal time increments, C1 is charged from the constant current generator formed by Q1, R2, RV1, R2 and LED1. Note that LED1 (a green LED — as an 'on' indicator) replaces the zener. The forward voltage drop of a LED behaves much like a zener, the LED used having a voltage drop of around 2.5 V. To vary the rate of charge (and thus the time it takes to charge C1 to a particular voltage) the current supplied by the constant current generator can be varied by varying the emitter resistance of Q1. RV1 performs this function.

The maximum period can be determined approximately from the following formula:

Total Time = 5 x C1

where C1 is in uF. Thus, a 33 uF capacitor (as specified) will charge to 5 V in around 165 seconds with RV1 set at maximum resistance. The tolerance on tantalum capacitors is quite broad, so the formula is only approximate.

The voltage across C1 'ramps' upward as it charges. As the input to IC1 is quite a high impedance, it has little effect on the charging rate of C1.

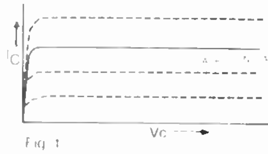


Fig 1

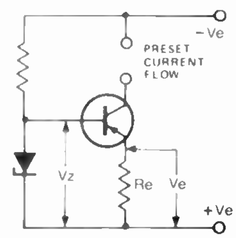


Fig 2

Let us now consider the overall operation of the timer, commencing at switch-on.

At switch-on, the output of the RS flip-flop formed by gates 'c' and 'd' from IC2 (pin 10) will be low as the inputs, pins 8 and 13, are low. Thus no bias is applied to the base of Q3 and the relay will not be operated. Its collector voltage will be the same as the +ve supply rail and thus the base of Q2 will draw current via R20 and Q2 will be on. C1 will be unable to charge as the collector-emitter junction of Q2 will shunt the collector current of Q1 to the 0 V rail. As there is no input to IC1, no LEDs will be lit.

When the START button is pressed (SW1), the output of the RS flip-flop (pin 10), formed by gates 'c' and 'd' from IC2, will go high, turning on Q3. The collector of Q3 will conduct and the relay will operate. The collector voltage of Q3 will fall to nearly 0 V and the base of Q2 will no longer be forward-biased and Q2 will thus turn off. The collector current of Q1 will then commence to flow into C1 and the voltage across it will rise. As the voltage at the input of IC1 rises, LEDs 2 to 11 will turn on at 0.5 V increments.

If we now assume that SW2 was set to select the fourth increment (pin 16 of IC1, driving LED 5), then the input of gate 'a' from IC2, connected as an inverter, would go low when LED 5 turns on. Initially, the input to gate 'a' from IC2 is held high by R15, its output will be low and C2 will be discharged. When its input goes low (at the selected increment) its output goes high and C2 charges rapidly via R17. Thus a voltage pulse is applied to pin 8 of IC2 — one input of the RS flip-flop. This causes pin 10 of IC2 (output of the RS flip-flop) to go low again, removing gate bias from Q3, which turns off, de-activating the relay. When this happens, the collector voltage of Q3 goes high and C3 charges via R19. Now, gate 'b' from IC2 is connected as an inverter, its input being connected to R19/C3. When pins 5/6 of IC2 go high, pin 4 goes low and the piezoelectric beeper sounds. C3 takes a second or two to charge, the voltage across R19 decreasing as it does so. When it falls below the 'low' threshold of pins 5/6 of IC2, pin 4 goes high once more and the beeper ceases to sound.

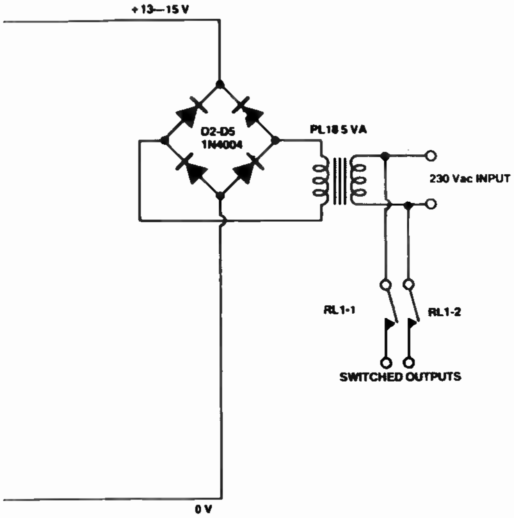
When the collector of C3 goes high when LED 5 lights (remember?), Q2 receives base bias once more, via R20. It turns on again, shunting the collector current of Q1 to 0 V and discharging C1. Thus the timer is reset at the end of the selected period.

By varying RV1, the time it takes C1 to charge to a particular voltage is varied, and thus the period of each increment and the total period can be varied. The time interval of the first increment is slightly shorter than the subsequent increments as Q2 is not capable of discharging C1 completely due to its collector-emitter saturation voltage (about 200 mV or so).

A conventional diode bridge rectifier is employed and C4 provides smoothing. A Ferguson pc-mount transformer is employed to drop the 240 Vac mains to a suitable voltage. Only one secondary winding from this transformer is used, providing 9 Vrms to the rectifier, which thus gives a dc supply of around 13-15 volts.

Resistors are used from each output of IC1 to each LED cathode to ensure that the outputs of IC1 drop below the 'low' threshhold of the inputs to gate 'a' of IC2 when the IC1 outputs are 'active'.

The relay contacts are rated at 5 A and will switch a load of up to 1200 watts, providing the load has a unity power factor (i.e: it's resistive).



PARTS LIST — ETI 259

Resistors .... all ½W, 5%
R1 .... 100k
R2,3,16 .... 1k
R4 .... 3k3
R5-14 .... 560R
R15,17,20 .... 10k
R18 .... 4k7
R19 .... 10M
RV1 .... 1M lin. pot.

Capacitors
C1 .... 33u/16 V tant.
C2 .... 10n greencap
C3 .... 220n
C4 .... 470u/25 V electro.

Semiconductors
D1 .... 1N914,1N4148 etc.
D2-D5 .... 1N4002,1N4004 etc.
IC1 .... LM3914
IC2 4001
Q1 .... BC307,BC177 etc.
Q2,Q3 .... BC547,BC107 etc.
LED1 .... TIL220G green LED
LED2-11 .... TIL220R red LEDs

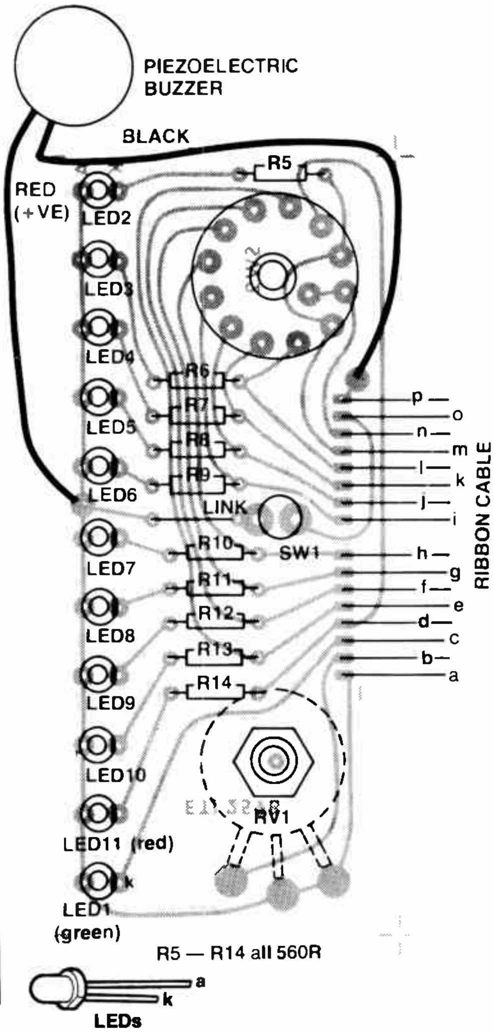
Miscellaneous
ETI-259a and ETI-259b pc boards; T1 — PL18/5VA transformer or similar; SW1 — miniature pushbutton; SW2 — 1-pole, 10-position rotary switch; RL1 — 12 V relay with 240 Vac/5 A contacts e.g: Fujitsu FRL-621DO12 or Takamisawa VB 12STAN or Pye 265/12/G2V; piezoelectric alarm or buzzer, e.g: Piezo-II type ESZ-11N; jiffy box 196 x 113 x 60 mm or similar; four-way or six-way terminal block; mains cord, cable clamp and plug; 3-pin mains socket; LED mounts; Scotchcal panel; ribbon cable; wire; nylon nuts and bolts, etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range:

$32 — $45

Note that this is an **estimate** only and **not** a recommended price.



for drilling the front panel. Centre punch them before drilling. Leave the panel at this stage, as it will be completed later.

The 3-pin mains outlet socket may be mounted to the box at this stage. Attach mains wire to each pin connection, using the appropriate colour coding (brown — active, blue — neutral, green/yellow — earth). Each wire needs to be about 70-80 mm long. Now secure the mains input cable. Strip the end first and cut the blue and brown wires so that they are 120-150 mm shorter than the green/yellow wire. This ensures that, should the cable ever be pulled out of the case, the earth wire will be the last to break.

The two pc boards may now be assembled. Tackle the smaller board first. Install the link first — it's in the middle of the board. The resistors should come next; these are all the same value — 560 ohms. Mount the LEDs next, inserting them in the board one by one and making sure you have each the right way round, as indicated on the overlay — cathode lead faces into the board. Each LED is positioned so that the distance between the board and the base of the LED is 12 mm. When distanced correctly, solder the leads in place.

The increment selector switch, SW2, may be mounted next. The holes in the pc board for its pins should be the correct size; check this. The switch can only go in one way. Carefully line up the pins and insert the switch in the board, pushing it all the way home. Solder the pins. Now the START pushbutton may be mounted. Make sure the holes for its pins have been drilled oversize too. You will need to trim the lugs on the pushbutton so that they fit in the pc board holes. Mount the pushbutton, making sure that the distance between the board and its mounting shoulder (with washer) is the same as that for SW2. You could temporarily mount the board to the front panel, using SW2 to secure it, and then solder the pushbutton's pins when the board is parallel to the panel.

The potentiometer is mounted last. Position it so that its lugs are over the appropriate pads on the pc board and then secure it to the board with its nut. Use a spring washer or a star washer under the nut. Then bend the lugs down to the pc board pads and solder them in place.

Last of all, attach two pieces of 8-way ribbon cable. These should each be about 130-150 mm long.

The front panel assembly may now be completed. If you're using a Scotchcal stick-on panel, this should be carefully attached to the ready-drilled aluminium jiffy box panel. Smooth it on, rubbing from the centre outwards to remove any bubbles. Cut the holes in the Scotchcal with a scalpel or other sharp-bladed knife. Insert the LED mounts in their holes next. Now you can mount the pc board, making sure that the LEDs all seat correctly in the mounts. Carefully tighten the nuts on the shafts of the START pushbutton and SW2 so as not to damage the Scotchcal on the panel. A large solder lug was secured between the washer for the pushbutton and the front panel to provide a mains earth▶

CHANGING THE PERIOD

The total time period may be altered by changing the value of C1. The approximate maximum period may be found from this formula:

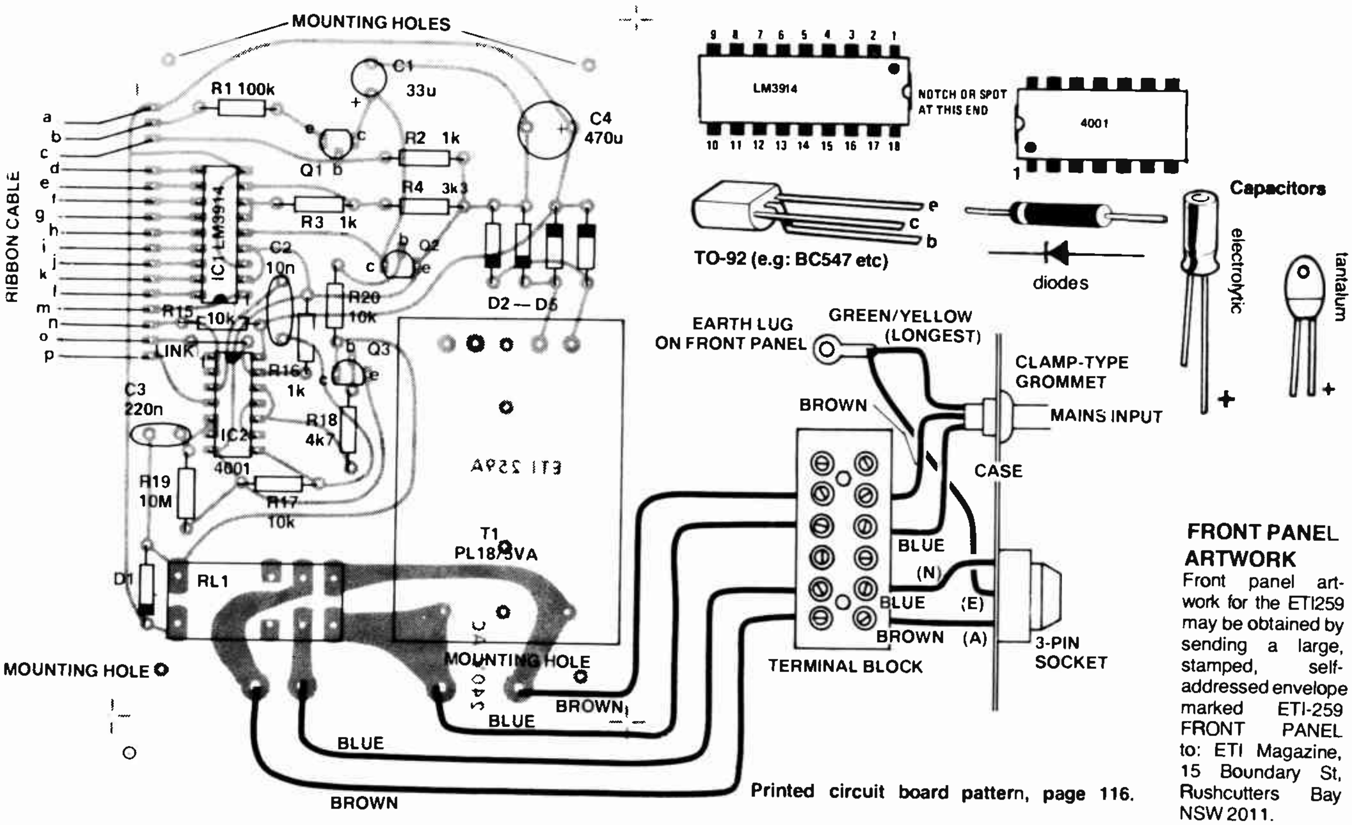
Period (approx.) = 5 x C1

where the value of C1 is in uF. It's only approximate as the tolerance on tantalum capacitors is quite broad. Thus with a 33u capacitor for C1, as specified, the maximum period is around 165 seconds or so. Given a desired period, calculate the capacitor value from:

C1 = period/5

and the value will be in uF. Choose the next highest preferred value, for safety's sake. You can then set the maximum period, and thus the period of the increments, using RV1, calibrating the unit with your watch. It's advisable not to use a capacitor any greater than about 120 uF — but this will give you a maximum period of 10 minutes!

Note that an RBLL-type electrolytic may be used for C1, but accuracy may suffer a little compared to tantalum types. The voltage never gets above 5 V, so a capacitor rated at 6 V, 10 V or 16 V is perfectly adequate.



Printed circuit board pattern, page 116.

FRONT PANEL ARTWORK

Front panel artwork for the ETI259 may be obtained by sending a large, stamped, self-addressed envelope marked ETI-259 FRONT PANEL to: ETI Magazine, 15 Boundary St, Rushcutters Bay NSW 2011.

point. Now mount the piezoelectric buzzer and solder its leads in place, as shown on the overlay. Attach knobs to the shafts of SW2 and RV1 last of all.

The next stage of construction to tackle is the large pc board. All the resistors and capacitors should be mounted first, taking care that you get C1 and C4 the right way round. Next, mount the diodes and the three transistors, again taking care with orientation. Mount IC1 (the LM3914) next — get it the right way round, followed by IC2. The latter is a CMOS IC and should only be handled by the ends of the package. When soldering it in place, solder pins 7 and 14 first, followed by the other pins. Use a hot iron with a clean tip when soldering the IC pins, solder each one quickly and pause every few joints to let the IC package cool down a little.

Mount the relay next. We used a type which can be readily soldered in place — a Fujitsu type FRL 621D012, although the board has been laid out to take several other common types. Make sure the board has been drilled out to accept the relay used before commencing construction.

The pc mount transformer can now be mounted to the board and its pins soldered in place. Note that it can only go on one way. Last of all the ribbon cable from the smaller pc board can be attached and then two pairs of mains wires, each about 40-50 mm long. These are the mains input and switched mains output leads. Use colour-coded wires, cut from mains cord, to avoid wiring errors.

The main pc board may now be mounted to the case. Use nylon nuts and bolts. Raise the board off the bottom of the box a few millimetres using fibre spacers. Use nylon nuts and bolts for the terminal block if it is bolted to the box too. Now complete the mains wiring, as indicated in the overlay/wiring diagram. The earth lead from the mains input cord goes to the solder lug attached to the front panel (under the pushbutton). A lead from this lug goes to the earth pin on the 3-pin mains output socket.

After a careful final check, you're ready to test the unit.

Testing

Set the 'Time Delay Adjust' control to minimum and the 'Increments' switch to 10. Plug the timer into the mains and turn it on. Wait five seconds or so for the power supply to reach full voltage and press the START pushbutton when the sweep second hand of your watch, or the seconds display on your digital watch, is at a convenient point. The LEDs 1 to 10 will light up, the piezoelectric buzzer sounding when LED 10 signals the end of the timing period. If you have used a 33u capacitor for C1, as per the parts list, then this should take close to 15 seconds. The relay should pull in when you press the START button, dropping out when LED 10 lights. You can calibrate the Time Delay Adjust pot. to suit the applications for which you use the project so that you obtain the required period.

A little experimentation and practice will show you how to use the unit to best advantage. ●

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.

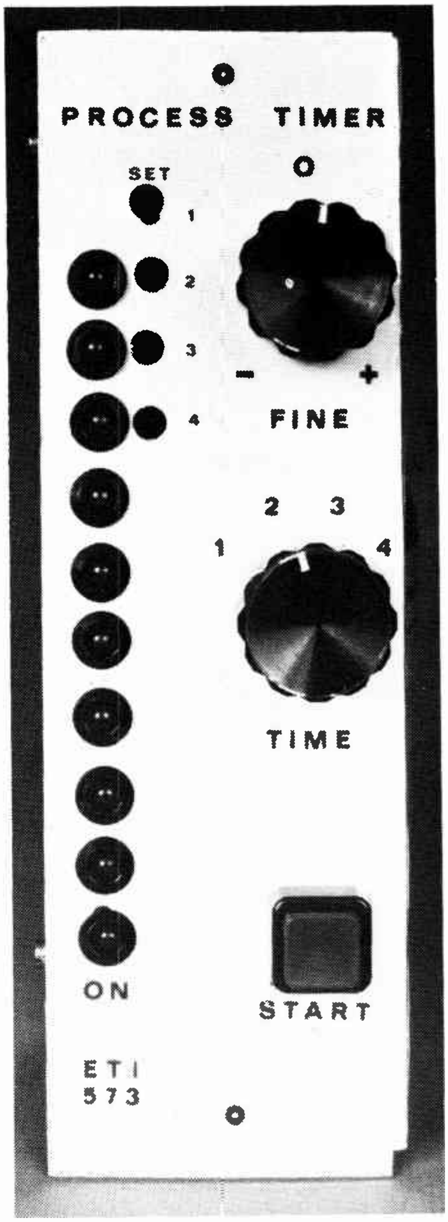
Following the completion of our darkroom here at ETI which we use for making negatives and printed circuit boards, it was decided a simple timer was needed to control the light source used for exposure. Because different times are used for exposing film, printed circuit photoresist and Scotchcal, the 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.

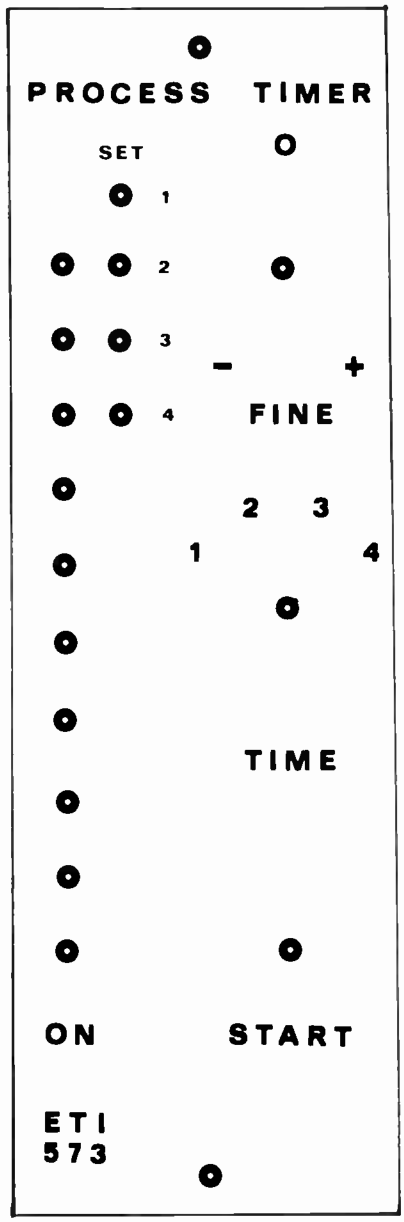
Someone then suggested it would make a good project – after all, there's very little we do here that many of our readers don't do themselves at home.

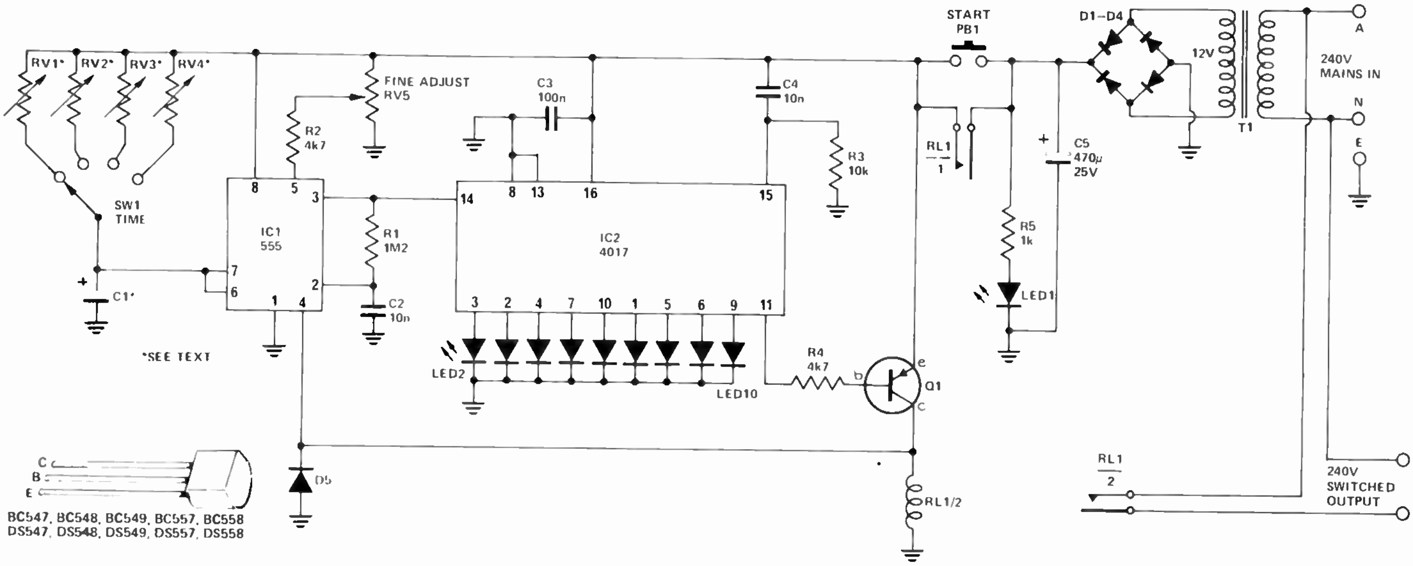
In fact, this timer is not just limited to the applications we use it for, but can be used to control anything from an egg timer to an injection moulding machine. Judging from some of the calls we get from readers, this timer should find its way into all sorts of applications.

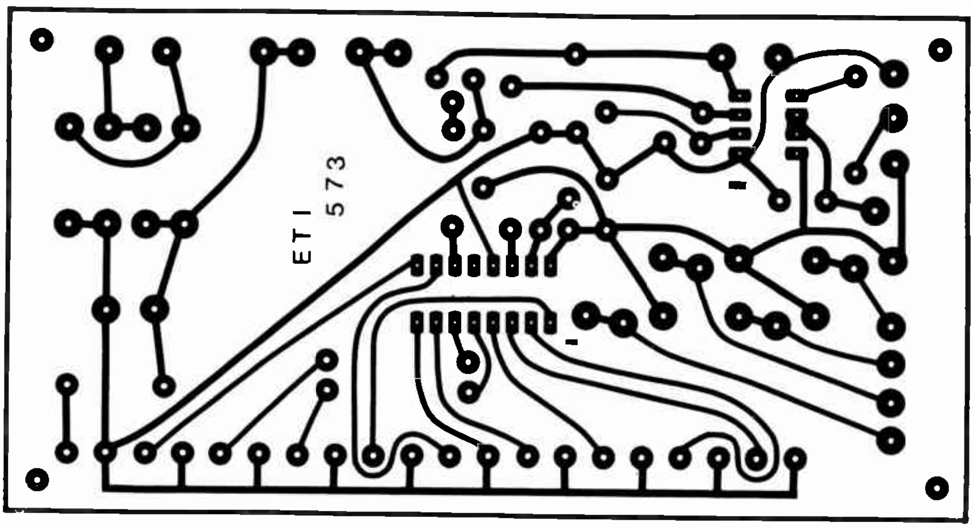
The technique

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 a·d 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

(main text continued page 100).

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.

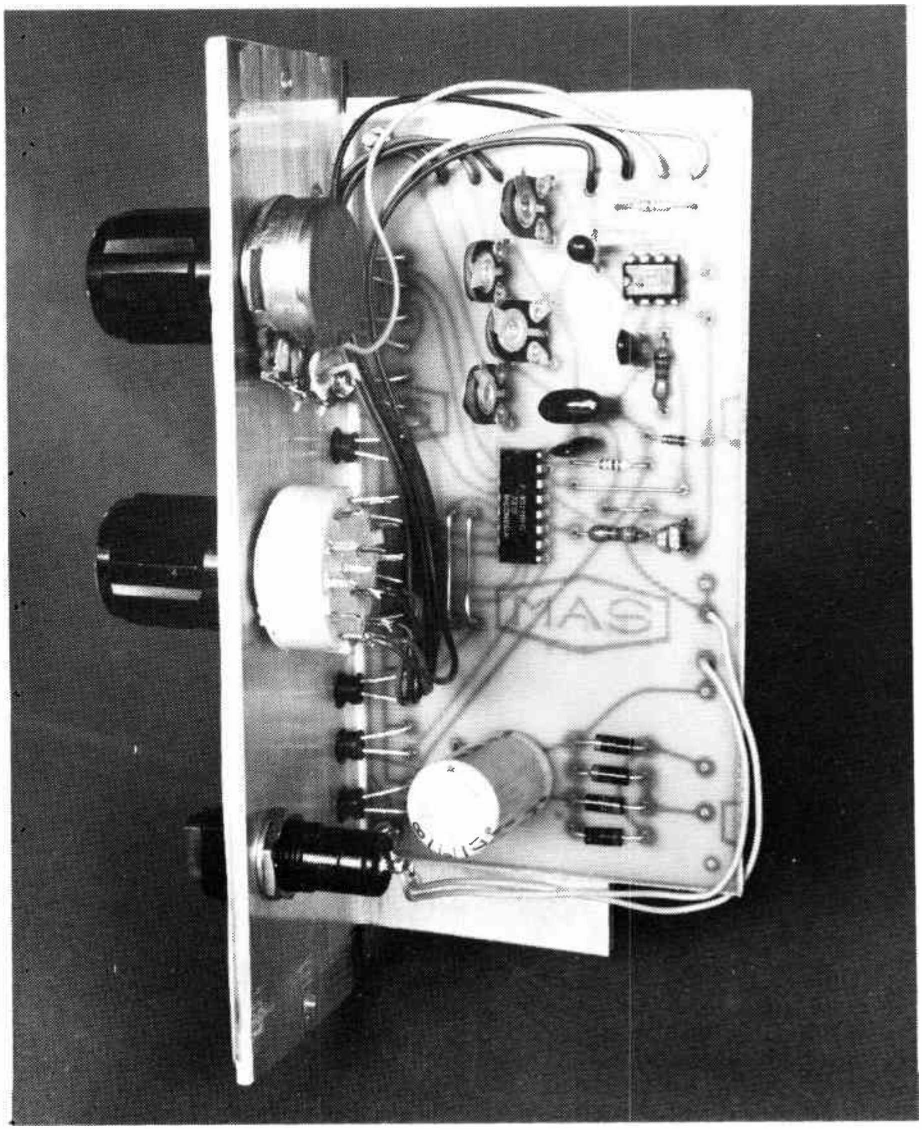
The timing period is set by the frequency of oscillation of ICI. This is dependent on the time constant of RV1-RV4 and C1. As either of these components are increased in value the time constant will increase and the frequency of oscillation decrease. Fine frequency adjustment is provided by RV5 which 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.

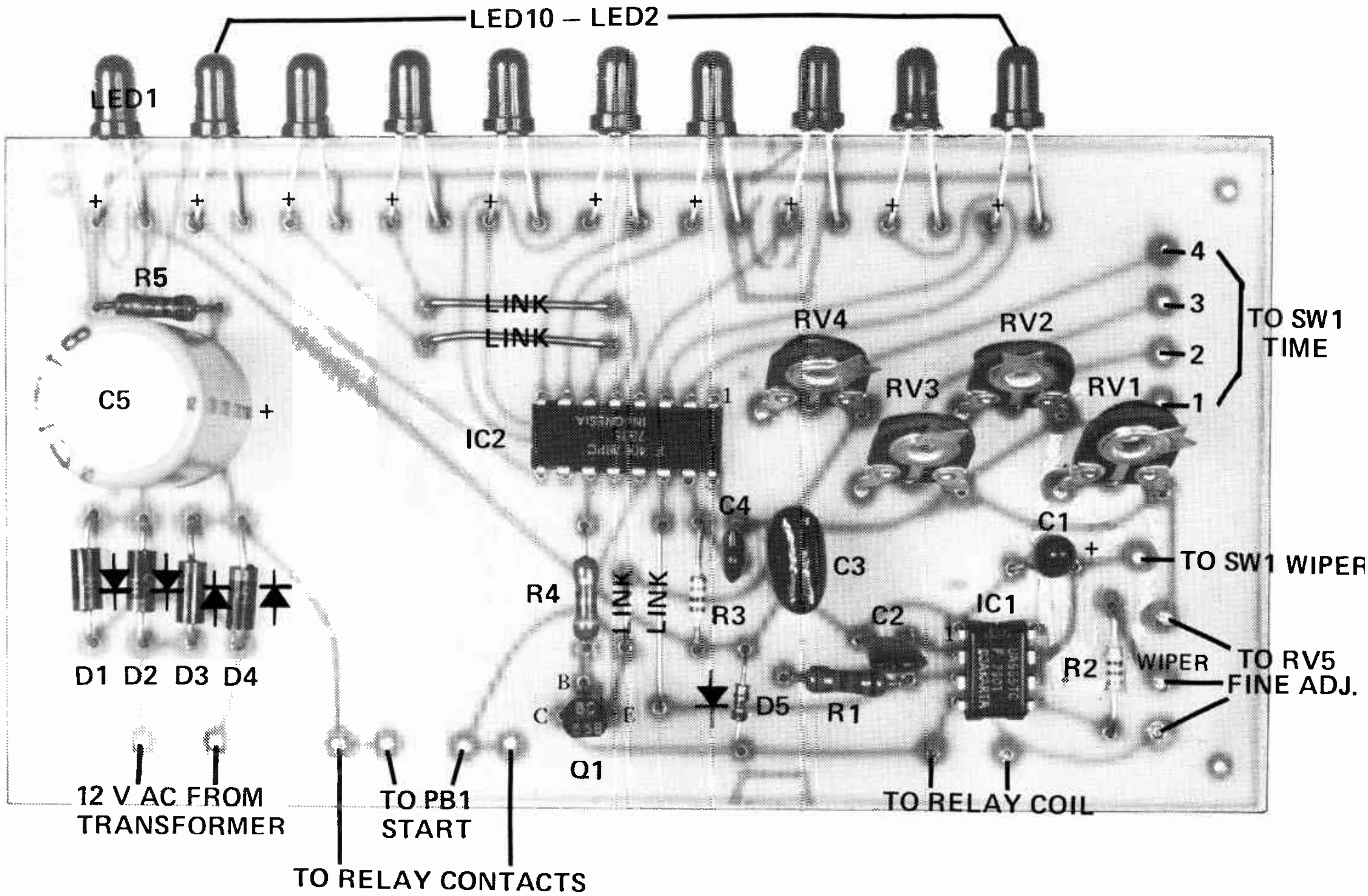
Output from the 555 is fed to the clock input of the 4017. After each pulse a different decoded output of the 4017 goes high, lighting each LED in turn. After the tenth clock pulse the output on pin 11 of the 4017 goes high. We shall come to what that does shortly.

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.

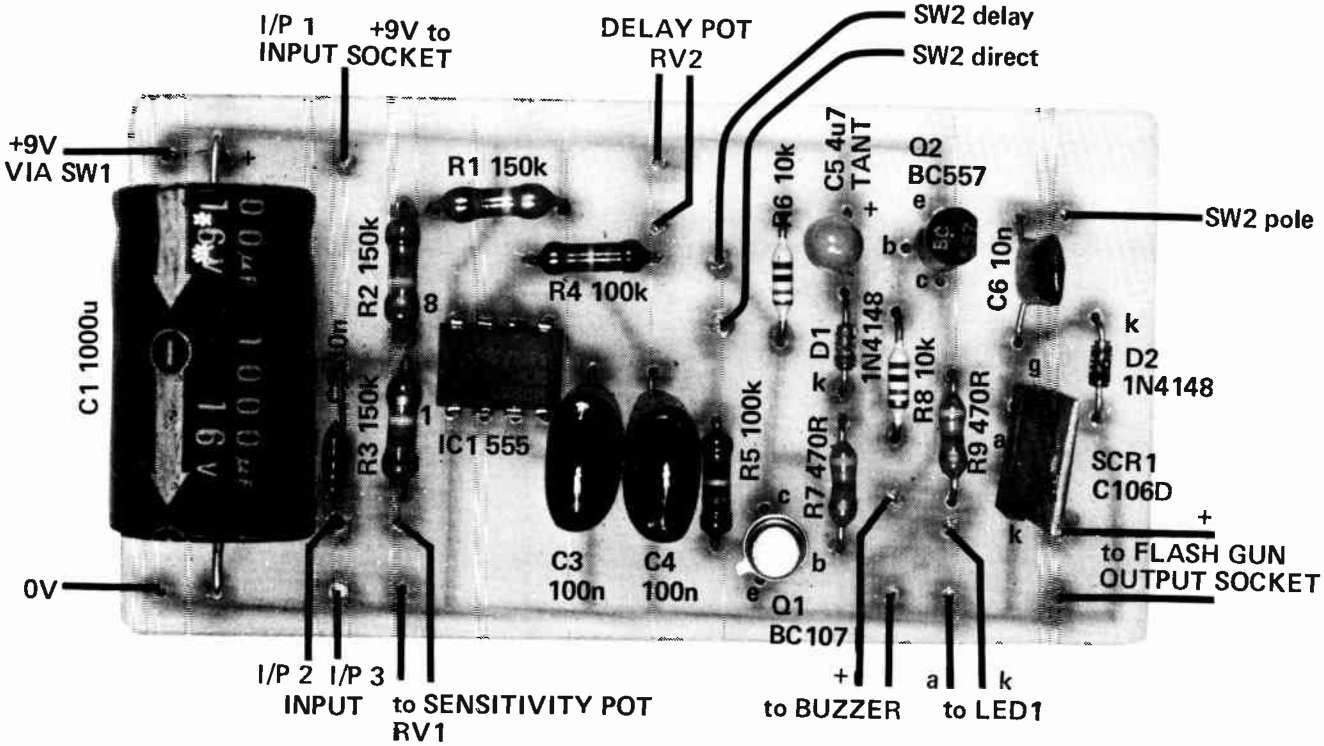
Simply monitor the positive supply after the relay contacts RL1/1 and measure the time the contacts operate. For other purposes it may be best to set the ranges by trial and error, such as when the unit is being used for a pc board or Scotchcal development timer. In either case, the fine adjustment control should be set in its mid position when calibrating. ●

Project 568

Sound or light operated flash trigger has many features

Phil Wait
Simon Campbell

You too can take spectacular action shots just like those shown in these pages. This project is simple to build, suits any flash unit and can be triggered in a number of ways.



NOTE: Printed circuit board artwork is on page 130.

PHOTOGRAPHICALLY 'freezing' an action while it is in progress is an extraordinarily difficult task unless you can accurately time the flash to 'fire' at a particular instant during the event. This project does exactly that. You can trigger your flash from a sound, such as that produced by a bouncing ball, or by light — by having an object break a beam of light for example. You can arrange to trigger the flash by a light source turning on, or turning off. In addition, this unit permits you to *delay* the triggering of the flash by a preset amount, allowing you to 'catch' the action at differing periods after the triggering event.

The attraction of this unit is that you need no fancy equipment to take good pictures like those you see on these pages. You don't have to have a fancy SLR camera — just a simple model on which the shutter can be locked open. We haven't tried it, but with a powerful flash gun even a pinhole camera should work!

The circuit

A 555 timer IC (surprise, surprise!) is employed to provide a trigger pulse from a suitable input sensor. This can be an inexpensive crystal microphone or a phototransistor connected to trigger the 555 from a light source turning on or a light source turning off. Obviously, the unit can be used as a slave flash trigger also.

The 555 is operated in the *monostable* mode. That is, when triggered by the input signal detector it provides a single pulse output, the width of this pulse being predetermined by a preset control. The pulse output of the 555 is arranged to turn on an SCR which is connected in series with the flash gun's power supply via an interconnecting cable.

To provide a variable delay, the SCR is triggered from the *trailing* edge of the pulse output from the 555. The width of the pulse can be varied with a potentiometer control. A minimum delay of about 10 milliseconds and a maximum delay in excess of 200 milliseconds can be obtained. If you require a shorter delay, the value of R4 may be reduced, but do not use a value less than 1k.

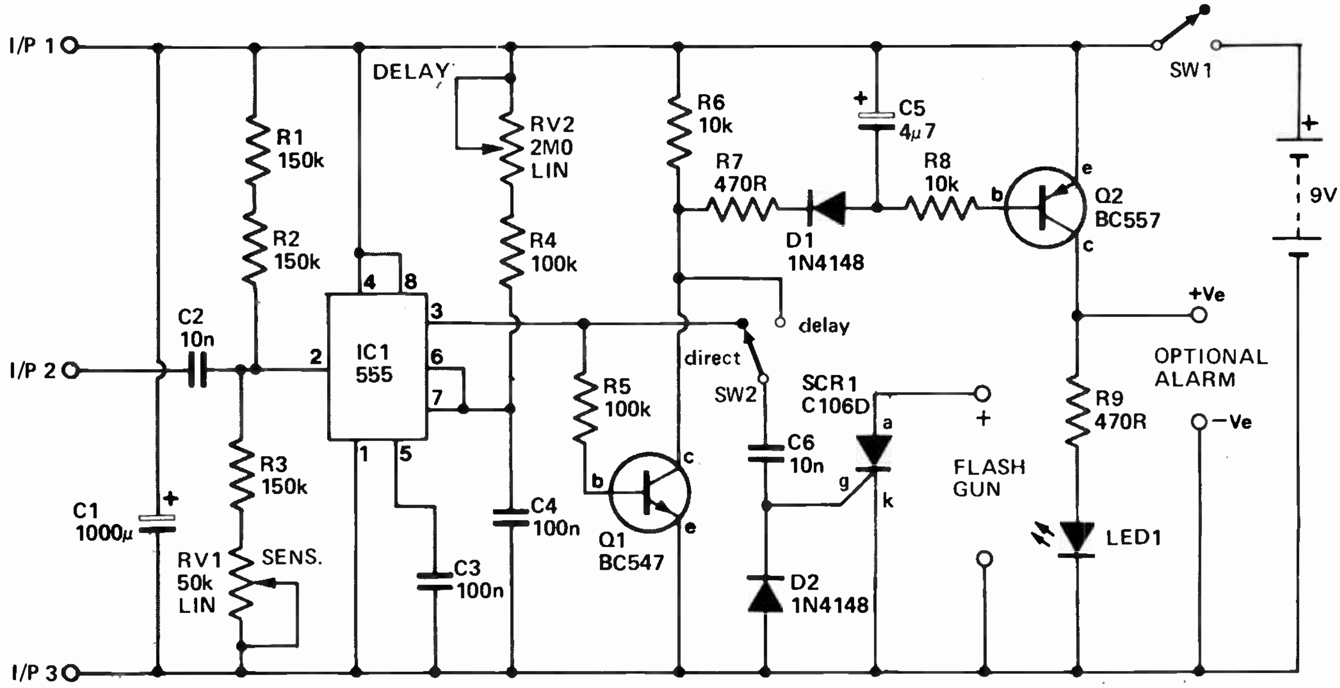
When setting up a shot, one needs some indication that the trigger unit is being correctly fired by the action, without having the flash gun 'popping' numerous times. For this reason we have included a LED on the front panel and a piezo buzzer to provide both a visual and an audible indication. The piezo buzzer is optional, but we found it handy as you can't always be involved in the action and watch the LED at the same time.

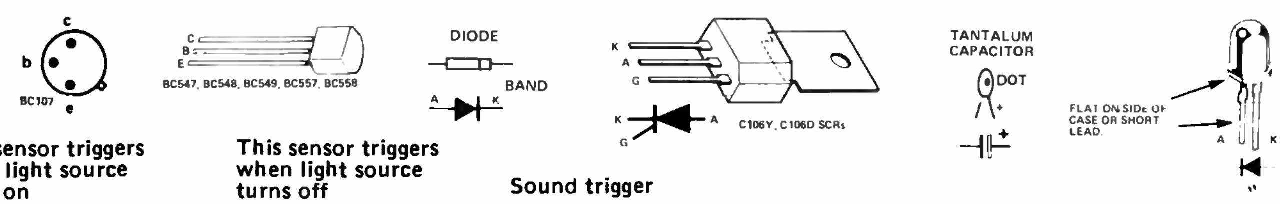
For 'rehearsals', the flash gun cable is disconnected. With everything set to go the sensitivity control on the trigger unit is set at some arbitrarily chosen level and the action initiated. If all is well, the LED will light and/or the buzzer will sound.

The whole unit is powered by a single 9V battery. A No. 216 transistor radio battery does the job nicely and should give long life.

Construction

We constructed our unit using a pc board to mount all the minor components. We recommend you use the pc board as it simplifies construction and avoids the more common wiring errors. The whole unit was assembled into a convenient 'jiffy' box measuring 160 mm long by 95 mm wide by 50 mm deep. All the major components were mounted on the aluminium front panel and wired to the pc board with hookup wire. We used a five-pin standard DIN socket for the input connector and a two-pin socket, usually used as a speaker connector, as a connector for the flash gun cable. The sensors generally need to be placed in a convenient position re- ▶

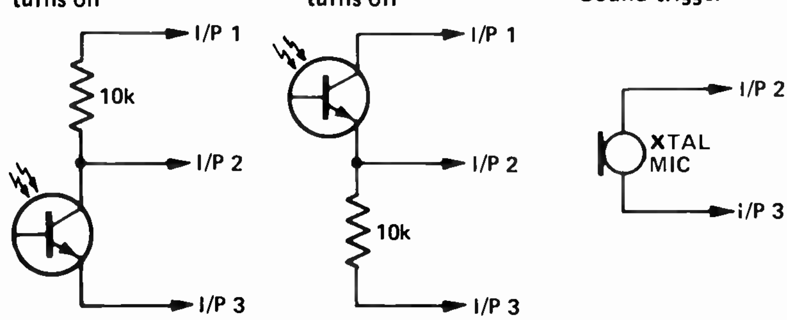




This sensor triggers when light source turns on

This sensor triggers when light source turns off

Sound trigger



Use phototransistors, type FPT100 or TIL78 or similar

HOW IT WORKS — ETI 568

IC1 is a 555 timer connected in the monostable mode. The timing period is determined by RV2, R4, C4 and is adjustable between 11ms and 230ms with the values shown. The trigger input of the chip is held just above its firing potential of one third supply voltage by adjustment of RV1 which acts as a sensitivity control. A negative-going signal is coupled to the input by capacitor C2. Note that the values of R1, 2, 3, RV1 provide a medium input impedance and screened cable may be required when the sensor must be separated from the unit.

When IC1 is 'fired' its output (pin 3) goes high for the monostable period. With SW1 switched to 'direct', this positive going pulse will fire the SCR and discharge the flash enabling the unit to be used as a slave flash.

There will be a finite delay owing to rise time of phototransistor response, propagation delay within IC1 and rise time of its output. However, this will be measurable in microseconds and should be negligible.

When used in the 'delay' mode, the output pulse is inverted by Q1 causing the flash to fire on the trailing edge of the monostable pulse. To avoid repeated use of the flash when setting up the unit, indicator LED1 is provided. Each negative excursion of Q1 collector causes C5 to charge via R7, D1 effectively stretching the monostable pulse and providing a clearly visible flash.

An optional alarm, for example a solid-state buzzer, can be connected into the circuit providing audible indication of triggering.

Capacitor C1 provides overall decoupling. Supply current is about 10 mA.

PARTS LIST — ETI 568

Resistors all ¼W, 5%
- R1,2,3 .... 150k
- R4,5 .... 100k
- R6,8 .... 10k
- R7,9 .... 470R

Potentiometers
- RV1 .... 50k lin
- RV2 .... 2M lin

Capacitors
- C1 .... 1000u electrolytic
- C2,6 .... 10n polyester
- C3,4 .... 100n polyester
- C5 .... 4u7 tantalum

Semiconductors
- IC1 555
- Q1 .... BC547, BC107 etc
- Q2 .... BC557, BC177 etc
- SCR1 .... C106D or similar
- D1,2 .... 1N4148 or 1N914
- LED1 .... any LED

Miscellaneous
- SW .... SP DT toggle switch
- SW2 .... SP DT toggle switch
- ETI-568 pc board; flash gun connector, crystal microphone with plug and socket (if used); 9V battery and battery clip; box to suit; buzzer (if required).

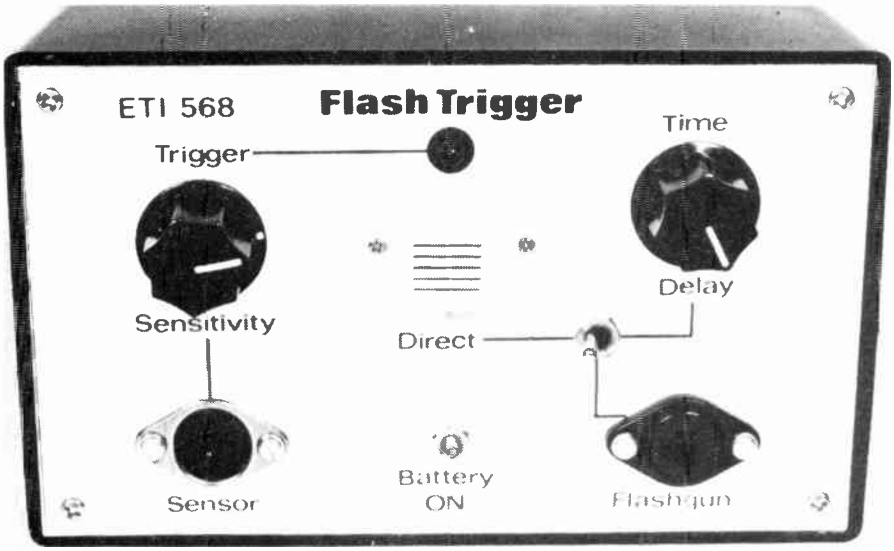
Additional Components for Light Operation:
Phototransistor FPT 100, TIL78 etc.
10k resistor.

mote to the trigger unit and we made up several cables for each of the different sensors.

Construction is best commenced by loading the components into the pc board. It is usually convenient to start with the resistors and capacitors. Take care with the orientation of the 4.7 μF tantalum capacitor and the 1000 μF electrolytic. The semiconductors can be mounted on the board next. Here too, take care to get them the right way around. Particularly watch the orientation of the IC and the two diodes.

Some mechanical work comes next. Mark out the front panel carefully and drill all the holes. Temporarily mount each individual component on the panel, just to make sure that they all fit without problems. We used a Scotchcal front panel to dress up the unit. If you are doing likewise, now's the time to attach it to the panel of the jiffy box. Having done that, finally mount the two pots, the two sockets, the switches, the LED and the buzzer (if you've elected to use one).

Now you can install the wiring between the pc board and the components on the front panel. Note that pin 1 of the input socket is wired to the pc board via a short length of shielded cable. This is to avoid pickup of stray signals, such as hum, which may cause triggering difficulties. Be careful with the connections to the LED and the two pots. The component overlay and wiring diagram should make this stage of the construction fairly clear.



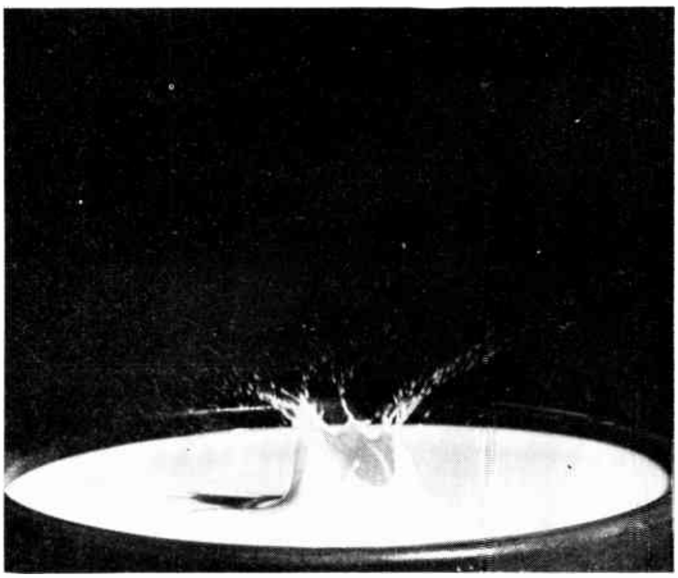
The prototype was housed in a 'jiffy' box measuring 160 mm long by 95 mm wide by 50 mm deep. The front panel was dressed up with a Scotchcal transfer. These should be available through suppliers — see Shoparound on page 128.

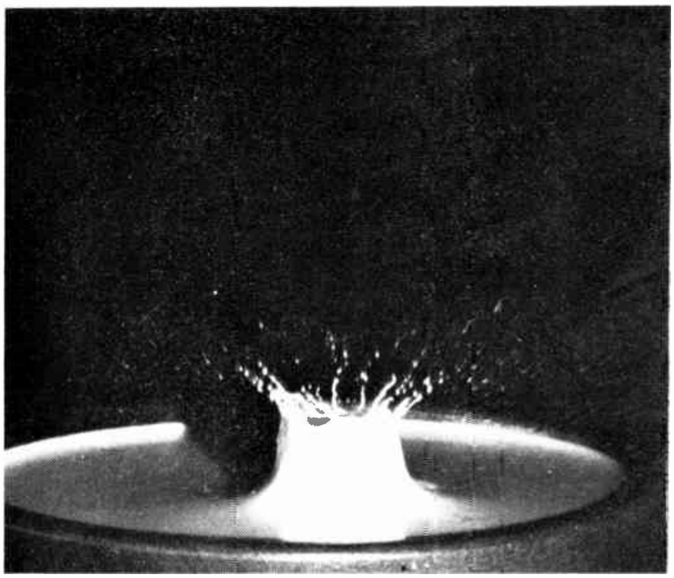
You don't have to use a DIN socket for the input connector as we have, indeed a tip-ring-and-sleeve jack socket could equally well be used. Any sort of socket having three connections will do the job. Similarly, we used a two-pin socket for the flash gun connector as we had it on hand. Both these connectors are readily available and this was the main consideration in our choice.

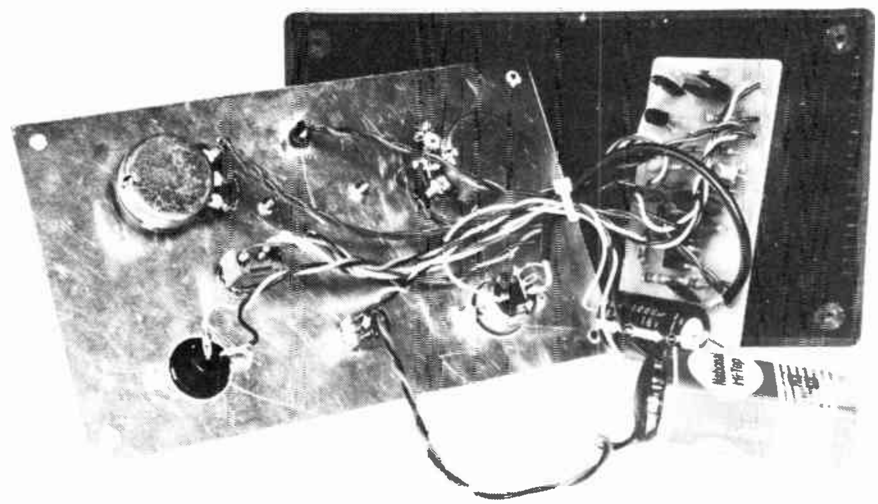
You will have to make up a suitable lead to go between the trigger unit's output connector and the flash gun's remote trigger connector. Use the appropriate connectors at each end.

Polarity is important as the trigger unit employs an SCR for the triggering 'switch' device. One way of determining

This series of pictures shows how the variable time delay facility can be used to capture the effect of a ball bouncing in a container of fluid (milk here). The shots were sound-activated and the time delay was set for delays between







Internal view of the completed prototype. Note that wiring between I/P2 and the panel-mounted input socket is via shielded cable. Sensors should be wired with shielded leads also.

the polarity of the flash gun is to measure the voltage present at its trigger socket with a multimeter.

Sensors

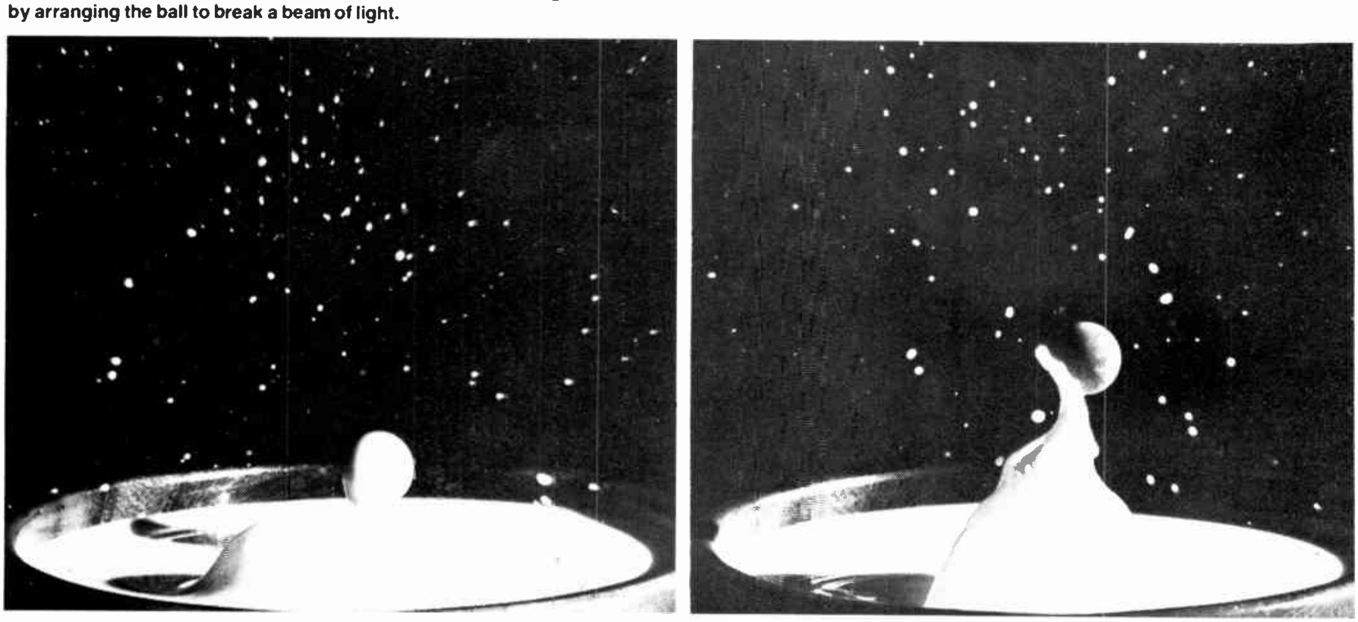
Before you can try out the unit, you will need to assemble some suitable sensors. The simplest is just a crystal microphone. We used an inexpensive 'lapel' mic and obtained excellent results. A crystal mic is recommended as it has quite a high output level. You can give the unit a 'dry run' at this stage. Set the Direct/Delay switch to Direct and the Sensitivity control to mid range and turn on. Clap your hands once and, if all is well, the LED will light and the buzzer will sound for a brief period. Set the unit to Delay and the Time control fully clockwise. Clap once more and again the LED will light following a brief delay. Experiment a little with the sensitivity control so that you get some idea of how it affects the operation.

There are two ways the unit can be triggered from a light source, as we said before — by a light source turning on, or a light source turning off. The different sensor circuit configurations are given in the accompanying circuits. An inexpensive, readily available phototransistor is employed — either a Fairchild FPT100 or a TIL78 from Texas Instruments. There are many similar devices available and no difficulty should be experienced here.

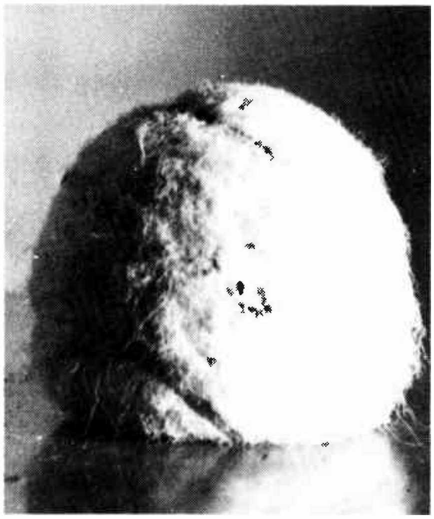
The phototransistor can simply be 'hung' from the leads at the end of a cable, the other end being terminated in the input plug (which suits the input socket used). The 10k resistor may be mounted in the input plug housing. There is plenty of room in a DIN plug. If you want something a little more salubrious, the phototransistor could be inserted in a small diameter plastic tube (say, 12 mm dia.) with the 'business' end of the device flush with the end of the tube. The tube can then be filled with epoxy resin. It's advisable to have the phototransistor attached to the cable before you do this!

Microphones usually come in their own housing, so there's no need to go to any trouble with them. The lapel mics come with a handy clip, so they can be attached to any convenient support. ▶

50 milliseconds and 200 milliseconds. Similar shots could be light activated by arranging the ball to break a beam of light.



Another sensor to try out is a silicon solar cell. To use one as a sensor with this unit, you will need to obtain one of those small 'transistor radio audio transformers' — the type having a "1000 ohm" primary and an "8 ohm" secondary, or similar. It is used 'back to front' in this application. Connect the solar cell directly across the transformer's low impedance winding and connect the high impedance winding between I/P2 and I/P3. It's simple, but it's sensitive. Suitable solar cells, or solar cell pieces, are obtainable from David Reid Electronics stores, Dick Smith Electronics stores, Ellistronics, Electronic Agencies, Radio Despatch Service (all advertisers in ETI) or Amtex Electronics of P.O. Box 285, Chatswood NSW 2067.



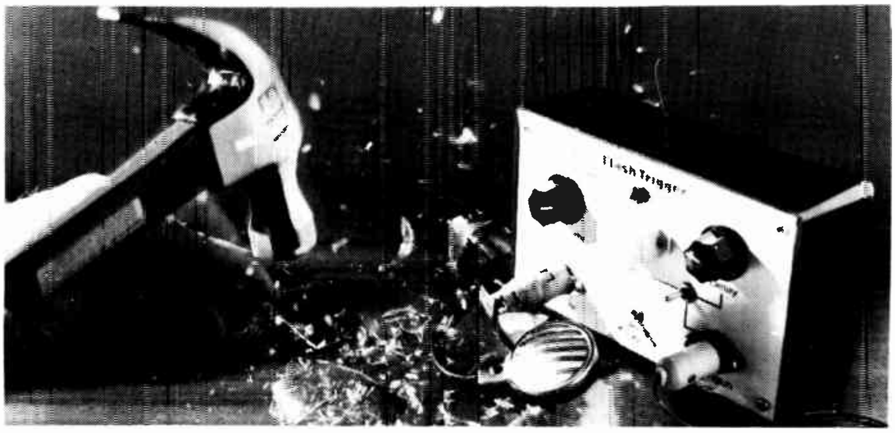
Above, a ball on the bounce. Top right, breaking a light bulb.

Using the trigger

You'll probably need a fair bit of practice before you get properly used to working with our flash trigger, but persevere — the results will be well worth it.

First of all, position the microphone or light sensor near the object to be photographed, taking care to keep it out of the camera's field of view. The sensitivity of the trigger is quite high, so it should be possible to place the sensor quite remote from the action. For scenes involving explosions or splashing liquids this is certainly advisable!

Set up your camera for the shot you want and then do a dry run of the action with the camera shutter closed and the flash gun disconnected. The purpose of this is to make sure that the trigger is being reliably fired by the action. If all



is working well, the front panel LED will light and the buzzer (if one is fitted) will sound. If not, adjust the sensitivity control or move the sensor.

Once you're happy with the operation of the trigger, you're ready to start shooting in earnest. Connect the flash gun to the trigger unit and set your camera aperture according to the exposure guide table supplied with the flash gun. Remember that the aperture setting given in the guide relates to the distance from the object being photographed to the *flash gun*, not to the camera. Take another look through the viewfinder, just to check that all the action will be in frame and neither the flash gun nor the sensor is visible.

The camera shutter cannot be triggered by the flash, so it must be set to the 'time exposure' or 'B' position. Before you open the camera shutter, make sure the room is in TOTAL darkness. Try not to trip over any of the equipment in the dark!

Open the camera shutter and set off the action, releasing the shutter button when the flash has fired. You may find a cable shutter release very useful if you don't have a friend helping you to set up the shots.

You should now have a picture, but at this stage you won't know whether or not you've captured the exact instant of the action you wanted. So set the trigger unit to give a different delay and shoot again. If your trigger is sound operated, you can get very fine control over the delay by taking advantage of the relatively slow speed of sound. Sound waves move at about 330 metres per second, so for every metre change in the object-to-microphone distance there's a 3 millisecond change in the triggering delay.

By this time you'll have spent quite a lot of time and trouble (and some money) in constructing and setting up your flash trigger, so don't be mean with film. Shoot a whole roll if necessary, to make sure of getting the one or two shots that you really want.

The ability of the flash trigger to freeze very fast action such as explosions or collisions will depend on the speed of your flash. Most camera flashes have a flash period around one millisecond which may produce a blurred picture in some circumstances. If you find your picture is blurred you will have to use a faster flash or strobe unit.

Calibrating the delay

If you wish you can use an oscilloscope to calibrate your delay control.

If you have a dual-trace oscilloscope, connect one vertical input to the sensor output and the other to the gate of the SCR. Set the oscilloscope to trigger from a positive going edge on the sensor output and the time base to 10mS per division. Switch the flash trigger to the delay mode and activate the sensor. Looking at the CRO you should see a delay between the first negative edge of the sensor output and the gate pulse. You should be able to vary the gate pulse, by rotating the delay control, from about 10 ms to 200 ms. As the trace will only sweep once for each trigger pulse, it may be difficult to see. Retriggering the sensor quickly with a flashing light will improve the visibility of the trace. Alternatively the sensor can be replaced with a low frequency pulse generator, but be careful not to have a pulse period shorter than the delay you are trying to measure. Measure the delay for each 20 degrees or so of the delay potentiometer and calibrate your scale. Our unit measured close to 11 ms minimum delay to a little over 200 ms at maximum.

The procedure for using a single trace oscilloscope is similar, except that the sensor output is fed to the external trigger input on the oscilloscope, and the trigger control set to trigger from a negative going edge. The vertical input is connected to the gate of the SCR and the sensor activated. The delay is then measured from the left hand edge of the trace to the gate pulse. ●

Project 578

Simple NiCad battery charger

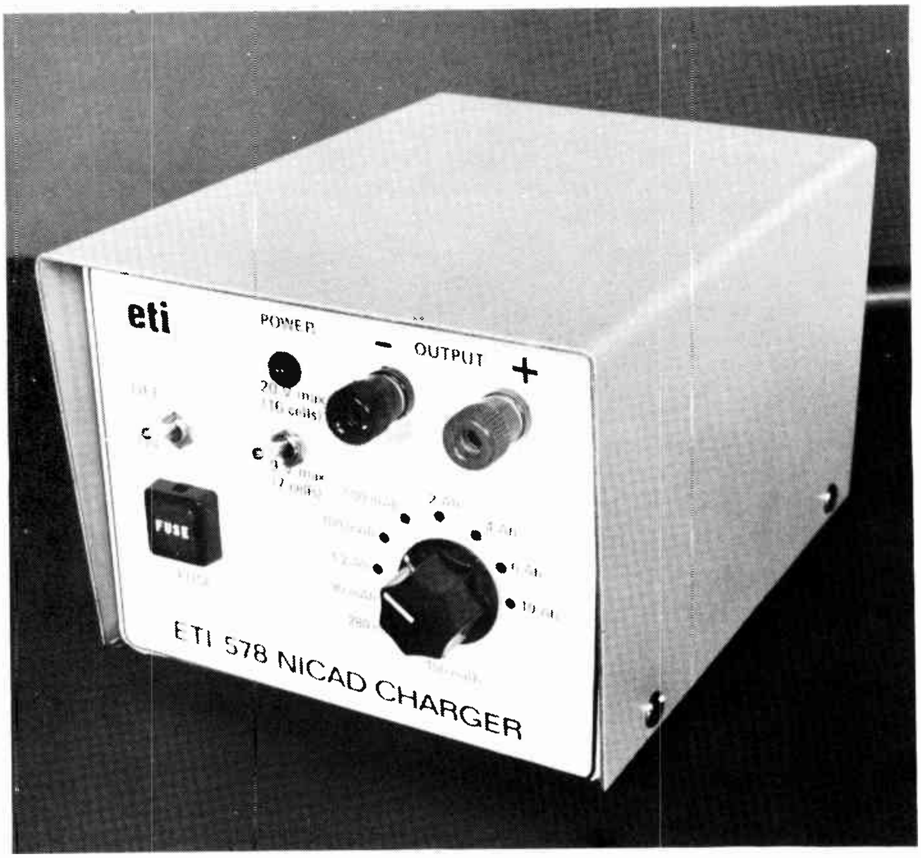
Protect your investment in Nickel-Cadmium cells (NiCad for short) with this simple charger. It's very reliable, easy to build and won't ruin the cells by over-charging, which is a common cause of NiCad battery failure.

Design: **staff**
Article: **Andrew Kay**

PRACTICALLY EVERYONE who owns and/or uses battery driven equipment that is used regularly is aware of the staggering cost of the batteries that seem to need replacement with monotonous regularity. They seem to have the perverse habit of running flat at the most inconvenient time (Murphy's law notwithstanding): they are getting dearer all the time: their output voltage drops quite rapidly with discharge and last, but most importantly, they deteriorate almost as quickly on the shelf as when they are in use.

Since it's not always practical to use mains-powered battery eliminators, one solution is a battery with a high 'ampere-hour efficiency'; that is, one whose voltage is much less affected by the discharge rate than the dry cell type. Also, it's handy if the battery can be recharged. The NiCad cell meets both these requirements. Although they are pretty pricey to start with, NiCad cells are capable (if treated properly), of up to *five hundred* charge/discharge cycles!

Just multiply the cost of your last battery replacement by five hundred and see the money that can be saved.



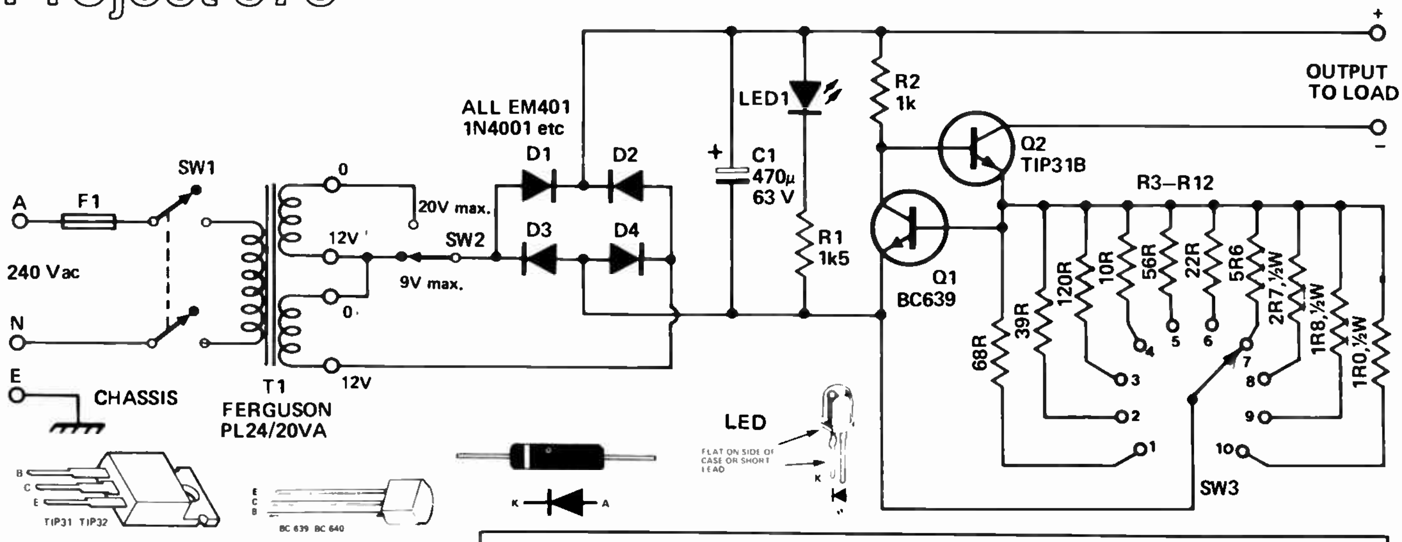
Care and feeding of NiCads

Now that you've been convinced of the economics of the matter, here are some basic but essential facts regarding NiCad cells.

The NiCad cell, like the lead acid unit, is a *secondary* cell or accumulator; i.e.: its chemical action is reversible. Passing direct current from an outside source (charger), converts electrical energy into chemical energy within the cell. The process is reversed when the cell is connected to an electrical load; the chemical energy stored within it during charging is converted to electrical energy which is dissipated by the load.

The NiCad cell needs a fairly constant charging current, this current being a function of the cell's capacity and the charging period. Cell capacity is expressed in Ampere-hours, abbreviated Ah, this being the current delivered by the cell, multiplied by the number of hours it will do so before reaching the discharged state. Take for example the 'AA' size NiCad cell which is equivalent to the U11 dry cell in dimensions and output voltage. It has a nominal capacity rating of 0.5 Ah; i.e: it will deliver half an amp for one hour; or 50 mA for 10 hours, 5 mA for 100 hours and so on.

However, there are physical limitations at higher current levels — one cannot expect to draw 50 A for 36 ▶



seconds or even 5 A for six minutes!

In fact, it is accepted practice to load the cells to only one tenth of the nominal Ah rating; i.e: if your circuit draws 50 mA average current, you should use at least a 0.5 Ah NiCad battery as a power source.

Similarly, to recharge a NiCad cell or battery to full capacity requires the same current-by-time multiplication sum. For example, to recharge an 'AA' NiCad cell it needs 0.5 A for one hour or 250 mA for two hours and so on.

Once again, owing to certain limitations — danger of cell rupture in particular — fast charging of our 0.5 Ah AA cell at 5 A for six minutes is definitely not on! Under certain circumstances NiCads can receive a 'rapid' charge and actually benefit, but perhaps we'll leave that subject till another time.

At this point we come to the basic problem of charging NiCad cells.

Danger of Overfeeding

Due to the nature of the NiCad cell, overcharging causes permanent damage. And it is quite hard to determine by ordinary means (such as a voltmeter) precisely where full charge occurs and overcharging begins. So it would seem that one must disconnect the cell from charging at, or before, the moment of full charge occurring!

Fortunately, there is a way around this problem which involves using a pre-determined low value of charging current. It is not a well known fact, but if the charging current is kept at one sixteenth of rated capacity then no permanent damage occurs, regardless of how long the cell remains on charge. In other words, you could leave your AA size NiCad cell connected to the charger for any convenient period, as long as the current was maintained at (500/16) mA

HOW IT WORKS — ETI 578

This charger consists of a step-down transformer, T1, a full-wave rectifier with capacitor-input filter (D1-D4 and C1), followed by a constant-current regulator involving Q1, Q2 and resistors R2 to R12, R3-R12 being selected by SW3 to provide the required charging current.

To understand how the constant-current regulator works, let's examine a simplified version of the circuit above - see Figure 1, below.

As the circuit stands, base current for Q2 will flow through R1 and Q2 will be turned on. Emitter current from Q2 will flow through R2, and if the voltage drop across R2 is above

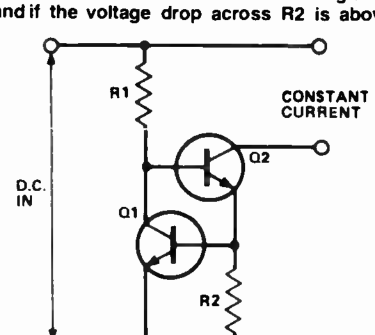


Figure 1.

about 0.5 - 0.6 V, Q1 will turn on. Current through R1 will then be shared between the base of Q2 and the collector of Q1.

Now, with a load connected across the "constant current" terminals, collector current will flow through Q2 via R2. Thus, the voltage across R2 will attempt to rise. However, the base-emitter voltage of Q1 cannot vary greatly from a value of 0.6 V — this is a characteristic of the transistor. Thus, more base current will flow in Q1. This results in a greater collector current in Q1, which "robs" some of the base current from Q2, reducing its collector current. Thus, we have negative feedback and the current through the collector of Q2, which is also the load current, will settle to a value such that about 0.6 V is maintained across R2. Therefore, a constant current is delivered to the load, the value of which is entirely determined by the value of R2.

The power dissipated in R2 is kept quite low as the voltage across it will be no greater than about 0.6 V, thus low wattage resistors may be used.

In the project's circuit diagram above, Q1 and Q2 can be readily identified as they are identical with those in Figure 1. Base current to Q2 is supplied by R2 (a 1k resistor) and the output, or charging, current is determined by the resistor selected by SW3, from resistors R3 to R12.

PARTS LIST — ETI 578

Resistors all ¼W, 5% unless noted

- R1 .... 1k5
- R2 .... 1k, 1W
- R3 .... 68R
- R4 .... 39R
- R5 .... 120R
- R6 .... 10R
- R7 .... 56R
- R8 .... 22R
- R9 .... 5R6
- R10 .... 2R7, ½W
- R11 .... 1R8, ½W
- R12 .... 1R0, ½W

Semiconductors

- Q1 .... BC639
- Q2 .... TIP31B
- D1-D4 .... 1N4001, EM401 or similar, 1A diodes
- LED1 .... TIL220R or similar red LED plus mount

Capacitors

- C1 .... 470u, 63V electrolytic

Miscellaneous

- F1 .... ¼A fuse and fuse holder to suit (240 Vac rated)
- SW1 .... DPST switch, 240 Vac rated
- SW2 .... SPDT switch
- SW3 .... single pole, 10 or 12 position switch
- T1 .... Ferguson PL24/20VA or similar, 12+12 V sec. at 800 mA.
- pc board ETI-578

Metal case to suit (we used a David Reid Electronics type, No.4., measuring 140 mm deep by 120 mm wide by 95 mm high); two "flat pack" heat sinks (Dick Smith H-3402 or similar) mains cable and three-pin plug; terminal block and cable clamp; rubber grommet; four rubber feet; piece of 1.6 mm thick cardboard; spaghetti sleeving; hookup wire; output terminals; solder lugs, nuts and bolts, two standoffs, Scotchcal front panel.

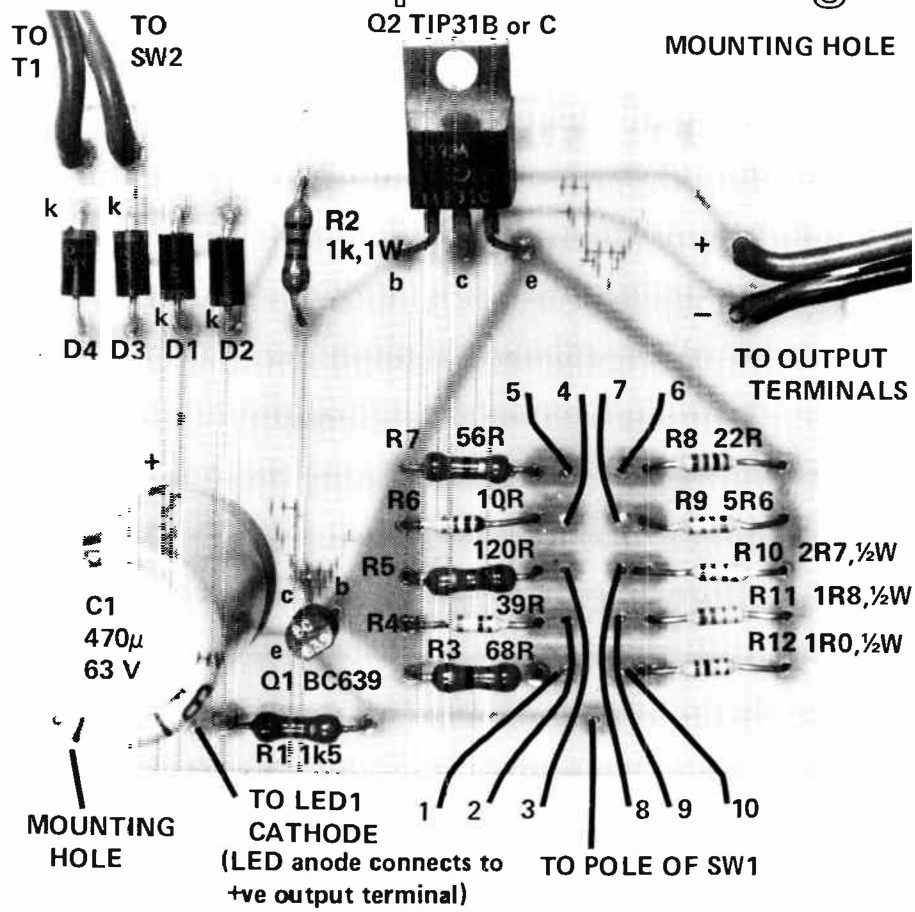
or 31 mA. Note that it would take at least 16 hours to fully recharge the cell.

The important thing of course is, you can't overcharge at this rate. The ETI-578 NiCad Charger is designed with this in mind. It provides a controlled charging facility for any one of ten types of commercially available NiCad cells. Table 1 shows the actual current ranges and the corresponding cell type numbers.

We used a simple voltage regulator and pre-determined values of current limiting resistors to get a ten-range constant current source. The output of the charger is very easily checked upon completion by connecting a current meter directly across the output. Remember that since this is a *constant current* source, the output current remains practically the same even if the output is shorted. The voltage goes up and down of course depending on the load.

One feature we have added is a switch (SW 2) to vary the input to the current regulator so that you can charge a string of cells, to a maximum of 16 (totalling about 20 V when charged).

Incidentally, the small sealed lead-acid batteries that have recently become available can also be charged using the ETI-578. These are generally available in ratings ranging from 2 Ah to about 9 Ah in 6 V and 12 V sizes.



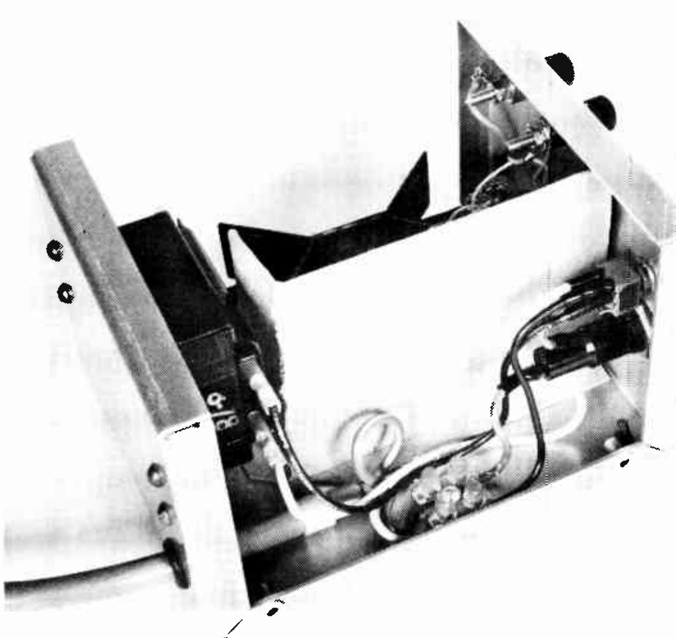
Component overlay for the pc board. Take care with orientation of the semiconductors.

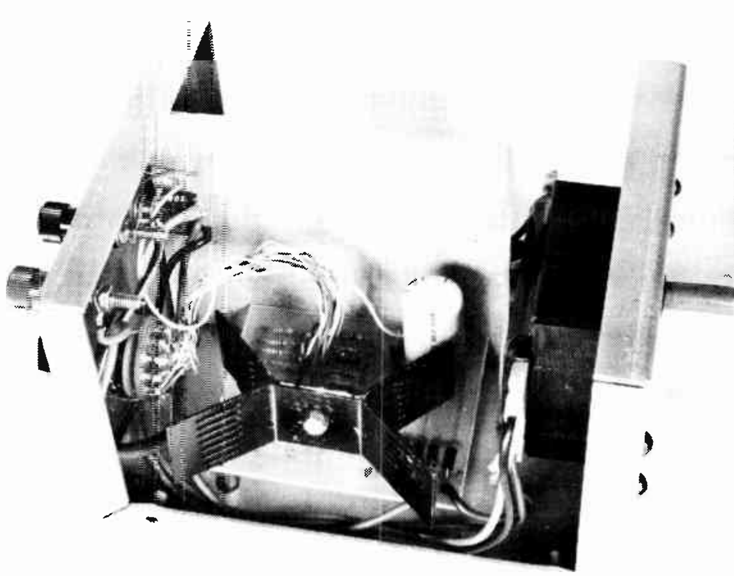
Construction

This should be very straightforward. Layout is absolutely uncritical so you can use any available case or box. We have not included any constructional details on suitable connectors between the output terminals and the cells because in most cases connection can be made via flying leads to the battery holder in the equipment itself.

Having collected all the necessary parts, start by laying out all the major components in position in the box. A little effort at this stage can save a lot of teeth-gnashing, filing, drill-snapping and other time wasting later on. Using a fine felt pen or soft lead pencil mark the holes for *every* chassis-mounted ▶

Internal views of the completed project. Note that a 1.6 mm thick cardboard 'divider' separates the mains wiring from the other components as a safety measure. It stands the full height of the chassis and may be glued or bolted in position. The view at left shows the general arrangement of the mains wiring (see also the diagram over the page). Sleeve all exposed connections. Use a rubber grommet at the mains lead entry, then a cable clamp and two-way terminal block. The earth lead is longer than the other two and is secured under a bolt used for it alone. The picture at right shows the pc board wiring to the major components.





component. Check that adequate clearance is allowed for later wiring and access.

One important point; keep all mains wiring to one side of the layout and use the following:-

- a suitable anchor for the mains cable,
- an insulated terminal block, and
- a fuse with fuseholder

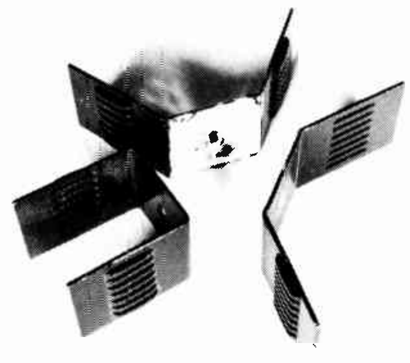
Having marked all the hole positions, drill and shape each one as necessary; remove all burrs and stray bits of metal, then check that all components fit properly before installing them.

After all panel-mounted parts are mounted, with the exception of the printed circuit board, assemble the pc board components. Fit the pcb-mounted wires (twelve for the range switch and one for the front panel LED). Check the polarity of the four rectifier diodes as well as the 470 uF capacitor.

Fit the printed circuit board into place using stand-off pillars. Identify the slider contact and the No. 1 position of the switch and connect the switch wiring starting at number one through to ten. Check the wiring, range by range, after you have finished.

When fitting the heatsink to the power transistor Q2, use a little silicon grease smeared on the contact surfaces; failure to do this may cause the transistor to fail on the higher ranges.

Fit the mains cable, terminal block, mains switch, and the fuse. Identify the earth lead and make a secure connection to the metalwork of the case.



The heatsink we used for Q2 was made up from two 'flatpack' heatsinks, Dick Smith No. H3402, bent as illustrated and mounted back-to-back on the transistor. This ensures they fit in the case. Use plenty of silicone heatsink compound to get good thermal conduction. The unmodified heatsink is shown at lower left.

Check this connection to the earth pin on the plug with a multimeter. Also check the active and neutral wires from the transformer to the mains plug.

Powering up

When all wiring is complete, insert a 250 mA fuse into the fuseholder and apply power. The LED should glow and you should be able to measure about 17 Vdc across C1 with SW2 in the "9V max." position and about 34 Vdc with SW2 in the "20V max." position. The reading should be within about 10-15%, if not, switch off and check your wiring immediately.

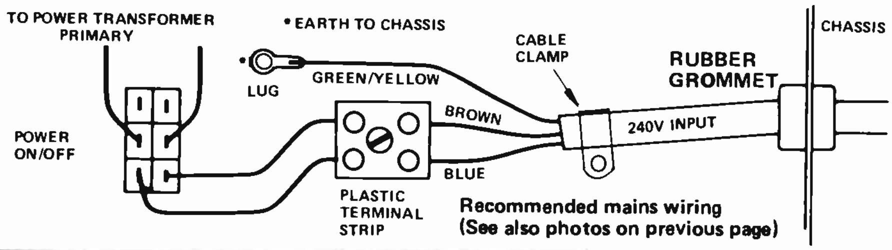
Assuming that everything is OK and your charger has not vaporised in the first five seconds carry out the following functional checks:

- connect a multimeter across C1 and short the output terminals while observing the meter reading. This should change only slightly, no matter which range has been selected. Typically, with SW2 on '20 V max.' on the 10 Ah range, the readings should be about 34 V with the output unloaded and 27 V with it short circuited. Switch off after this test.
- Set the meter to read current and connect it across the output, positive lead to positive terminal. Set the charge range switch to position 1 and the meter to a suitable current range. Switch the charger on. Check the reading against the figure given in Table 1. Repeat this check range by range, not forgetting to change the meter ranges of course!

If most of the ranges check out OK (within 10%) but one or two are a long way out, it's most probably caused by an incorrect value series limiting resistor (R2 to R11).

If the first two or three ranges are fine but the output is insufficient on the higher ones, either Q1 or Q2 is faulty. Finally, short the output, switch on, and leave running for a few minutes. Test the temperature of Q2 by placing your finger tip against the body of the transistor. If an imprint of the manufacturer's name is left in your flesh, overheating is indicated! Check that the heatsink is attached tightly to the transistor.

When connecting up the unit for use do not forget to observe correct polarity; the positive terminal on the charger connects to the positive on the battery, the negative charger terminal to the battery negative. ●



Recommended mains wiring
(See also photos on previous page)

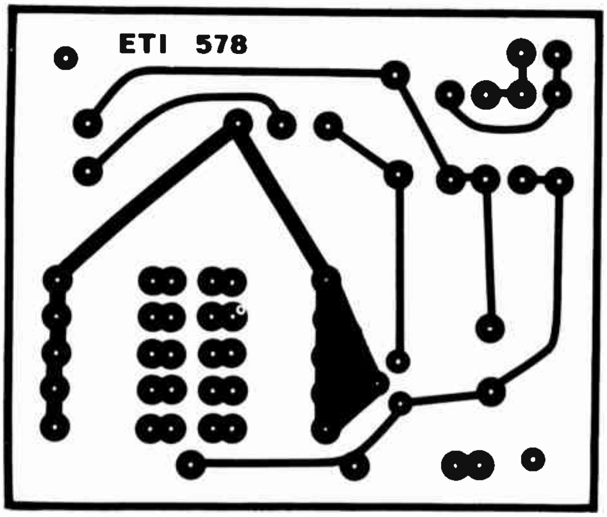


TABLE 1

Position	Resistor	Current	Cell type and capacity
1	R3	9 mA	150 mA hour Button cell
2	R4	17 mA	280 mA hour Button cell
3	R5	5.5 mA	90 mA hour, PP3
4	R6	75 mA	1.2 A hour, PP9
5	R7	11 mA	0.18 A hour, AAA
6	R8	31 mA	0.5 A hour, AA
7	R9	125 mA	2 A hour, C
8	R10	250 mA	4 A hour, D
9	R11	375 mA	6 A hour
10	R12	625 mA	10 A hour

Switchmode charger delivers "fast charge" to NiCads

This project will charge your NiCad batteries to near rated capacity when you need them in a hurry. It can't overcharge either!

Jonathan Scott

HOW OFTEN have you suddenly needed a set of NiCads only to find that they have little or no charge left in them ? Fuses always blow when torch batteries are at a minimum; events happen when flashgun batteries have been completely exhausted and the 6m band opens just as your rig's portable power pack is getting unusably weak.

These are basic corollaries of Murphy's Law.

NiCads are strange things. They have many wierd and wonderful habits, like the 1% per day (very approximately) self discharge rate. All these factors take some foresight to circumvent, since the recommended charging procedure is the 10 hour rate for 14 hours. But even this apparently elementary approach has drawbacks. The batteries must not be left on indefinitely at this rate. About 24 hours is the recommended maximum duration. It is safe to leave them on the 50 hour rate indefinitely, but here they suffer from even greater apparent capacity reduction than on the 10 hour rate! What's more, this is worsened if they are recharged before being substantially discharged! All in all, a steady discharge cycle followed by just the right amount of charge delivered at a moderate rate gives the healthiest cells. However, this leads us back to the problem of them not being always on hand at full capacity or being damaged by continuous overcharging.

This is where the *fast charger* comes in. It seems that flat NiCads will not only tolerate a controlled fast charge but actually benefit from it in terms of recovery of apparent capacity.

The ETI-563 not only charges "but quick", as the Americans say, but turns itself off preventing "cooking" that will surely follow your forgetting the job. In addition, it achieves this with the inherent efficiency of a switchmode supply. Imagine your flashgun rejuvenated to near full power in just 15 minutes. The effective downtime of penlite cells is thus made bearable to all but the most impatient of persons. Finally the whole device runs so cool that the only heatsink is mounted internally, allowing the unit to fit in a space of only 80 x 150 x 150 mm — small enough for a camera bag or travelling case, at a pinch.

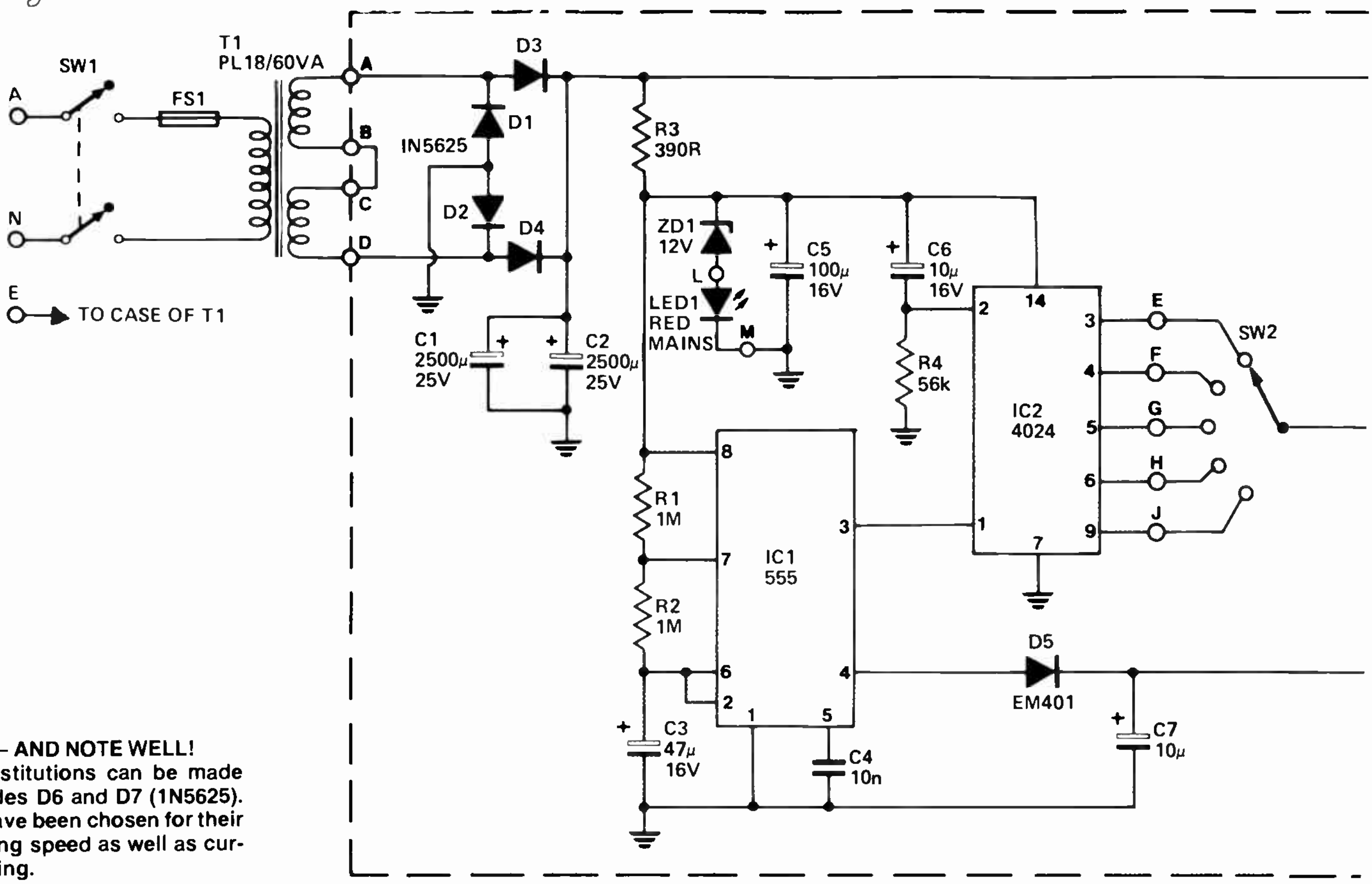
The completed project was housed in a smart PacTec case. Front panel is Scotchcal and will be available from the usual sources (see Shoparound on page 128).

Operation

The device is basically a constant current source delivering about 2.4A, controlled by a timer. The timer is reset at turn-on and permits the current to flow for a period after that. The period is chosen by the capacity selector switch. Thus, the supply is always delivering the maximum current, and merely finishes when the current delivered should have charged the batteries in question.

It is relatively simple to use. Firstly, turn the unit off — this allows the timer to reset. Connect the batteries — up to 12 volts of cells in series — across the terminals. If they are connected backwards they will see a very low impedance and may damage themselves discharging, or if flat they will be charged in the reverse direction, which is very unhealthy! The polarity LED will indicate if cells are connected correctly, but it will not detect voltage of less than two cells-worth. All of which adds up to saying that a double check is a good idea at this point. Next, select the capacity, setting the duration of the charge. Then, turn on. When the due time has elapsed the 'charge' LED will go out, indicating that the unit has shut off.

The charger delivers slightly more than the capacity of the battery. This is designed to allow for the inefficiency of the recharging process; i.e: it takes 14 hours at the 10 hour rate to fully charge up a cell under normal circumstances so ▶



NOTE — AND NOTE WELL!
No substitutions can be made for diodes D6 and D7 (1N5625). They have been chosen for their switching speed as well as current rating.

it will take more than an hour at the one hour rate — in fact, more like 1½ hours. The faster you go, the worse the efficiency. If you are not in too much of a hurry, it is a good idea to give a second burst at half capacity later on, to ensure complete charging; though *be careful*, as most NiCads will not like more of a burst at one time than the unit delivers.

For example, let us assume your 2 Ah NiCad torch is quite flat — you left it on last night (absent-minded twit!). So you hook it up and set for a 2 Ah charge. One hour later it turns off. About 2.4 Ah of charge has gone in in one hour, which is all that is likely not to upset the cells. You could pack it up in your camping bag now, as it will have something like 60% charge. However, if you aren't in a big hurry, when you come back two hours later, you put it on again for a 1 Ah (½ hr) charge. At worst, it will then be 90% or so charged, so that's OK.

As you can see, it is alright to give the batteries a second run provided it is spaced some time away from the first. It is alright also to charge batteries that are not fully exhausted. It is unwise to just regularly fast charge without any use in between, or to deliver more than the correct capacity charge in one hit. Similarly it is alright to deliver a half capacity charge to a cell you know to be

HOW IT WORKS

Looking at the circuit, it may be divided into several sections with simple discrete functions: An unregulated dc supply consisting of SW1, T1, D1-D4, C1 and C2; a timing circuit made up of IC1, IC2, Q1 and associated components; the actual switchmode circuit comprising Q4, D6, L1 and surrounding components; the supply controlling circuitry involving Q2, Q3, Q5 and R15. There are also three LED function indicators to give the user some idea of what is going on inside. Each of these sections will be treated in turn.

The unregulated supply is fairly conventional, delivering between 17 V and 25 V at a maximum of about 3 amps. It must be capable of briefly delivering the 2.5 amps starting current required by the regulator controller. Diodes D1 to D4 could in fact have been 1A types, but they would be slightly overtaxed at turnon and thus, in the interests of reliability, 3A types have been specified.

A regulated supply of about 13.7 V is provided for the ICs by R3, C5, ZD1 and LED 1. In this position, LED 1 serves to indicate that the mains voltage is applied and is sufficient to run the unit — if the line voltage falls, LED 1 will dim or go out, indicating an 'unhealthy' condition.

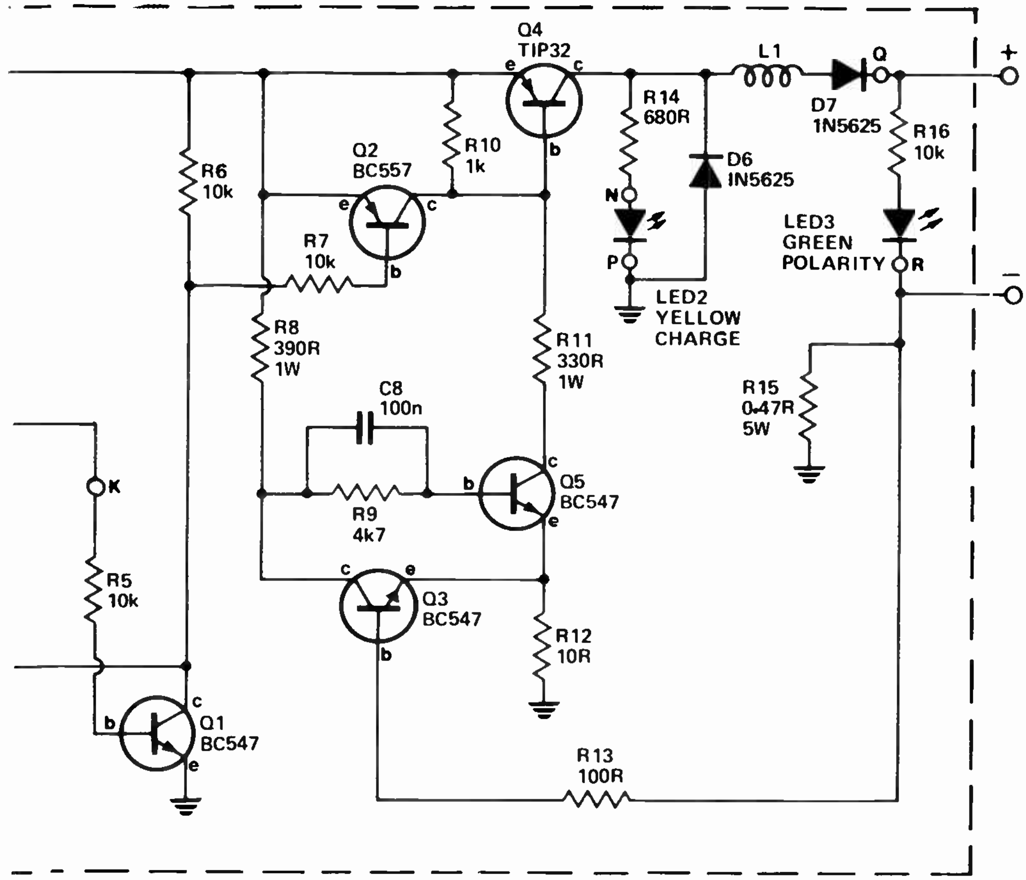
The electronics will withstand the situation indefinitely. However, if the line voltage is very low the current delivered may not reach the correct level for charging (2.4A) and the unit will consequently not be able to deliver the correct charge to the cells being charged at the time.

IC1 is connected as an astable multivibrator with a period of around 110 seconds. IC2 is a seven-stage binary counter. C6 and R4 ensure that, at turnon, the counter is reset to zero. The five, more significant, outputs are made available on the five contacts of SW2. Due to the resetting, no matter which position SW2 is set to, the base of Q1 is initially held low and so it is turned off. However, C7 holds its collector low for a fraction of a second. This has the effect of momentarily holding Q2 on. The purpose of this will be pointed out later on.

Once C7 charges up to rail potential via R6, pin 4 of IC1 is no longer held low and so IC1 is free to commence oscillation. It oscillates until sufficient pulses are counted by IC2 to send high the output selected by SW2. Just how many pulses this represents is a function of which output was selected, and hence SW2 defines the duration of the timer interval.

When the selected output does go high, Q1 is turned on, Q2 is turned on and IC1's reset line is held low, inhibiting further clocking of the counter, IC2.

When Q2 is turned on, it diverts any possible drive current from the base of Q4, ensuring that it is held off and that no current is passed from the unregulated supply to the load. Q2 also holds Q4 off momentarily after initial power-up in order to give the transformer a chance to charge C1 and C2 without having to



— ETI 563

cope, at the same time, with the starting current of the main switching regulator circuitry.

Once the timer has run its course Q2 holds the regulator off, preventing any further charging of the connected cells. During charging (i.e: when Q4 is conducting) Q2 does not conduct and can be ignored.

When, a split second after turn on, Q2 isolates, Q3/Q4/Q5 are able to start regulating. Initially, Q3 will be held off via R13 and R15, and Q5 will be turned on by current flowing into its base via R8 and R9. Thus, it will draw current through R11 and turn Q4 on. Q4 will immediately saturate, raising its collector voltage to near rail potential. A current will build up through Q4, L1, D7 the load (consisting of the cells to be charged) and R15. The rate of current build-up will be limited by the inductance of L1. When this current builds up to about 2.5 A, 1.2 V will be dropped across R15. The current Q5 is drawing via the base of Q4 will develop about 0.5 V across R12, and thus the 1.2 V across R15 will be enough to turn Q3 on. When Q3 turns on it removes drive from Q4's base, turning it off. Since the collector load of Q3 is higher than that of Q5 it draws less current and the voltage appearing on their common emitter resistor, R12, drops a small amount, turning Q3 on harder.

Transistors Q3 and Q5 actually form a Schmitt trigger. Q5 now having been turned off, Q4 also turns off. The collapsing field in L1 tries to maintain the output current and, having no other path, conducts via D6, referred to as the "freewheel" diode. When the current in L1 decays sufficiently for the voltage across the current sense resistor, R15, to fall to the lower 'Schmitt' level of Q3/Q4, both these transistors again change state, and the circuit returns to the initial conditions.

The whole cycle repeats and the average load current is held constant. LED 2 turns on whenever Q4 turns on, and will glow more brightly when the switchmode circuit is running at a higher duty cycle. For those interested, this gives an idea of how much power is being delivered by the supply.

The power dissipation of the electronics will be substantially independant of the load current/voltage product. i.e: unlike a conventional regulator, the switchmode device does not dissipate a significantly larger amount of power when the load drops less voltage.

R16 and LED3 simply detect correct voltage applied across the terminals. Owing to the voltage drop of the LED, it will not detect a voltage less than about 2 V.

Reverse-connected batteries will see a low impedance in the regulator circuitry via D7, L1, D6 and R15 — so quite a large current may flow from the batteries if they have some charge left and the voltage is above several volts. The POLARITY indicator (LED3) should light, if more than 2 V is left in the batteries, before power is applied.

only half or slightly less used up — just don't overcharge badly or charge too long at the fast rate. The cells will get warm, but not burning hot, if all is well.

In fact, it's a good idea to have two chargers: a 'standard' one, like the ETI-578 (page 107) for 'regular' use, and this one for 'emergencies'.

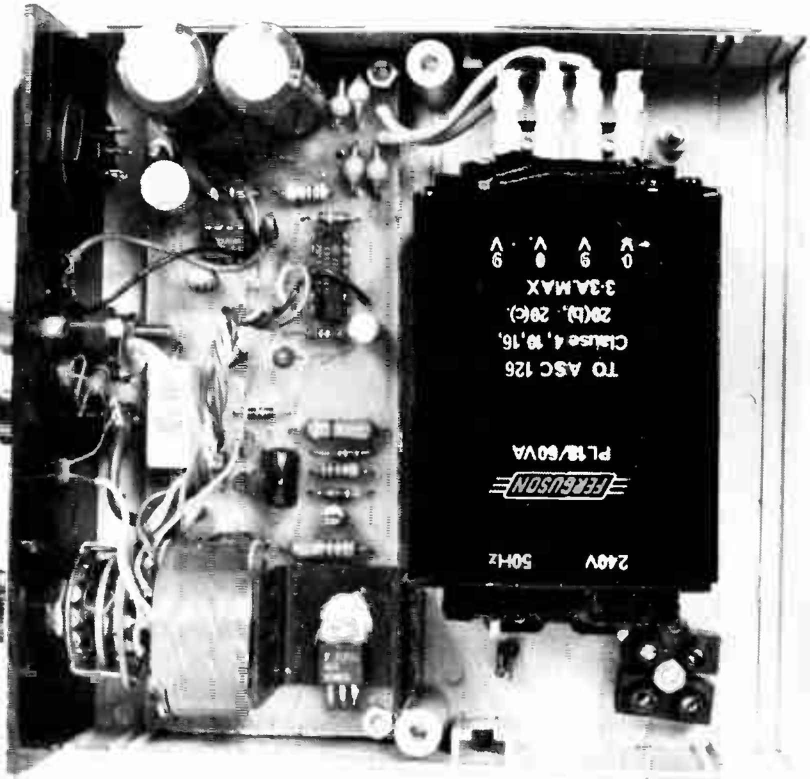
Construction

This project is relatively easy to construct if you follow the layout and wiring diagrams. It is best to commence construction by drilling and working the case. We housed the unit in a PacTec plastic case measuring 155 mm wide by 65 mm high by 160 mm deep. This case comes apart in four pieces — a top piece and a bottom piece plus front and rear panels. The rear panel was drilled to take a mains cable clamp and the mains fuse. The front panel contains the three LEDs, the capacity selector switch, the output terminals and the mains (labelled "START") switch. Take care with the placement of SW2 as it backs right onto the coil, L1, mounted on the pc board. Also, the bolt on one or both of the output terminals should be shortened to clear the components on the pc board. If you use a different mains switch to the one we selected, take care that it will clear the components on the pc board behind it. We chose a Dick Smith type, cat. no. S-1393, as it takes up little space behind the panel and is easy to operate.

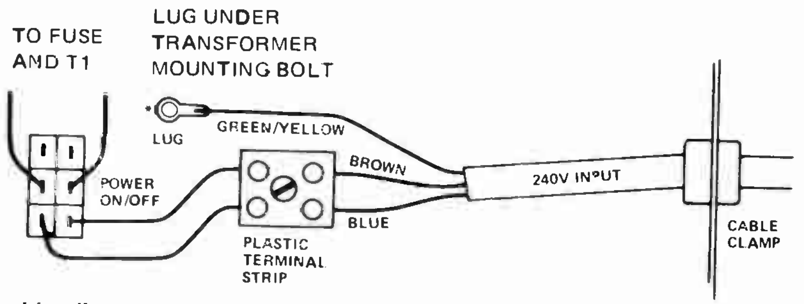
Using the unloaded pc board as a template, mark the mounting hole positions on the bottom of the case and then drill them to size. Then, using the transformer as a template, mark and drill its mounting holes, and a hole for the mains input terminal block.

The printed circuit board may be assembled next. Using the component overlay as a guide, mount all the resistors and capacitors taking care that you have the electrolytics and tantalums correctly oriented. Next, mount the diodes. Make sure you have them correctly oriented, as well. The TIP32 and its heatsink may be mounted next. Smear a little silicone grease on the metal tab of the transistor case and on the heatsink. Put the transistor leads in place but don't solder them yet and place the heatsink in position on the pc board. Bend the transistor over such that the hole in its metal tab and the holes in the heatsink and pc board line up. Bolt them all together. The transistor leads may now be soldered.

The coil, L1, may be wound and mounted next. Coil winding details are ▶



Internal view of the project, showing general placement of components. Mains wiring has been removed for the sake of clarity.



Mains wiring diagram

COIL DATA

The coil, L1, is not critical in value. It needs to have an inductance of at least 300 uH and present a minimum of internal resistance. It should also be physically compatible so that it fits in the space between the rear of SW2 and the heatsink on Q4.

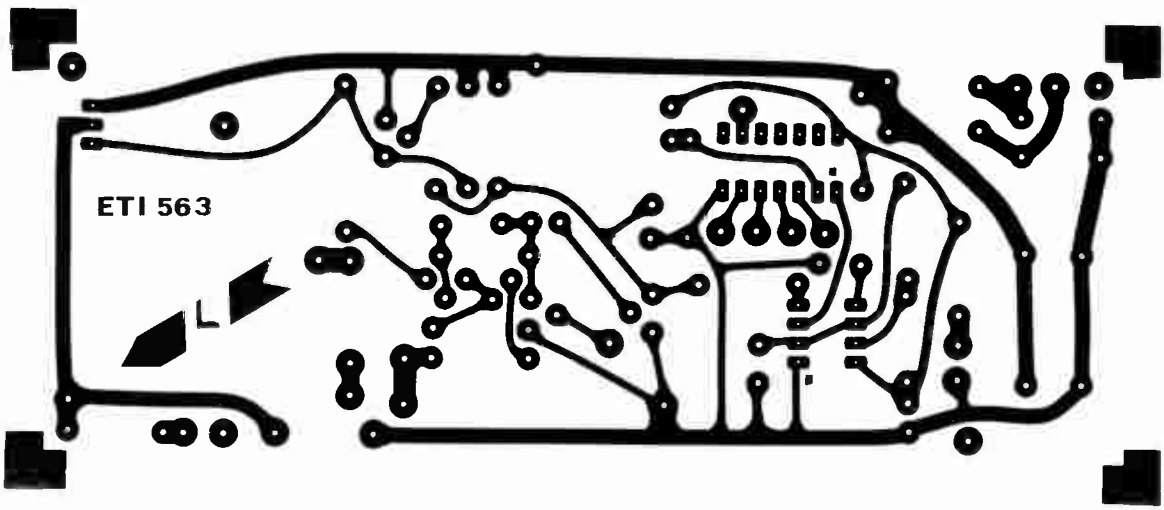
For the sake of simplicity, we wound ours on a standard Philips pot core former. The coil consists of about 120 turns of 1.0 mm diameter enamelled wire. The former has an internal diameter of 21 mm and is 19 mm deep. The internal resistance of the coil turned out to be about one ohm. This is really about the upper limit of internal resistance that the circuit will tolerate and no thinner gauge should be used. It gets quite hot, not surprisingly, as it dissipates more than Q4! Note that no core is used.

A free-wound coil wound with 1.25 mm diameter enamelled wire would doubtless run cooler. Inductors intended for use in loudspeaker crossover networks will also suffice, providing they have an internal resistance below one ohm.

given in the accompanying box. Whatever coil you use, make sure it will fit in the space between the heatsink and the rear of SW2 mounted on the front panel.

The two ICs should be mounted last. Again, ensure these are correctly oriented. After all the components are mounted, the external wiring from the pc board may be done. The connections to the transformer secondary are fortunately supplied with slide-on connectors. Cut two to length and attach them to their positions on the pc board. Note that, from the wiring diagram, the two *outer* terminals of the transformer secondary connections are bridged to connect the windings in series. Make up a short lead to effect this connection, as shown in the internal picture.

Wiring to SW2 is fairly straightforward. Refer to the overlay drawing for details. These wires may be colour-



coded to assist identification, or attached one at a time. Make sure they're all long enough. Wiring to the front panel components can only be done with the whole unit disassembled. The two wires from the pc board to the output terminals should be of a heavy gauge (10/010 as a minimum) as the output current is 2.4A. Note that R16 is mounted between the positive output terminal and the anode of LED3.

The mains wiring should be connected as shown in the wiring diagram. The rear of the mains switch should be protected by sleeving and/or a 'separator' made from heavy card. Mains wiring should be done in heavy gauge wire, such as 10/010, with suitably rated insulation. Some wires stripped from your mains cable would suffice. Make sure the earth lead to the transformer case is longer than the mains active and neutral input wires going to the terminal block. Sleeve the terminals of the fuse holder.

Check everything before you finally assemble the components into the case. Assemble the rubber feet before mounting the pc board and transformer to the bottom of the case.

Powering up

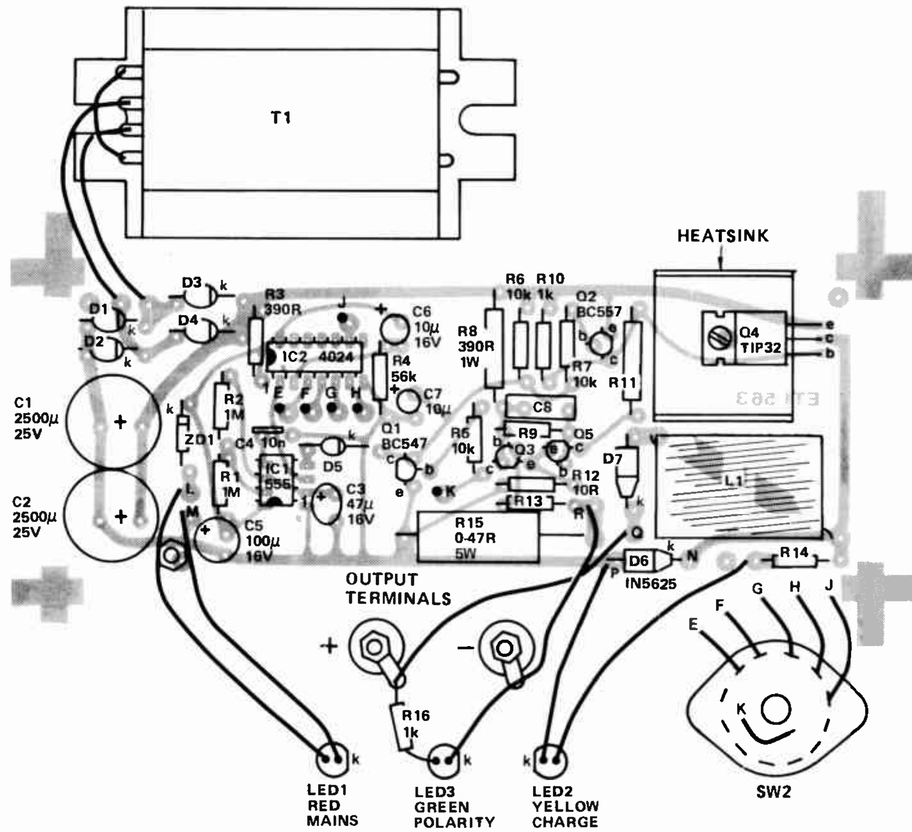
No electrical adjustment or alignment is necessary. Connect an ammeter in series with a discharged battery and connect to the output terminals — watch polarity. Select the minimum capacity (250 mAh). Plug in and turn the START switch on. The three LEDs should light and the ammeter should read close to 2.4 A. If all is not well, switch off and check your wiring again.

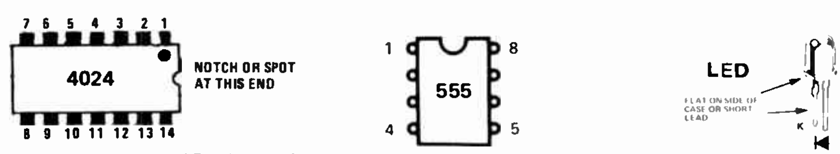
The charge times of the capacity selector switch should be checked. Should they be extremely short or long, this could be due to a large tolerance in C3. To compensate for this, R2 may be adjusted down to 560k or up to 1M5, say, to reduce or increase the time, respectively.

Using it

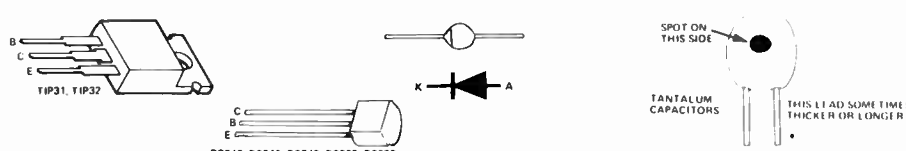
The unit should be switched OFF before connecting a battery. When you connect the battery, the green LED, marked POLARITY, should light if the battery has been correctly connected. If the battery is completely discharged, the LED will not light as it requires somewhat over 2 V to operate. In this case, carefully check the battery connections.

If all is well, turn the capacity selector switch to the appropriate position and operate the START switch. At the appropriate time later, the unit will switch off and your battery will be ready for use. ●





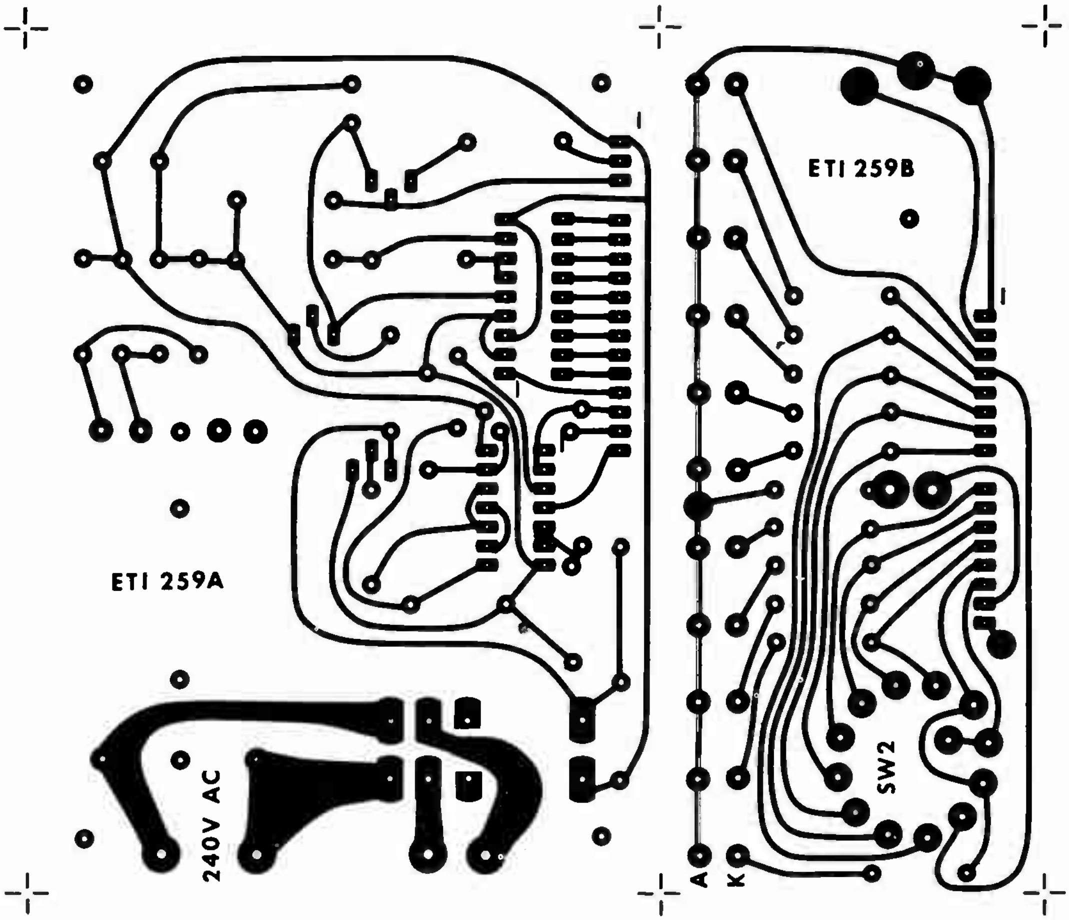
ICs viewed from top

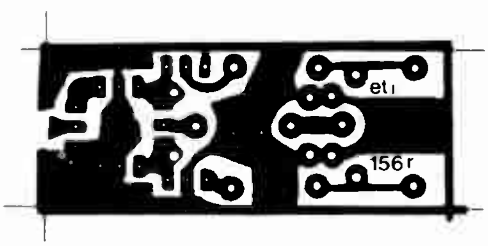


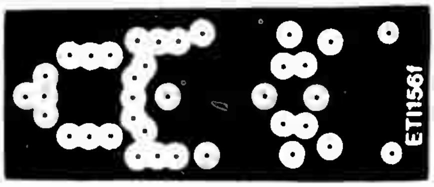
PARTS LIST — ETI 563

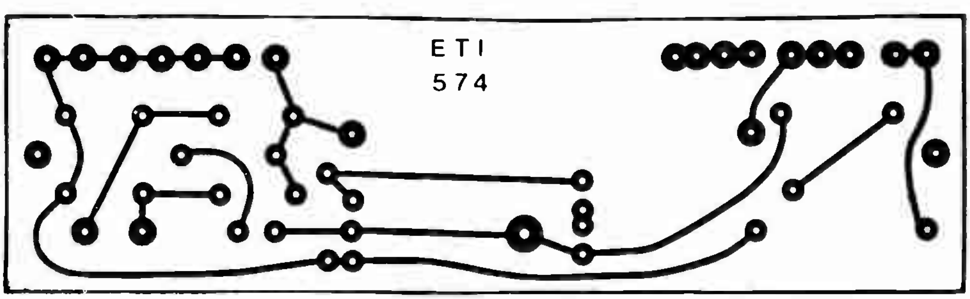
Resistors	all ½W, 5% unless noted	IC2	4024
R1,R2	1M	Q1,Q3,Q5	BC547 or similar
R3,R8	390R	Q2	BC557 or similar
R4	56k	Q5	TIP32
R5,6,7,16	10k	D1,2,3,4,6,7	1N5625, 3 A diodes
R9	4k7	D5	EM401 or similar
R10	1k	LED1	TIL220R, or sim. (red)
R11	330R	LED2	TIL220Y, or sim. (yellow)
R12	100R	LED3	TIL220G, or sim. (green)
R14	680R		
R15	0R47 (0.5 ohm), 5W wirewound		
Capacitors			
C1,C2	2500u, 25 V electro		
C3	47u, 16 V tantalum		
C4	10n greencap		
C5	100u, 16 V electro		
C6,C7	10u, 16 V tantalum		
C8	100n greencap		
Semiconductors			
IC1	555		

Miscellaneous
Case — PacTec 155 mm x 160 mm x 65 mm, plus four rubber feet to suit; Transformer PL18/60VA 2 x 9 V @ 3 A or similar; Fuse: 500 mA 3AG; Fuse holder to suit; DPDT switch (SW1): Dick Smith No. S-1393 or similar (see text) rated at 240 Vac, 1 A or more; Single-pole five position switch (SW2); Knob to suit SW2; Scotchcal front panel; one red and one black terminal; One two-way mains barrier strip connector; Mains cable clamp; Mains cable and three-pin plug; Heatsink: Dick Smith No. H-3402; Wire; Nuts, bolts etc.


ETI 259A
240V AC
ETI 259B
SW2
A
K


eti
156r

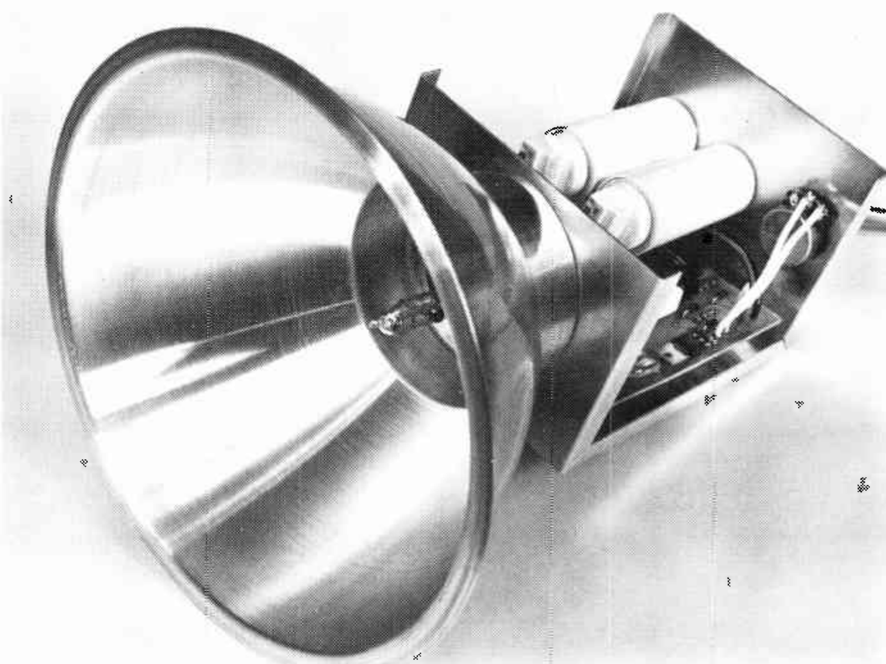

ETI156f


ETI
574

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.

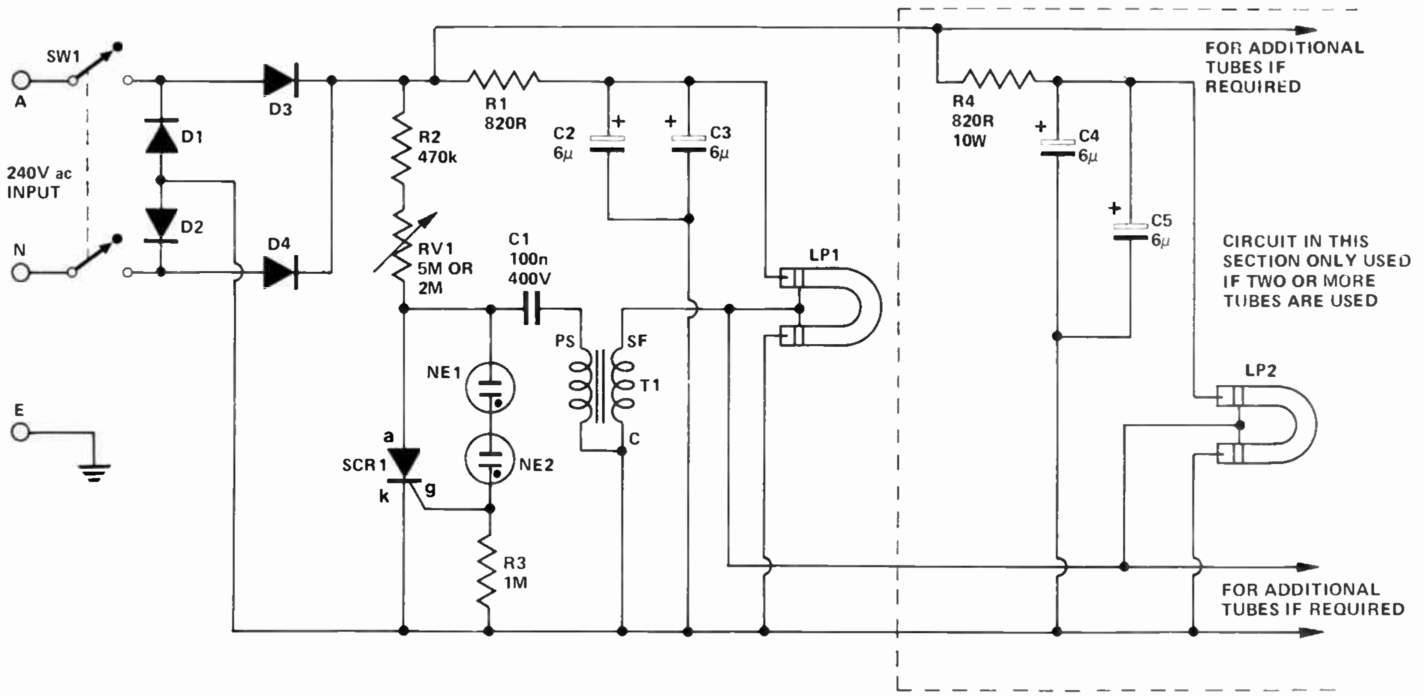
To avoid this occurring again we decided to use a conventional bridge rectifier to power the complete circuitry.

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.

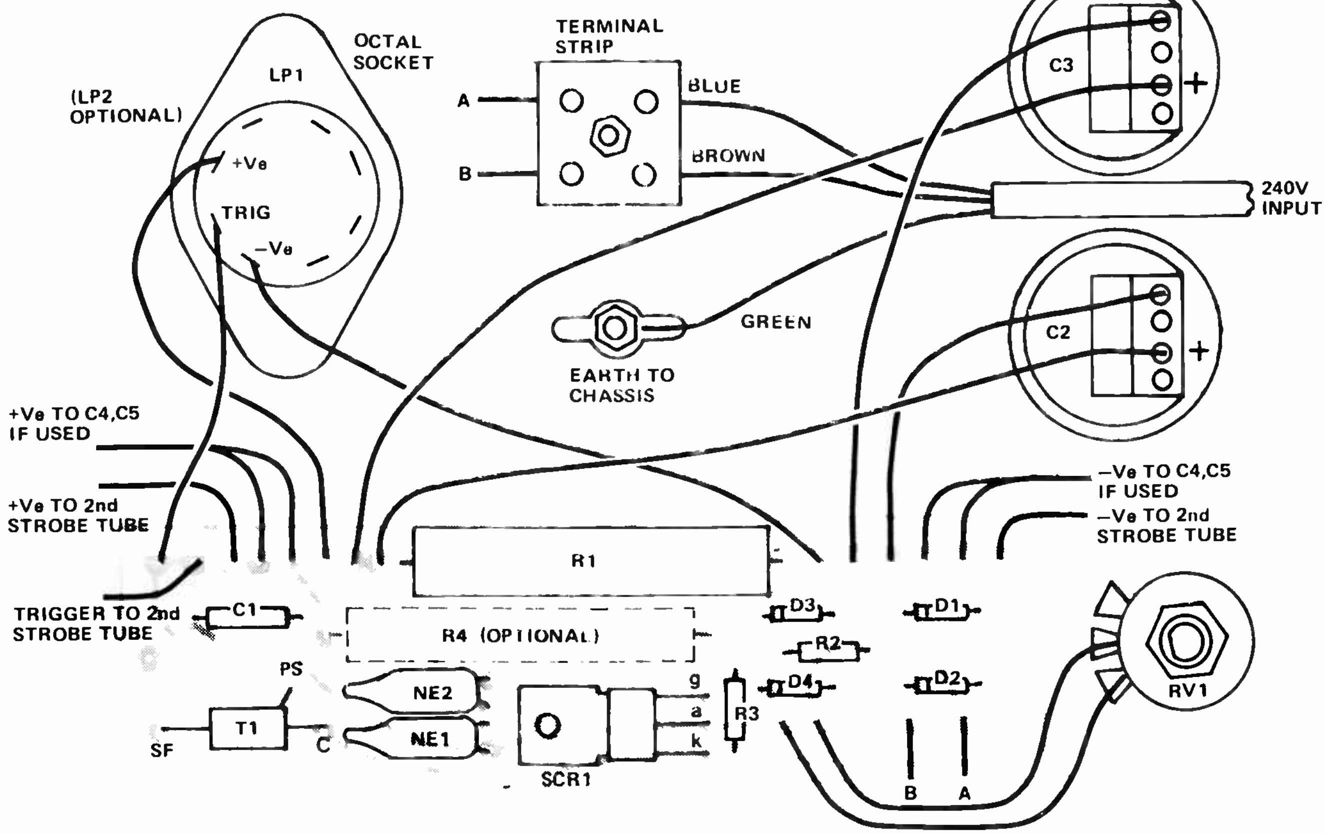
The resistor between the gate of SCR1 and ground, R4, prevents spurious triggering of SCR1.

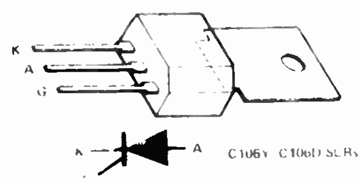
used. The capacitors specified have a threaded mounting bolt protruding from the base, making mounting a simple matter. Also mounted on this end of the box are the flash speed potentiometer and the power switch. The power cord passes through the panel also, being secured by a clamp-type grommet. A two-pole 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.

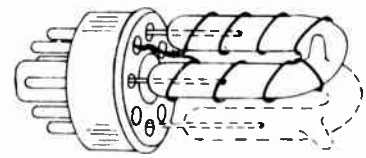
If one strobe tube is used, only two capacitors will be required. These should be mounted, so that two more may be mounted at a later stage if another strobe tube is added. The potentiometer may have a value of either 5M or 2M, depending on which is the more readily available. The 5M pot. will give a 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 board artwork is on page 116.







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)

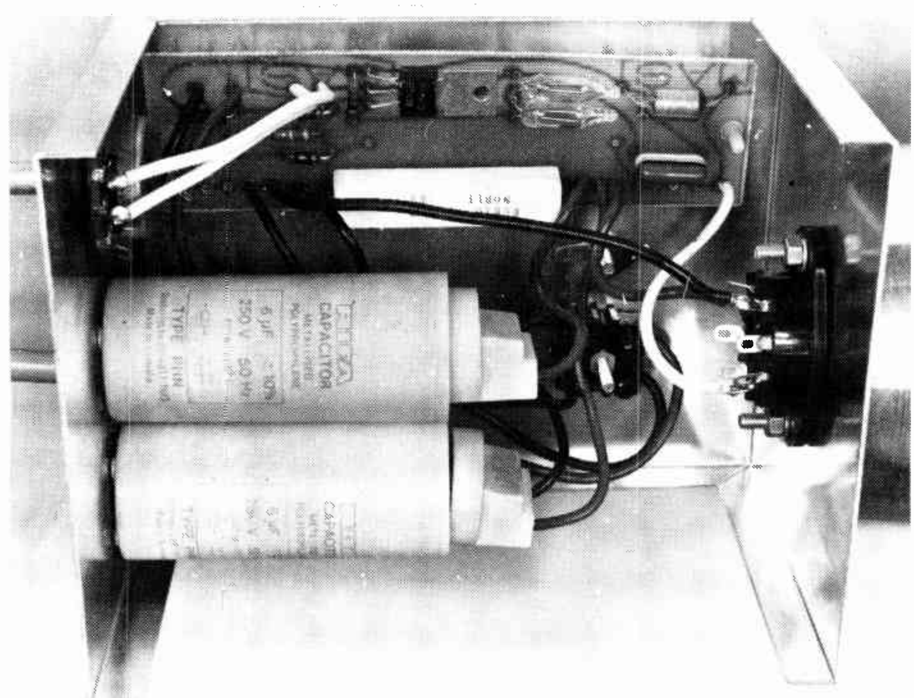
Capacitors
C1. . . . . . . .100n 400Volt polycarbonite
C2,C3,C4*, C5* . . . . . 6μF 240Vac capacitor (RIFA type PHN)

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.

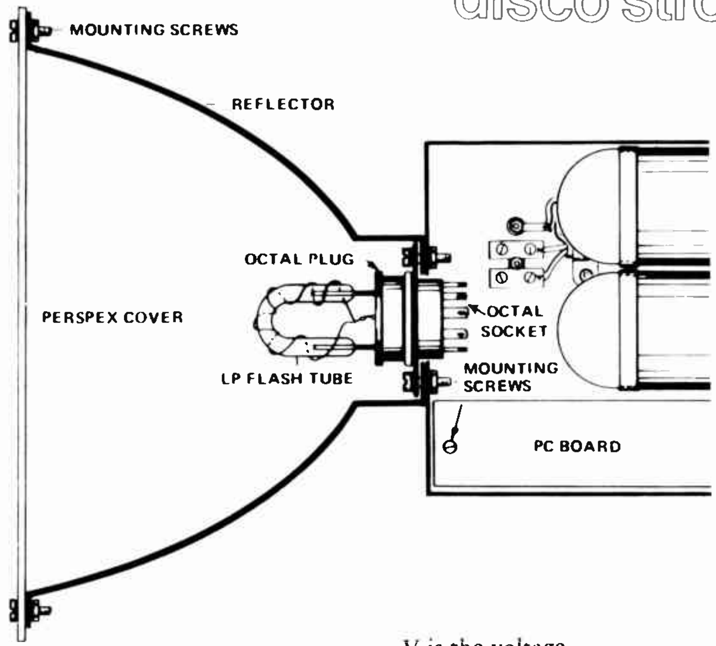
The strobe tube itself is not a critical component. Two types are commonly available. The type MFT1210 from Circuit Components of Bexley NSW is one such unit. Another is that advertised by Dick Smith, (catalogue No. S-3882).

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 – may 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.

Drum up a storm — with this percussion synthesiser

Design: **Ray Marston**
Development: **Geoff Nicholls**

With this instrument you can simulate drums, cymbals, snares and bongos as well as making an assortment of 'wonderful' noises.

THIS ATTRACTIVE musical instrument has two 'percussion simulator' channels, one to simulate the sound of normal drums only, the other to simulate the sounds of all types of drums, including snares, plus metallic percussion sounds such as cymbals, etc. On each channel, the envelope decay times and the basic musical tones, etc, are fully variable, using the manual controls, to enable a wide range of percussion sounds to be simulated. The outputs of the two channels are mixed internally and can be fed to an external power amplifier from a single output socket. The complete instrument may be powered from a 12 V battery pack (8 x AA cells) or a 12 Vdc plug pack supply.

Design

The synthesiser comprises two essentially similar channels. Channel 1 is built around a voltage-controlled amplifier (half an NE570N). The input signal is modified to produce the characteristic sharp attack, slow decay envelope of percussive sounds. This is done by the input amplifier, IC1, which drives a rectifier, D1, which charges a capacitor, C1. The voltage on this capacitor drives the envelope input of the VCA via a buffer, IC2. C1 is discharged via RV2 — producing the 'decay', RV2 controlling the rate of decay.

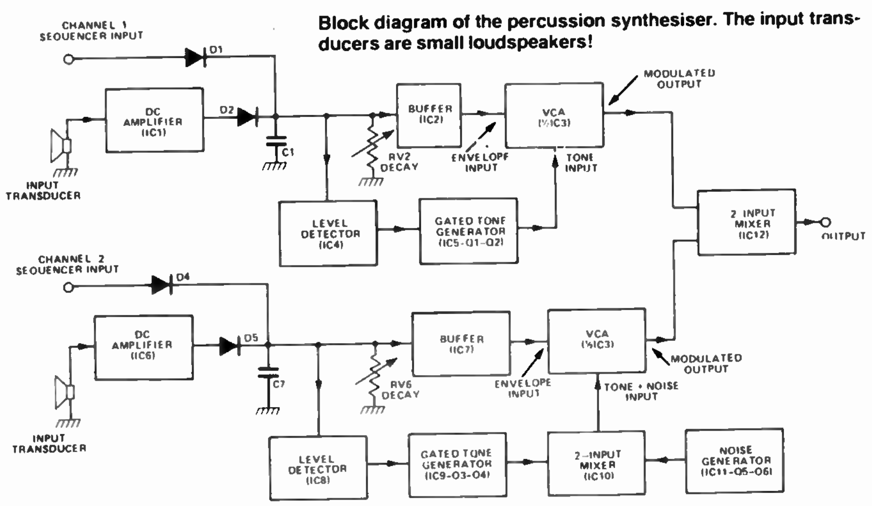
A level detector, IC4, also takes its input from C1, and drives a gated tone generator (IC5, Q1, Q2), the output of which provides signal or tone input to the VCA. Thus when the input transducer is struck, the gated tone generator is triggered and its output is modified or modulated by the envelope signal applied to the VCA. The resultant signal is applied to a two-input mixer, IC12.

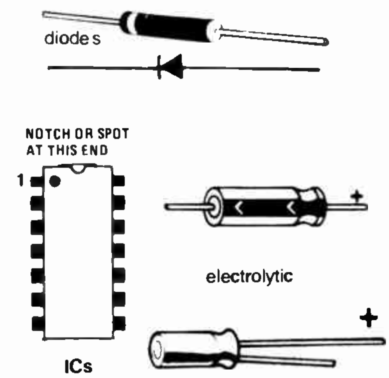
Channel 2 is largely similar, but has two additions — a noise generator (IC11, Q5, Q6) and a mixer, IC10. The outputs of the noise generator and the Channel 2 gated tone generator are mixed and applied to the signal input of the Channel 2 VCA (the other half of IC3). The 'tone + noise' signal thus produced is modulated by the envelope signal in the same way as before and applied to the other input of the two-input mixer, IC12.

Thus sounds involving a combination of tone and white noise (cymbals, for example) may be simulated, or sounds made up predominantly of white noise (e.g. snares) may also be produced.

Provision has been made for a 'sequencer' so that the synthesiser may be operated 'automatically' to produce a 'programmed' rhythm. We will be describing such a project in a forthcoming issue.

Block diagram of the percussion synthesiser. The input transducers are small loudspeakers!





We housed our project in a light but sturdy ABS plastic case and attached a Scotchcal label to the front panel — artwork for this panel and for the pc board is reproduced on page 130. The two 'transducer' inputs, the output and supply input are located on the rear panel. Small speakers serve as input transducers and are mounted in separate small boxes.

Construction

This is best commenced by doing all the mechanical work. The case we used is made by Sigea Australia, a Melbourne-based firm, and is entirely constructed of ABS plastic. It comprises a U-shaped base, the two turn-ups serving as front and rear panels, plus a U-shaped lid which overhangs front and rear. The lid is secured to the base by four screws, two on either side, beneath which two projections extend, serving as feet. The particular case model we used is designated EC.1002. It measures 210 mm wide by 225 mm deep by 80 mm high, overall, and there is ample room inside. Being plastic, it's easy to drill and cut holes in. We understand some kit suppliers will include this case with their kits. However, if you're assembling all the components yourself then any suitable case of adequate size — remember, there are ten pots on the front panel! — will serve the purpose. If you don't have your case ready-drilled, then that's the first job to tackle. Drilling details for the front panel are given in the accompanying diagram. The pc board may be located conveniently in the base of the box and the input and output jacks, etc, mounted on the rear panel to suit yourself.

Cut the potentiometer shafts to suit the knobs being used. The knobs employed on our prototype are a plastic, slip-on variety that are quite cheap and attractive. Ours were obtained from Jaycar, 125 York St, Sydney. These require about 8 mm of shaft beyond the thread.

If you're using a Scotchcal front panel, carefully attach this to the case front panel. Now, identify which pot goes where on the panel and secure each in position, taking care not to damage the Scotchcal on the panel. Note that, from the rear, all the pots face one way — with their terminals to the left. All the knobs are best put on at this stage.

Now you can commence assembly of the pc board. There are five links on the board and these should be inserted first. Follow with the resistors and green-caps. If you are using IC sockets, put these on next, taking care you orient them the correct way. Note that all except IC3 face the same way. The electrolytic capacitors and diodes may be mounted next; make sure you put them in the right way round. Next come the transistors. Watch Q1 and Q3 — the board was originally laid out for transistors having an e-c-b pinout, but most commonly available types have an e-b-c pinout. You'll have to cross the base and collector legs for Q1and Q3, unless you have transistors with the e-c-b pinout.

The pots may be wired next. Wiring between the pc board and the pots is done with ordinary hookup wire. Note that single 0 V hookup wire is best run to the 'earth' end of RV2 first and then to the appropriate lugs of RVs 4, 6, 8 and 10. The 0 V wire connects to the most anticlockwise terminal, when looking at the rear of the pot (see accompanying diagram). Now run the other wires between each pot and the pc board.

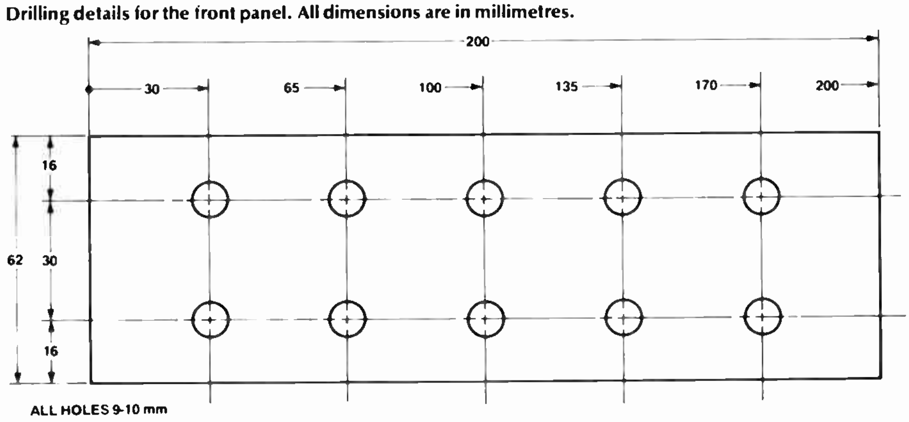
Wire up the input and output sockets. Channel 1 input is wired to RV1, channel 2 to RV5. Wire the power supply leads from the board to the plug pack input socket. Check the polarity of your plug pack — some are wired with −ve to the inner connector, some with +ve.

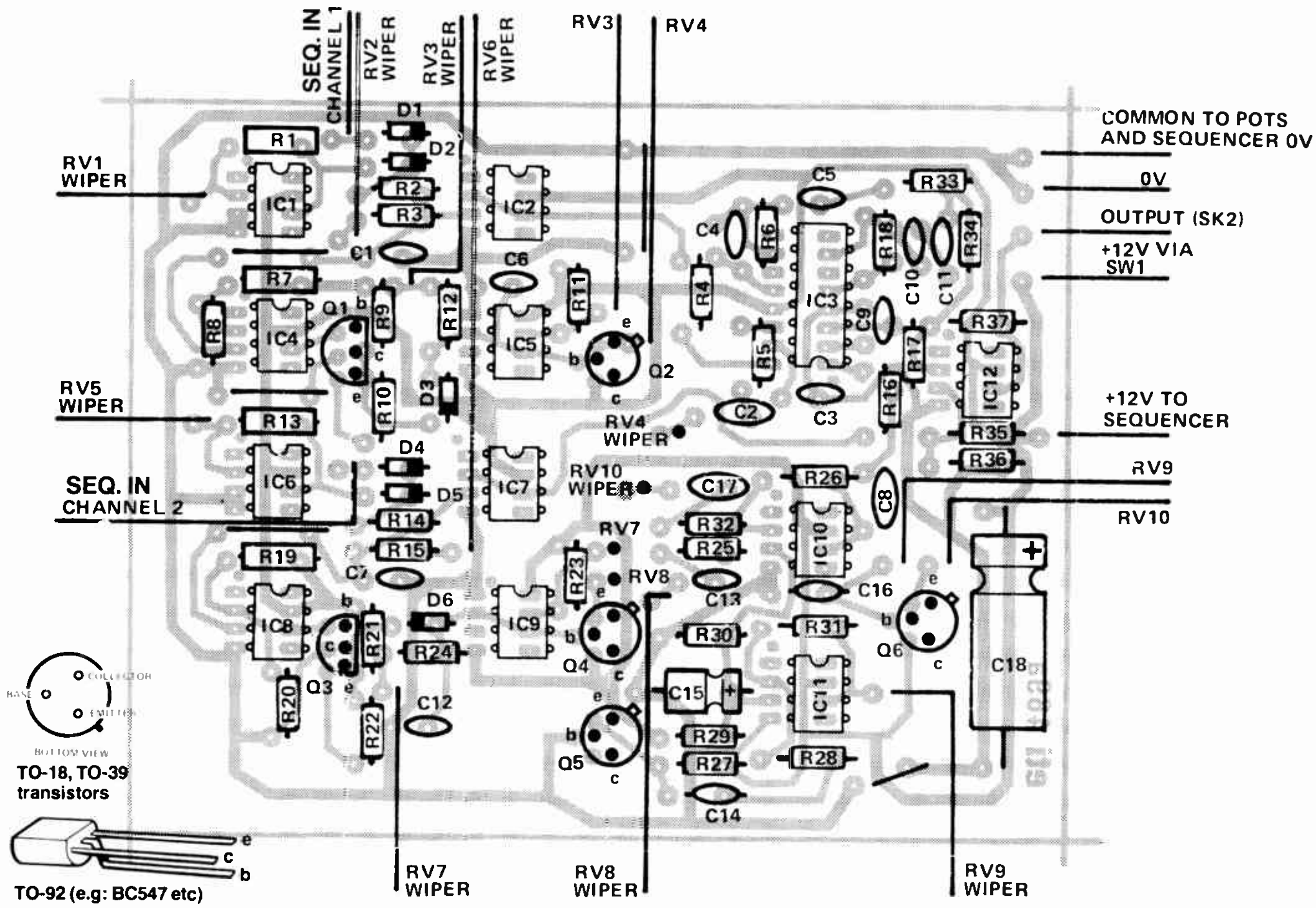
The input 'transducers' are simply small speakers. These may be conveniently mounted in a small jiffy box. You can glue them straight in the bottom — cone down. Tapping the base of the box will cause the speaker to give an output signal. Hook them up with the shielded cable.

Note that the input socket needs to be a stereo, switched type connected such that the two inputs are shorted to 0 V when the input is disconnected. This prevents the input op-amps of each channel from 'floating' with no input, in which case the op-amp offset will give rise to a continuous output — which you don't want!

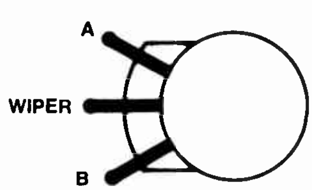
If you're powering this unit from a battery pack, we suggest you obtain one which takes eight 'AA' cells and provides a series connection to produce a nominal 12 V. They come with a handy press-fit connector as found on 9 V transistor radio batteries. The battery pack may be attached to the rear panel in a vertical position, which affords ▶

Drilling details for the front panel. All dimensions are in millimetres.





Component overlay. Note that the board has been laid out for the Q1 and Q3 transistors with an e-c-b pinout. Watch the pinout of the transistors you use; you may have to cross the base and collector leads.



POTENTIOMETER CONNECTIONS

POT.	A	WIPER	B
RV1	TO SK1, CH.1	TO PCB, R1	—
RV2	—	TO PCB, R3	TO 0 V
RV3	TO PCB, R11	TO PCB, R12	—
RV4	TO PCB, Q2	TO PCB, C2	TO 0 V
RV5	TO SK1, CH.2	TO PCB, R13	—
RV6	—	TO PCB, R15	TO 0 V
RV7	TO PCB, R23	TO PCB, R24	—
RV8	TO PCB, Q4	TO PCB, C13	TO 0 V
RV9	TO PCB, IC11	TO PCB, C16	—
RV10	TO PCB, Q6	TO PCB, C17	TO 0 V

PARTS LIST — ETI-469

Resistors .... all ½W, 5%
R1, 13, 25, 26, 31 .... 1M
R2, 12, 14, 24 .... 4k7
R3, 15 .... 33k
R4, 7, 16, 19, 27, 33,
34, 37 .... 100k
R5, 17 .... 22k
R6, 18, 35, 36 .... 47k
R8, 20 .... 6k8
R9, 21 .... 1k
R10, 22 .... 680R
R11, 23 .... 2k2
R28, 32 .... 10k
R29, 30 .... 56k

Capacitors
C1, 3, 5, 6, 7, 9, 11,
12, 13 .... 100n ceramic
C2, 8, 14, 17 .... 220n greencap
C4, 10 .... 33p ceramic
C15 .... 10u/25 V axial electro.
C16 .... 10n ceramic
C18 .... 1000u/16 V axial electro.

Potentiometers
RV1, 4, 5, 8, 10 ...... 50k lin.
RV2, 6 .... 2M lin.
RV3, 7 .... 100k lin.
RV9 .... 250k lin.

Semiconductors
IC1, 2, 4, 6, 7, 8 ...... CA3140
IC3 .... NE570N
IC5, 9 7555
IC10, 11, 12 741
Q1, 3 .... BC557
Q2, 4, 5, 6 .... BC549

Miscellaneous
SK1 .... stereo 6.5 mm phone skt with switch
SK2 .... mono 6.5 mm phone skt
LS1, LS2 .... 50 mm, 8 ohm speakers

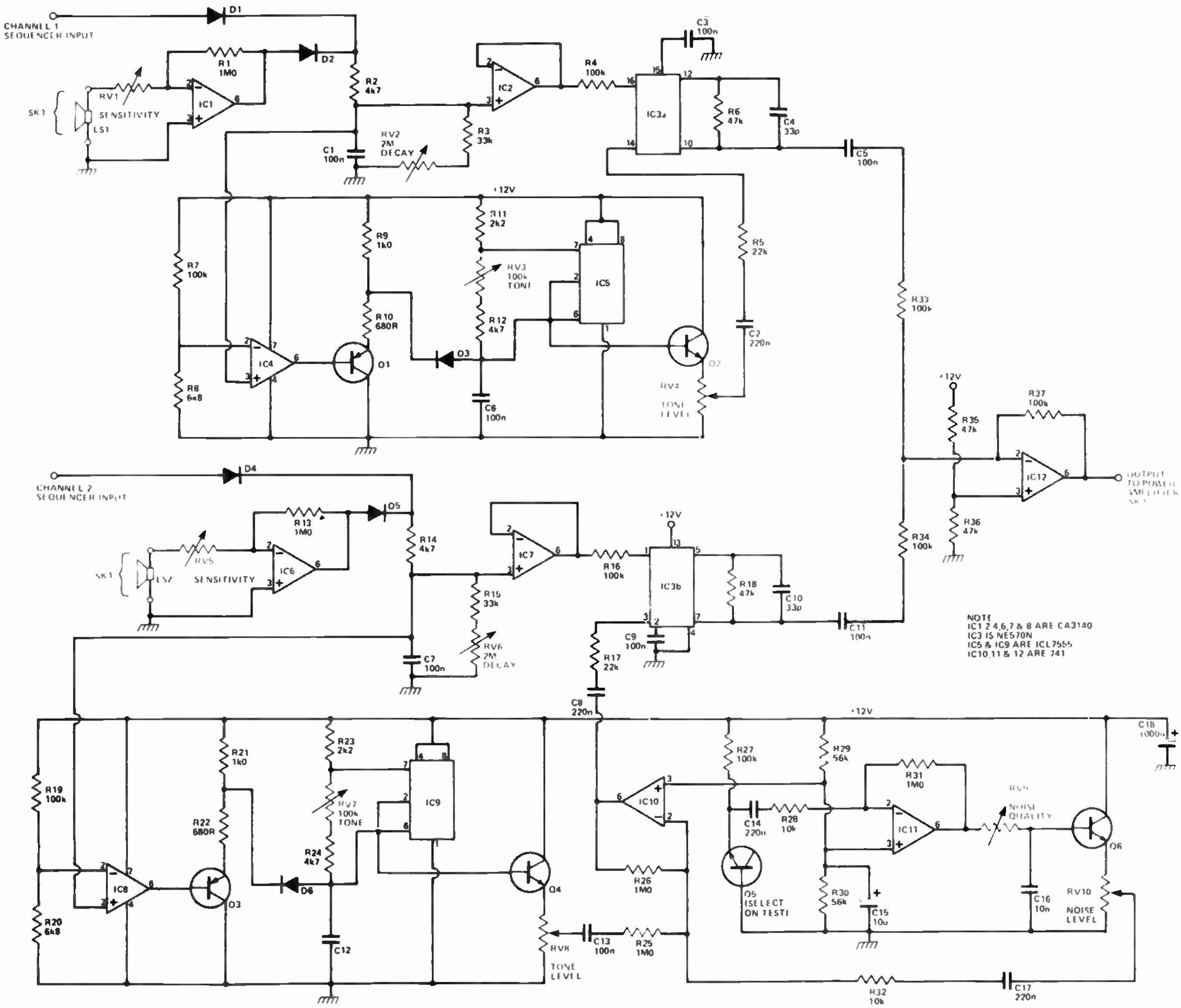
ETI-469a pc board; 10 knobs; case to suit (e.g: Sigea EC.1002); 12 Vdc plug pack (if required); two small jiffy boxes; Scotchcal panel; wire etc.

Price estimate

We estimate the cost of purchasing all the components for this project will be in the range

$85 — $95

Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



HOW IT WORKS — ETI-469

Overall operation is explained in the main text. As the two channels are similar, we'll start the circuit description with the operation of Channel 1, as all the circuit blocks in this channel are common to both channels.

CHANNEL 1

When used in the manual mode the instrument is played using an external transducer such as a speaker (LS1), which is connected to the input of a high-gain dc amplifier, IC1. Each time the transducer is tapped, the output of IC1 jumps abruptly positive and rapidly charges C1 via D2-R2; C1 then discharges exponentially via R3-RV2, to produce the characteristic fast attack/slow decay modulation waveform of a percussion instrument. The waveform is then fed to one half of the dual VCA, IC3, via unity-gain buffer IC2, where it is used to control the gain of the VCA.

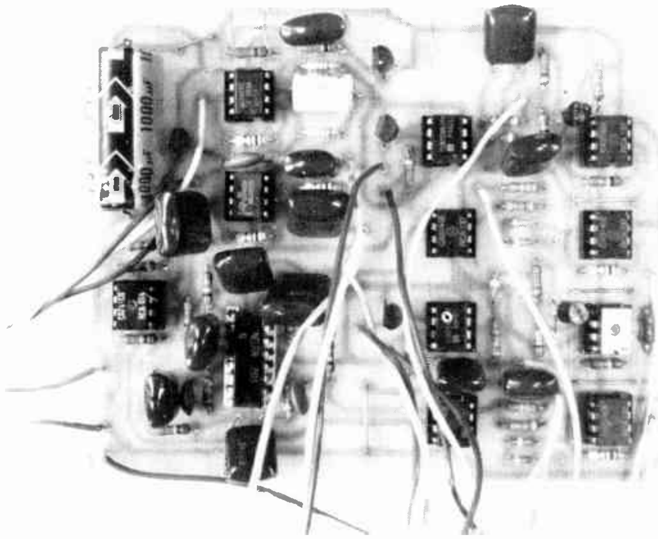
Note that the C1 modulation generator can be activated by either the transducer or by a pulse signal fed to C1 via D1-R1 from the independent sequencer circuit. The C1 voltage is monitored by comparator IC4, which gates on astable IC5 whenever the C1 voltage exceeds a few hundred millivolts. The astable generates a symmetrical ramp waveform, which is buffered by Q1 and fed to the 'tone' input of the VCA via level control RV4. The tone of the astable can be varied over the range 83 Hz to 1.4 kHz with RV3.

Thus each time the channel is activated (by the transducer or by a sequencer) a modulation waveform is fed to one input of the VCA and a tone signal is fed to the other, to produce a modulated tone signal at output pin 10 of IC3. The signal is fed to one input of a two-input mixer, IC12. A wide variety of drum sounds can be simulated by suitable adjustment of RV2, RV3 and RV4.

CHANNEL 2

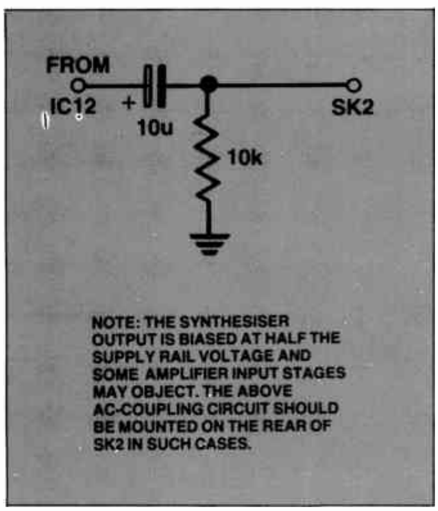
Channel 2 is similar to channel 1, except that the output of the tone generator (from RV8) is fed to the VCA via a two-input mixer designed around IC10. The other input to this mixer is derived from a noise generator designed around Q5-IC11 and Q6. Here, the reverse-biased base-emitter junction of Q5 is used as a noise source and the noise signal is then amplified by IC11, filtered by RV9-C16 and made available via level control RV10.

The instrument is powered from a 12 V supply, derived from eight 1V5 cells. This supply is also used to power the auto-manual sequencer unit.



access to both sides for changing the batteries when necessary. A strip of double-sided sticky pad is ideal for attaching the battery pack. Note that you will need a power switch. A small toggle switch can be mounted on the rear panel in a convenient position or you can get a switch pot for one of the controls (i.e: RV1 or RV5).

Having wired everything up, make the usual visual checks for missed solder joints, solder bridges, dry joints, incorrectly orientated components, etc. Connect the input transducers and the plug pack and connect the sythesiser output to the input of an amplifier. Set the channel 2 sensitivity control fully anticlockwise ('off'). Set all the channel 1 controls to mid position and turn the



unit on. It'll probably go 'boing'. Now, tap the channel 1 transducer. You should get a clear 'boing' sound output. If not, check your wiring. Don't forget to check that power is getting to the pc board. If all is well, set all channel 2 controls to the mid point and tap the channel 2 transducer. You should get a 'boing' mixed in with a 'crash'. If it tests out OK, finally secure the pc board in place and put the case together.

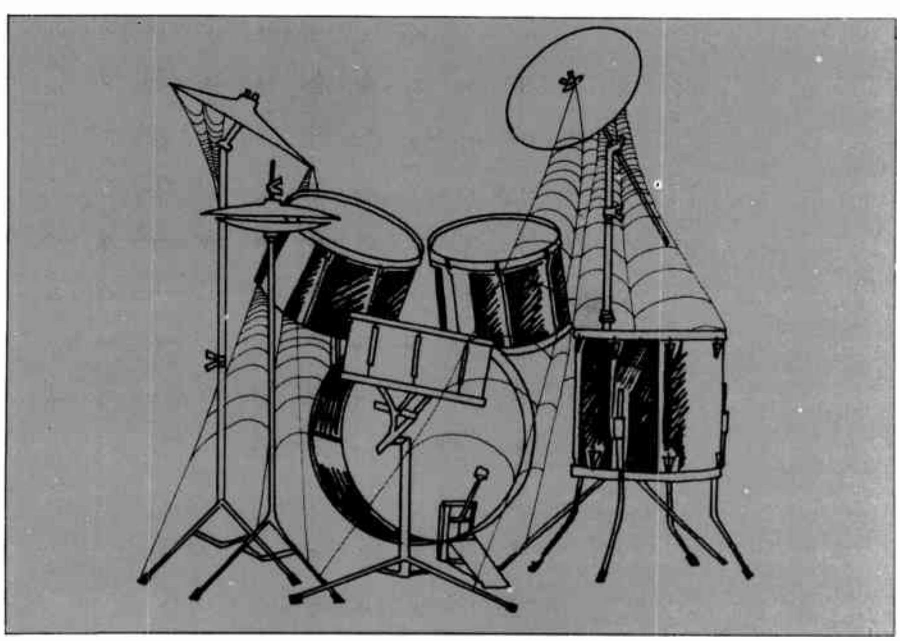
Now, play to your heart's content! You will need to explore how each control functions — how it affects the sound produced — in order to be able to use the synthesiser effectively. There's no substitute for a good fiddle!

If it doesn't work

There are a few fundamental steps you can take to isolate a fault or faults if the unit doesn't work first off. Obviously, make sure power is getting to the pc board. Check this *at the pc board*. The easiest place to do this is across C18. Trace your power input wiring if all is not as it should be. Next, check that you have all five links installed.

Channel 1 doesn't work? Attach a temporary lead to the channel 1 sequencer input (anode of D1). Briefly touch it on the +ve terminal of C18. You should get a 'boing' in the output (all controls set mid-way). If this works, but tapping LS1 doesn't, look for a wiring fault or incorrect orientation of IC1. Otherwise, there's something awry between IC2, IC3 and IC12. Try temporarily bridging the junctions of R5/C2 and R33/C5. Temporarily disconnect one end of D3. Turn the unit on and you should have a tone output. If not, then look for a fault around IC5, Q2 and possibly IC12. You could use a crystal earpiece to check for a tone at the emitter of Q2 to see that IC5 and Q2 are functioning. If the temporary bridge gives a tone output then check for a fault around IC3. Check that its orientation is correct — it faces the opposite direction to all the other ICs. Remove the bridge and restore D3 when you get it going.

Similar procedure can be applied to channel 2. If the noise generator does not produce noise, try connecting a crystal earpiece to the emitter of Q6. If no noise is present, try using a different transistor for Q5. Note that pin 3 of IC11 should be around half the supply rail voltage. Same goes for IC10. If not, check R29 and R30 for the right values and that IC10 and IC11 are correctly orientated. ●



Take everything—but not my Babani Books!!!

REACTANCE/FREQUENCY CHART FOR AUDIO AND RF.
Enables the reactance of any capacitor or resistor to be read off immediately — from 10 Hz to 100 MHz. Reasonant frequencies of LC networks ditto.
196 **75¢**

PRACTICAL TRANSISTORISED NOVELTIES FOR HI-FI
Circuits for audio power meter, stereo phone adaptor, multi channel mixers, gain control, contour network etc. etc.
201 **$1.30**

HI-FI LOUDSPEAKER ENCLOSURES
Data for building corner reflex, bass reflex, exponential horn, folded horn, tuned port, Klipschorn labyrinth, tuned column, loaded port and multi speaker panoramics. Clear dimensioned diagrams included.
205 **$3.50**

DIODE CHARACTERISTICS, EQUIVALENTS & SUBSTITUTES
Includes signal, zener, rectifier diodes etc. Full interchangeability data and characteristics of thousands of diodes of all types with every possible alternative. Includes UK, USA, European, Russian, and Far Eastern devices.
211 **$4.60**

AUDIO ENTHUSIASTS' HANDBOOK
Discusses audio and hi-fi topics including record/playback curves, stylus compliance, disc recordings — then and now, evaluating loudness, equipment compatibility, acoustic feedback, equipment performance figures and standards etc. etc.
214 **$4.05**

BUILD YOUR OWN ELECTRONIC EXPERIMENTERS' LAB USING ICs.
Includes many circuits and designs for constructing test and measuring instruments mostly using modern ICs. Includes AF osc, FET pulse detector, hi-impedence Vm, square wave osc, pulse gen, logic probe, lo-range ohmmeter, bridge, signal tracer etc.
218 **$3.10**

SOLID STATE NOVELTY PROJECTS
A number of novelty projects using modern ICs and transistors. Includes 'Optomin' — a musical instrument played by reflecting a light beam with your hand, water warbler for pot plants, music tone generator, LEDs and ladders game, touch switch, electronic roulette wheel etc.
219 **$3.10**

BUILD YOUR OWN HI-FI & AUDIO ACCESSORIES
Essential for keen hi-fi and audio enthusiasts. Projects include stereo decoder, three-channel mixer, FET preamp for ceramic pick ups, mic preamp with adj bass, stereo dynamic noise limiter, loudspeaker protector, voice-operated relay etc.
220 **$3.10**

28 TESTED TRANSISTOR PROJECTS
Some circuits are new, others are familiar designs. Projects can be split and/or combined for specialised needs.
221 **$4.60**

SOLID STATE SHORT WAVE RECEIVERS FOR BEGINNERS
Design and construction of several solid-state shortwave receivers giving high level of performance yet utilising relatively few inexpensive components. See also 226.
222 **$4.60**

50 PROJECTS USING CA 3130 ICs.
The CA3130 is an advanced operational amplifier capable of higher performance than many others: circuits often need fewer ancillary components. Interesting and useful projects in five groups. Audio projects. RF projects. Test equipment. Household projects. Misc. projects.
223 **$4.60**

50 CMOS PROJECTS
Many interesting and useful projects — multivibrators, amplifiers and oscillators, trigger devices; special devices.
224 **$4.60**

PRACTICAL INTRO TO DIGITAL ICs
Introduction to digital ICs (mainly TTL 7400). Besides simple projects, includes logic test set to identify and test digital ICs. Also includes digital counter timer.
225 **$4.60**

HOW TO BUILD ADVANCED SHORT WAVE RECEIVERS
Full practical constructional details of receivers with performance equal to commercial units. Also add-on circuits of Q meter, S meter, noise limiter etc.
226 **$4.60**

BEGINNERS' GUIDE TO BUILDING ELECTRONIC PROJECTS
Enables total beginners to tackle electronic projects. Includes component identification, tools, soldering, building methods, cases, legends etc. etc. Practical basic projects are included.
227 **$4.60**

HANDBOOK OF RADIO, TV, INDUSTRIAL & TRANSMITTING TUBE & VALVE EQUIVALENTS
Equivalents book for amateurs and servicemen. More than 18,000 old and new valves from UK, USA, Europe, Japan et al. CV (military) listings with commercial equivalents included.
BP2 **$2.25**

FIRST BOOK OF PRACTICAL ELECTRONIC PROJECTS
Full constructional data, circuits, components lists for many practical projects including audio distortion meter, super FET receiver, guitar amp, metronome etc.
BP23 **$2.55**

GIANT CHART — RADIO, ELECTRONICS, SEMI-CONDUCTOR & LOGIC SYMBOLS
Identify those symbols at a glance. A must for beginners and advanced enthusiasts alike. Professionals can always hide it in their desks! A steal at only . . .
BP27 **$2.20**

50 FET PROJECTS
Projects include amplifiers and converters, test equipment, tuners, receivers and receiver aids, mixers and tone controls etc etc. The FET used is not critical. This book is of interest and value to SW listeners, radio amateurs, hi-fi enthusiasts and general experimenters.
BP39 **$6.10**

IC555 PROJECTS
One wonders how life went on before the 555! Included are basic and general circuits, motor car and model railway circuits, alarms and noise makers plus section on subsequent 556, 558 and 559s.
BP44 **$6.45**

MOBILE DISCO HANDBOOK
Most people who start mobile discos know little about equipment or what to buy. This book assumes no preliminary knowledge and gives enough info to enable you to have a reasonable understanding of disco gear.
BP47 **$4.60**

ELECTRONIC PROJECTS FOR BEGINNERS
This book gives the newcomer to electronics a wide range of easily built projects. Actual components and wiring layouts aid the beginner. Some of the projects may be built without using soldering techniques.
BP48 **$4.60**

LM 3900 IC PROJECTS
Unlike conventional op amps, the LM 3900 can be used for all the usual applications as well as many new ones. It's one of the most versatile, freely obtainable and inexpensive devices around. This book provides the groundwork for simple and advanced uses — it's much more than a collection of projects. Very thoroughly recommended.
BP50 **$4.95**

LONG DISTANCE TV RECEPTION (TV-DX)
Written by UK authority, the book includes many units and devices made by active enthusiasts. A practical and authoritative intro to this unusual aspect of electronics.
BP52 **$6.60**

PRACTICAL ELECTRONIC CALCULATIONS & FORMULAE
For the practical person's workbench. Bridges gap between technical theory and cut-and-dried methods which work but leave the experimenter unfulfilled. There's a strong practical bias. Tedious and higher maths avoided where possible. Many tables included. This one's a beauty!
BP53 **$8.25**

HOW TO BUILD YOUR OWN SOLID-STATE OSCILLOSCOPE
Project divided into sections for builder individually to construct and test — then assemble into complete instrument. Includes short section on scope usage.
BP57 **$5.50**

SECOND BOOK OF CMOS IC PROJECTS
Leading on from book number 224 '50 CMOS IC PROJECTS', this second book provides a further selection of useful circuits mainly of a fairly simple nature. Contents have been selected to ensure minimum overlap between the two books.
BP59 **$5.10**

BEGINNER'S GUIDE TO DIGITAL ELECTRONICS
Covers all essential areas including number systems, codes, constructional and sequential logic, analog/digital analog conversion.
BP61 **$3.50**

ELEMENTS OF ELECTRONICS
This series provides an inexpensive intro to modern electronics. Although written for readers with no more than basic arithmetic skills, maths is not avoided — all the maths is taught as the reader progresses.
The course concentrates on the understanding of concepts central to electronics, rather than continually digressing over the whole field. Once the fundamentals are learned the workings of most other things are soon revealed. The author anticipates where difficulties lie and guides the reader through them.
BOOK 1 (BP62): All fundamental theory necessary to full understanding of simple electronic circuits and components.
BOOK 2 (BP63): Alternating current theory.
BOOK 3 (BP64): Semiconductor technology leading to transistors and ICs.
BOOK 4 (BP77): Microprocessing systems and circuits.
BOOK 5 (BP89): Communications.
This series constitutes a complete inexpensive electronics course of inestimable value in hobby or career.
Books 1/2/3 **$8.25 (each)**
Book 4 **$10.80**
Book 5 **$9.95**

SINGLE IC PROJECTS
Simple to build projects based on a single IC. A few projects use one or two transistors as well. A strip board layout is given for each project plus special constructional and setting up info. Contents include low level audio circuits, audio power amps, timers, op-amps and miscellaneous circuits.
BP65 **$5.10**

BEGINNER'S GUIDE TO MICROPROCESSORS & COMPUTING
Introduction to basic theory and concepts of binary arithmetic, microprocessor operation and machine language programming. Only prior knowledge assumed is very basic arithmetic and an understanding of indices.
BP66 **$6.40**

COUNTER DRIVER AND NUMERAL DISPLAY PROJECTS
Well-known author F.G. Rayer features applications and projects using various types of numerical displays, popular counter and driver ICs, etc.
BP67 **$6.40**

CHOOSING AND USING YOUR HI-FI
Provides fundamental info invaluable when buying hi-fi. Explains tech. specs, advice on minimum acceptable standards and specs for adequate sound. Also invaluable advice on how to buy and install and maximise your equipment's potential. Includes glossary of terms.
BP68 **$6.10**

ELECTRONIC GAMES
How to build many interesting electronic games using modern ICs. Covers both simple and complex circuits for beginner and advanced builder alike. Good one!
BP69 **$6.40**

ELECTRONIC HOUSEHOLD PROJECTS
Most useful and popular projects for use around the home. Includes two-tone buzzer, intercom, smoke and gas detectors, baby alarm, freezer alarm etc. etc.
BP71 **$6.10**

A MICROPROCESSOR PRIMER
This small book takes the mystery out of microprocessors. It starts with a design for a simple computer described in language easy to learn and follow. The shortcomings of this basic machine are then discussed and the reader is shown how these are overcome by changes to the instruction set. Relative addressing, index registers follow as logical progressions. An interesting and unusual approach.
BP72 **$6.40**

REMOTE CONTROL PROJECTS
Covers radio, infra-red, visible light, ultrasonic controls. Full explanations are provided so that the reader can adapt the projects for domestic and industrial as well as model use.
BP73 **$7.15**

ELECTRONIC MUSIC PROJECTS
Provides constructors with practical circuits for the less complex music equipment including fuzz box, waa-waa pedal, sustain unit, reverb and phaser, tremolo generator etc. Text covers guitar effects, general effects, sound generators, accessories.
BP74 **$6.40**

ELECTRONIC TEST EQUIPMENT CONSTRUCTION
Describes construction of wide range of test gear including FET amplified voltmeter, resistance bridge, field strength indicator, heterodyne frequency meter etc.
BP75 **$6.40**

POWER SUPPLY PROJECTS
Designs for many power supplies including simple unstabilised fixed and variable voltage regulators — particularly for electronics workshops. Also included are cassette power supply, Ni-Cad charger, voltage step-up circuit and simple inverter, plus info on designing your own supply. All designs are low voltage types for semiconductor circuits.
BP76 **$6.50**

PRACTICAL COMPUTER EXPERIMENTS
How to build typical computer circuits using discrete logic. This book is useful intro to devices such as adders and storers as well as a general source book of logic circuits.
BP78 **$6.50**

RADIO CONTROL FOR BEGINNERS
How complete systems work with constructional details of solid state transmitters and receivers. Also included — antennas, field strength meter, crystal controlled superhet, electro-mechanical controls. Ideal for beginners. Section dealing with licensing etc. not applicable to Australia.
BP79 **$6.40**

POPULAR ELECTRONIC CIRCUITS — BOOK 1
Yet more circuits from Mr Penfold! Includes audio, radio, test gear, music projects, household projects and many more. An extremely useful book for all hobbyists, offering remarkable value for the designs it contains.
BP80 **$7.15**

ELECTRONIC SYNTHESISER PROJECTS
For the electronic music enthusiast, an invaluable reference. This book is full of circuits and information on how to build analogue delay lines, sequencers, VCOs, envelope shapers, etc. etc. The author takes a clear and logical approach to the subject that should enable the average enthusiast to understand and build up what appears to be a quite complex instrument.
BP81 **$6.45**

ELECTRONIC PROJECTS USING SOLAR CELLS
Well-known author Owen Bishop has designed a number of projects that benefit from solar power and obviate the problems encountered with batteries, such as weight and bulk, frequency of replacement, and failure when batteries are exhausted.
BP82 **$7.15**

VMOS PROJECTS
A book to suit the dyed-in-the-wool experimenter. Though primarily concerned with VMOS power FETs and their applications, power MOSFETs are dealt with, too, in a chapter on audio circuits. A number of varied and interesting projects is covered under the headings: Audio Circuits, Sound Generator Circuits, DC Control Circuits and Signal Circuits. Learn while you build.
BP83 **$7.20**

DIGITAL IC PROJECTS
Companion to No. 225 Practical Introduction to Digital ICs and BP61 Beginner's Guide to Digital Electronics. The projects included in this book range from simple to more advanced projects — some board layouts and wiring diagrams are included. The more ambitious projects have been designed to be built and tested section by section to help the constructor avoid or correct any faults that may occur.
BP84 **$7.20**

INTERNATIONAL TRANSISTOR EQUIVALENTS GUIDE
Companion to BP1 and BP14 equivalents books, but contains a huge amount of information on modern transistors produced by over 100 manufacturers. Wherever possible, equivalents are subdivided into European, American and Japanese types. Also shown are the material type, polarity, manufacturer and indication of use or application.
BP85 **$10.85**

AN INTRO TO BASIC PROGRAMMING TECHNIQUES
Ideal for beginners seeking to understand and program in BASIC. Book includes program library for biorhythms, graphing Y against X, standard deviations, regressions, generating musical note sequences, and a card game.
BP86 **$6.60**

SIMPLE LED CIRCUITS — BOOK 2
Sequel to BP42. Further light-emitting diode circuits. If you liked BP42 you'll love this one. If you don't know either it's well worth buying both!
BP87 **$5.05**

ELECTRONIC CIRCUITS FOR MODEL RAILWAYS
Constructional details of a simple model train controller, a controller with simulated inertia, a high-power controller, an electronic steam whistle and a 'chuff generator'. Signal systems and train lighting and RF suppression also covered.
BP95 (was 213) **$6.60**

ORDER FORM

Send to ETI Book Sales, 4th Floor, 15 Boundary St, Rushcutters Bay NSW 2011.
Please allow 4-5 weeks for delivery. Trade enquiries welcomed.

Please forward:

Post & Handling: 1 — 4 books: $1.35 11 — 20 books: $3.50
5 — 10 books: $2.70 Over 20 books: $5.00

Book	Qty.	Book	Qty.	Book	Qty.	Book	Qty.	Book	Qty.
196	......	224	......	BP50	......	BP67	......	BP79	......
201	......	225	......	BP52	......	BP68	......	BP80	......
205	......	226	......	BP53	......	BP69	......	BP81	......
211	......	227	......	BP57	......	BP71	......	BP82	......
214	......	BP2	......	BP59	......	BP72	......	BP83	......
218	......	BP23	......	BP61	......	BP73	......	BP84	......
219	......	BP27	......	BP62	......	BP74	......	BP85	......
220	......	BP39	......	BP63	......	BP75	......	BP86	......
221	......	BP44	......	BP64	......	BP76	......	BP87	......
222	......	BP47	......	BP65	......	BP77	......	BP89	......
223	......	BP48	......	BP66	......	BP78	......	BP95 (was 213)	..

I enclose $ .... (inc. p & h.)

Name ....

Address ....

.... Postcode ....

Shoparound

THIS PAGE is to assist readers in the search for components and printed circuit boards for the projects in this book. Where companies are mentioned only by name, we have listed their complete addresses at the end of this section.

ETI-499 150W MOSFET amp

This project is stocked as a kit by All Electronic Components, Rod Irving Electronics, Electronic Agencies, Jaycar and Altronics. For those assembling their own components, the 2SJ49 and 2SK134 MOSFETs are widely available, as are the Elna 8000u/75 V electrolytic capacitors. Heatsinks may be a little harder to find. Rod Irving's HS4 or HS5 heatsink is quite adequate for many applications, but for a stringent performance at top flight, you'll need Philips' 65D6CB. This is also stocked by Rod Irving Electronics as well as Jaycar and Electronic Agencies. The Ferguson PF4361/1 power transformer is obtainable from the same sources. Although not supplied in kit form, all components for the project are obtainable from Radio Despatch in Sydney.

ETI-492 sound bender

Kits for this project are stocked by Dick Smith Electronics, Rod Irving Electronics, All Electronic Components and Jaycar. All the components are widely stocked, even the XR2206 special function IC.

ETI-257 relay driver

All the components for the Universal Relay Driver Board are stocked by most component suppliers. Printed circuit board suppliers are listed later. A kit is stocked by Rod Irving Electronics and All Electronic Components.

ETI-157 marker generator

All Electronic Components and Rod Irving Electronics stock kits for this project. Most components for it are widely available, with the exception of the 1 MHz crystal. The crystal is obtainable from the two suppliers just mentioned as well as Applied Technology.

ETI-328 LED oil temp. meter

This project is available as a kit, with the special dipstick probe, from All Electronic Components. The VDU dipstick probe is stocked by the following stores in each state:

General Auto Instrument Service
47 Egerton St
Lidcombe NSW

Automotive Instrument Service
180 Coventry St
South Melbourne Vic

M.A.X. Instruments
662 Beaudesert Rd
Salisbury Qld

Auto Instrument Service
11 Dequetteville Terrace
Kent Town SA

Auto Instrument Service
153 Francisco St
Belmont WA

Philco Electronics
1134 Sturt Hwy
Winnellie, Darwin NT

ETI-332 electronic stethoscope

Kits for this project are stocked by Rod Irving Electronics and All Electronic Components. Radio Despatch can supply all the components but doesn't stock a kit.

ETI-329 ammeter

Only All Electronic Components and Rod Irving stock kits for this project. If you want to hunt around for the components, fortunately most are readily available. The LM394 IC is stocked by Rod Irving Electronics, Ellistronics, All Electronic Components, Jaycar, Electronic Agencies and Applied Technology. Most of these suppliers also stock suitable meters. Scotchcal meter panels are available from the suppliers mentioned later.

ETI-333 reversing alarm

The Murata piezo alarm featured in this project is stocked by David Reid Electronics, Radio Despatch, Electronic Agencies, Rod Irving Electronics and All Electronic Components. However, it's not the only piezo alarm that may be used and many types are available from almost any electronic component supplier. Kits for this project are stocked by Electronic Agencies, All Electronic Components and Rod Irving Electronics.

ETI-1501 neg. ion generator

This project is widely stocked as a kit. You'll find it in Dick Smith Electronics, Jaycar, Electronic Agencies, Rod Irving Electronics and All Electronic Components. The only special component is the FX2242 potcore, and the above stores should be able to supply it.

ETI-567 core balance relay

Kits for this project are stocked by Dick Smith Electronics, All Electronic Components and Rod Irving Electronics. Radio Despatch should be able to supply all the components, though they don't stock a kit. If you're assembling the project yourself then the only uncommon item is the FX2242 potcore, and all the above suppliers have them.

ETI-599 infrared remote control

Available as a kit from Electronic Agencies and All Electronic Components. All parts can be supplied by Radio Despatch also. If assembling it yourself, the only special components are the CQY89 infrared LED and the BPW50 infrared sensitive diode. These can be obtained from the above-mentioned suppliers as well as Altronics, Magraths, Tasman Electronics, Radio Parts, Kalextronics and Jaycar. Scotchcal panel and pc board suppliers are listed later.

ETI-729 UHF masthead amp

Kits for this are stocked by Rod Irving Electronics, All Electronic Components and Jaycar. For the dyed-in-the-wool home-brewer, the OM350 amplifier chip is available from Radio Despatch, Magraths, Ellistronics, Altronics and Tasman Electronics. All other parts are generally standard stock items. Note that a fibreglass pc board is necessary.

ETI-735 UHF TV converter

All Electronic Components and Dick Smith Electronics carry this as a kit. The OM350 used in the RF stage is obtainable from the suppliers mentioned for the ETI-729 masthead amp. The C1604 tuning capacitor for the tunable version is obtainable from David Reid Electronics — get the 14 pF one. The 15 pF Johnson capacitor mentioned is available from General Electronic Services, 99 Alexander St, Crows Nest NSW 2065. Note that the project requires a fibreglass pc board.

ETI-156 100 MHz probe

Although nobody carries this project as a kit, parts should be reasonably easy to obtain. For the LH0033CG IC try Magraths, Rod Irving Electronics, Radio Parts and Radio Despatch Service. The Jabel probes are distributed by Watkin Wynne, 32 Falcon St, Crows Nest NSW, (02)43-2107.

ETI-1503 battery charger

Only All Electronic Components carry this as a kit, to our knowledge. The only 'stock' transformer suitable for this project that we can find is the Dick Smith Model M-2000. The DEC type MC2U relay is also a Dick Smith part, No. S-7200. The Fujitsu type FRL264/DO12/02CK is also suitable and is distributed by IRH Components through a number of suppliers. The Arcol HS25 0R22 resistor (R1) is obtainable from Everest Electronics, 61 Compass Drive, Seaford SA 5169. The project is housed in a K&W case, No. C1066. These are widely available. The meter, M1, is by University Graham Instruments and available through Radio Despatch Service and Magraths.

ETI-824/825 slot car controllers

All Electronic Components and Rod Irving Electronics stock these two projects in kit form. The sloping-front case used for the ETI-825 is a Vero case, available through Warburton Franki. Another suitable type is the 'Amtex 20' case, sold by Amtex Electronics of PO Box 285, Chatswood NSW 2067. (02)411-1323. These can be obtained at Radio Despatch and David Reid Electronics.

ETI-259 incremental timer

Rod Irving Electronics, All Electronic Components and Electronic Agencies stock this project as a kit. All components are obtainable at Radio Despatch Service. All parts for this project are generally standard stock items, so no difficulty should be experienced. Panel and pc board suppliers are listed later.

ETI-573 process timer

All Electronic Components are the only kit stockists for this project, to our knowledge. Components are generally stock items and pc board and Scotchcal panel suppliers are listed later.

ETI-568 flash trigger

Electronic Agencies, Rod Irving Electronics and All Electronic Components stock this project in kit form. All components are readily available and Scotchcal panel and pc board suppliers are listed later.

ETI-578 simple NiCad charger

Only All Electronic Components stock this as a kit, we understand. As usual, components are readily available. The case used in our prototype came from David Reid Electronics.

ETI-563 fast NiCad charger

All Electronic Components and Rod Irving Electronics stock this project in kit form. Most components are readily available, but you may have to shop around for the 1N5625 (D6, D7) diodes — accept no substitutes. Many suppliers now stock the PacTec case (e.g. Dick Smith, Cat. No. H-2505).

ETI-574 disco strobe

All Electronic Components and Dick Smith Electronics stock this project in kit form. For those enthusiasts not starting from scratch, the strobe tube and trigger transformer are obtainable from Circuit Components, 383 Forest Rd, Bexley NSW, and from Tandy stores, Dick Smith Electronics and All Electronic Components. The discharge capacitors (6.5 uF, type PHN) are available through All Electronic Components, Dick Smith, George Brown and Martin de Launay.

ETI-469 percussion synth.

Altronics, All Electronic Components, Rod Irving Electronics, Dick Smith Electronics, Jaycar and Electronic Agencies are all stocking this one in kit form The case we used in the prototype is model EC.1002, made by Sigea of PO Box 49, Thornbury Vic. 3071.

PC boards, panels etc.

Every pc board for the projects published in this anthology may be obtained from the following firms:

RCS Radio
651 Forest Rd
Bexley NSW 2207

All Electronic Components
118 Lonsdale St
Melbourne Vic. 3000

In addition, many of the boards are stocked by Radio Despatch Service. If they haven't got your requirements in stock, they can have them made to order for you. Here they are:

Radio Despatch Service
869 George St
Sydney NSW 2000

The same three firms can provide Scotchcal front panels for our projects, too.

Many of the pc boards and panels for the projects published here may be obtainable from the following firms:

Mini Tech
P.O. Box 9194
Auckland N.Z.

Rod Irving Electronics
425 High St
Northcote Vic. 3070

James Phototronics
522 Grange Rd
Fulham Gardens SA 5024

Sunbury Printed Circuits
10 Counihan St
Sunbury Vic. 3429

Jemal Products
P.O. Box 168
Victoria Park WA. 6100

Kits & Components

All Electronic Components
118 Lonsdale St
Melbourne Vic. 3000

Altronics
105 Stirling St
Perth WA. 6000

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

George Brown & Co
174 Parramatta Rd
Camperdown NSW 2050

David Reid Electronics
127 York St
Sydney NSW 2000

Electronic Agencies
115-117 Parramatta Rd
Concord NSW 2137

Ellistronics
289 Latrobe St
Melbourne Vic. 3000

Dick Smith Electronics
Mail Order
P.O. Box 321
North Ryde NSW 2113

Jaycar
125 York St
Sydney NSW 2000

Kalextronics
101 Burgundy St
Heidelberg Vic. 3084

Magraths
208 Little Lonsdale St
Melbourne Vic. 3000

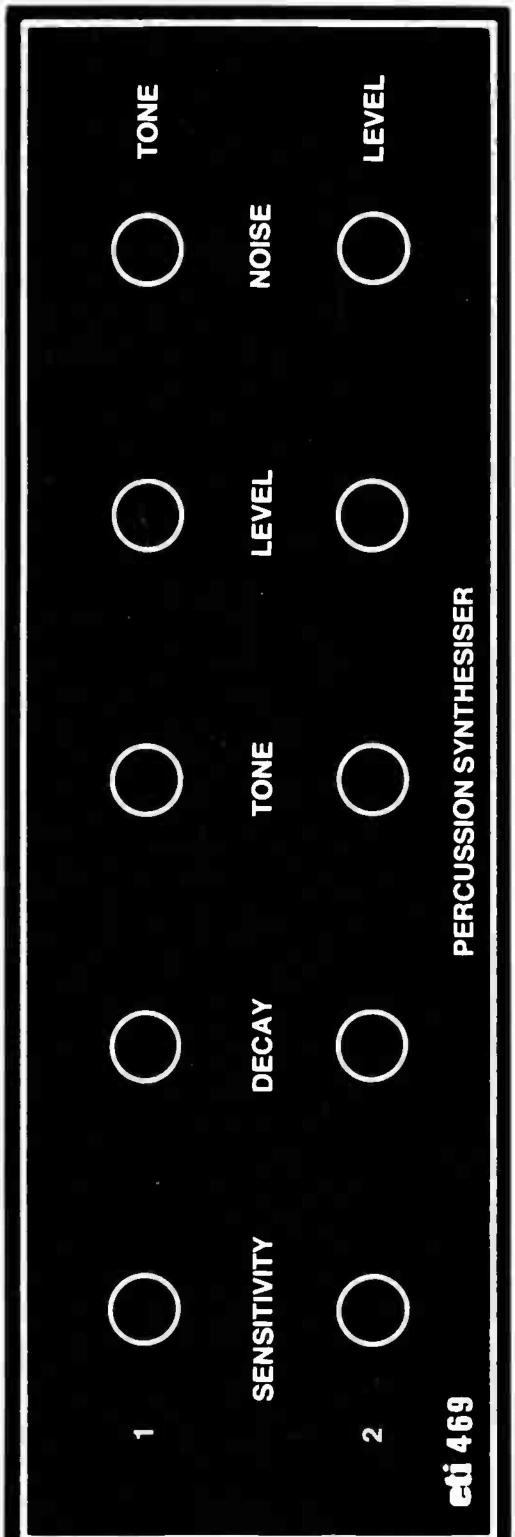
Martin de Launay
287 Clarence St
Sydney NSW 2000

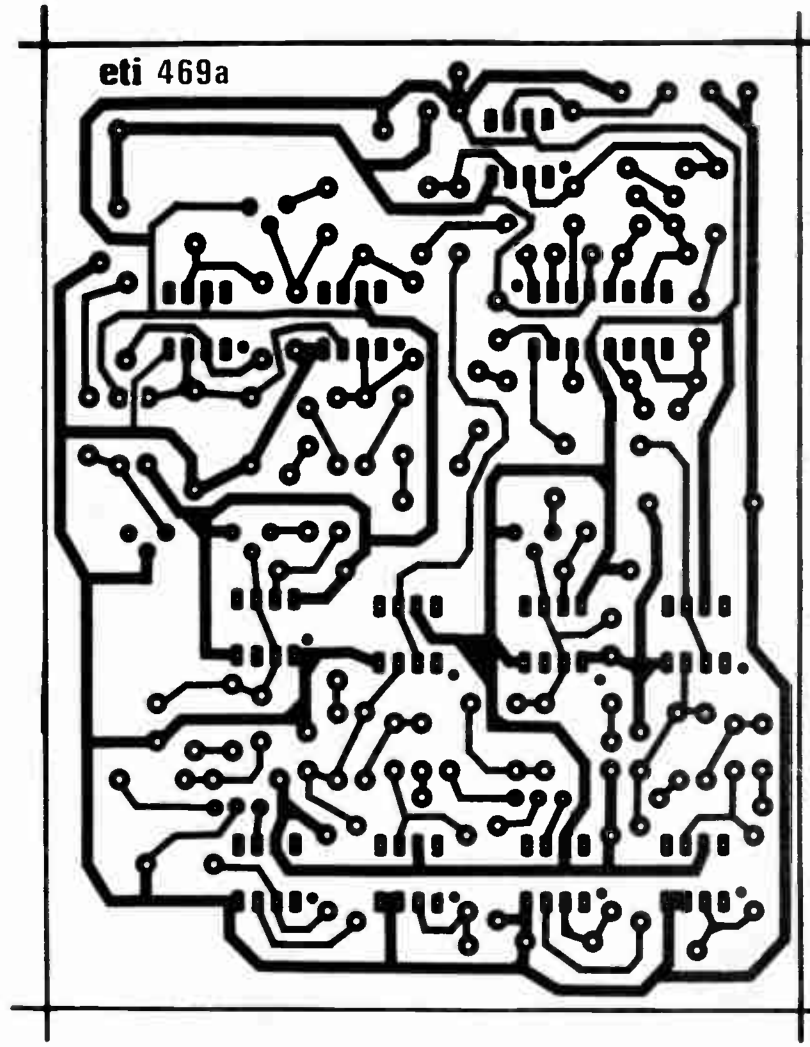
Radio Despatch Service
869 George St
Sydney NSW 2000

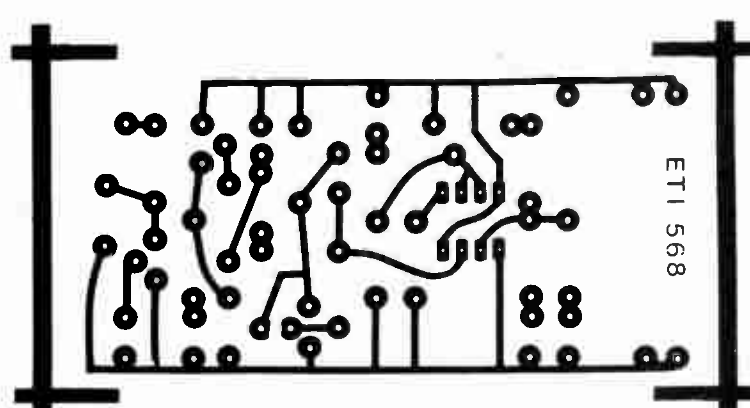
Radio Parts
562 Spencer St
West Melbourne Vic. 3003

Tandy Electronics
280 Victoria Rd
Rydalmere NSW 2116

Tasman Electronics
12 Victoria St
Coburg Vic. 3058


TONE
NOISE
LEVEL
LEVEL
TONE
DECAY
SENSITIVITY
1
2
PERCUSSION SYNTHESISER
eti 469


eti 469a


ETI 568

E. D. & E. (SALES) PTY. LTD., NOW

ALL ELECTRONIC COMPONENTS

118 LONSDALE STREET, MELBOURNE, VIC. 3000. TEL: 662-3506.

WE STOCK THE LARGEST RANGE OF KITS AND PRINTED CIRCUIT BOARDS IN AUSTRALIA AS WELL AS OUR HUGE RANGE OF COMPONENT PARTS AND VALVES.

STEREO UNITS
S1 ETI 484 Compressor Expander
S2 ETI 482 50 watt per channel Amplifier
S3 ETI 482A Preamp Board
S4 ETI 482B Tone Control Board
S5 ETI 485 Graphic Equalizer
S6 ETI 480 50 watt Amplifier less H/S & bracket
S7 ETI 480 100 watt Amplifier less H/S & bracket
S9 ETI 443 Expander Compressor
S10 ETI 444 Five watt stereo
S12 ETI 438 Audio Level Meter
S13 ETI 440 25 watt Stereo Amplifier including metalwork
S18 ETI 426 Rumble Filter
S19 ETI 429 Simple Stereo Amplifier
S21 ETI 417 Over LED Distortion Monitor
S33 E.A. Musicolour III 1000 w/ch
S35 ETI 470 60 watt audio amplifier module
S36 ETI 4000 Series 60 watt stereo amplifier
S37 ETI 451 Hum Filter for Hi-Fi systems
S38 E.A. Stereo Infrared Remote Switch
S39 ETI 455 Stereo Loudspeaker Protector
S40 E.A. Super-Bass Filter Less Power Pack
S42 E.A. Stylus Timer
S43 ETI Series 3000 Amplifier 25w/ch
S44 ETI 477 Mosfet power amp module inc. brackets
S45 ETI 457 Scratch/Rumble Filter
S46 ETI 458 VU Level Meter
S47 ETI 479 Bridging Adaptor

PRE-AMPLIFIERS AND MIXERS
P1 ETI 445 Stereo Pre-Amplifier
P2 ETI 449 Balance Mic Pre Amplifier
P6 ETI 419 Mixer Pre-amplifier — 4 ch. Mixer Pre-amplifier — 2 ch.
P7 ETI 401 F.E.T. 4 Input Mixer
P10 E.A. Playmaster 145 Mixer
P11 ETI 446 Audio Limiter
P12 ETI 471 High Performance Stereo Pre-amplifier
P13 ETI 477 Moving Coil Cartridge Pre-Amp
P14 ETI 474 High to low Impedence Interface
P15 ETI 467 4 Input Guitar/Mic. Pre-amp Suits
P16 E.A. Moving Coil Pre amplifier (Battery)
P17 E.A. Moving Coil Pre amplifier (Plug Pack)
P18 ETI 478 MM Moving Magnet Pre-amp (Series 5000)
P19 ETI 478 MC Moving Coil Pre-amp (Series 5000)
P20 ETI 478 Series 5000 Pre-amplifier
P21 E.A. Vocal Cancellor

GUITAR UNITS
G1 ETI 447 Audio Phaser
G2 ETI 413 2 x 100 watt Bridge Amplifier
G5 ETI 413 100 watt Guitar Amplifier
G6 ETI 410 A.D.U. for your Guitar
G14 ETI 452 Guitar Practice Amplifier
G15 ETI 466 300 watt Amp module — less H/S & Transformer
G16 ETI 454 Fuzz-Sustain less foot switch
G17 HE 102 Guitar Phaser
G18 ETI 450A Bucket Brigade
G19 ETI 450B Mixer for above

AUDIO TEST UNITS
AT1 ETI 441 Audio Noise Generator
AT2 ETI 128 Audio Millivolt Meter
AT4 ETI 102 Audio Signal Generator
AT5 E.A. A.F. Tone Burst Generator
AT7 ETI 137 Audio Oscillator
AT8 ETI 138 Audio Power Meter
AT9 HE 105 Bench Amplifier (less case)
AT10 E.A. Audio Test Unit

ELECTRONIC GAMES
EG1 ETI 043 Heads and Tails
EG2 ETI 068 L.E.D. Dice Circuit
EG3 E.A. Electronic Roulette Wheel
EG4 ETI 557 Reaction Timer
EG5 ETI 814 Dinky Die
EG6 E.A. Selectalott
EG7 HE 107 Electronic Dice
EG8 E.A. Photon Torpedo
EG9 HE 123 Alien Invaders

METAL DETECTORS
MD1 ETI 549 Induction Balance Metal Detector includes wire for search head
MD2 ETI 561 Metal Locator less dowel and tubing potplant stand
MD3 ETI 1500 Discriminating Metal Locator (undrilled case)
MD4 ETI 1500 Discriminating Metal Locator (predrilled case)
MD5 ETI 562 Geiger Counter with ZP 1310 Tube
MD6 ETI 566 Pipe and Cable Locator
MD7 E.A. Prospector Metal Locator including headphone

POWER SUPPLIES
PS1 ETI 132 Experimenters Power Supply
PS2 ETI 581 Dual Power Supply (High Powered Version)
PS3 ETI 712 CB Power Supply
PS4 ETI 131 Power Supply
PS6 ETI 105 Laboratory Power Supply
PS7 ETI 111 I.C Power Supply
PS9 E.A. 1976 Regulated Power Supply
PS11 E.A. C.B. Power Supply
PS12 ETI 142 Power Supply 0-30 V 0-15 A (fully protected)
PS13 ETI 472 Power Supply
PS14 E.A. Power Supply for Dream 6800
PS15 ETI 577 Dual 12V supply
PS16 E.A. Power Saver
PS17 ETI 480PS Power Supply for ETI480 (100 watt Amp)
PS18 E.A. Bench Mate Utility Amplifier/Power Supply
PS19 HE 108 Power Supply

COMPUTER AND DIGITAL UNITS
C1 ETI 633 Video Synch Board*
C2 ETI 632M Part 1 Memory Board V.D.U.*
C3 ETI 632P Part 1 Power Supply V.D.U.*
C4 ETI 632A Part 2 Control Logic V.D.U.*
C5 ETI 632B Part 2 Control Logic V.D.U.*
C6 ETI 632C Part 2 Character Generator V.D.U.*
C8 ETI 632 U.A.R.T. Board*
C9 ETI 631-2 Keyboard Encoder*
C10 ETI 631 A Sch. Keyboard (less keyboard)*
C14 ETI 638 Eprom Programmer
C15 ETI 637 Cuts Cassette Interface
C16 ETI 651 Binary to Hex Number Converter
C17 ETI 730 Getting Going On Radio Tele Type
C18 E.A. Dream 6800 Computer for Beginners less keyboard and cover
C22 ETI 660 Basic Computer
C23 ETI 660 Basic Computer incl colour option on board expandable memory, RF modulator case and power supply
C24 ETI 760 Video RF Modulator
C25 E.A. Eprom Pogrammer

TEST EQUIPMENT
TE2 ETI 133 Phase Meter
TE4 ETI 129 R.F. Signal Generator
TE6 ETI 706 Marker Generator
TE8 ETI 122 Logic Tester
TE9 ETI 124 Tone Burst Generator
TE11 ETI 116 Impedance Meter
TE15 ETI 704 Cross Hatch Dot Generator
TE16 ETI 120 Logic Probe
TE17 ETI 121 Logic Pulser
TE34 ETI 487 Real Time Audio Analyser
TE35 ETI 483 Sound Level Meter
TE36 ETI 489 Real Time Audio Analyser
TE37 ETI 717 Cross Hatch Generator
TE38 E.A. 3 Mhz Frequency Counter
TE42 E.A. Transistor Tester incl. BiPolar & F.E.T.S
TE43 ETI 591 Up Down Pre-setable Counter
TE44 ETI 550 Digital Dial (less case) includes
TE45 ETI 144 Expanded Scale R.M.S. Voltmeter
TE46 ETI 148 Versatile Logic Probe
TE47 ETI 724 Microwave Oven Leak Detector
TE48 ETI 150 Simple Analog Frequency Meter
TE49 ETI 151 Linear Scale Ohm Meter
TE50 ETI 152 Linear Scale Capacitance Meter
TE51 E.A. Digital Capacitance Meter
TE52 ETI 589 Digital Temp. Meter
TE53 E.A. T.V. C.R.O. Adaptor less Power Pack
TE54 E.A. XTAL Locked Pattern Generator
TE55 E.A. Decade Resistance Sub Box
TE56 E.A. Capacitance Sub Box
TE57 E.A. Decade Capacitance Sub Box
TE58 E.A. Tantalum Capacitance Sub Box
TE59 ETI 140 1 GHZ Frequency Meter/Timer
TE60 ETI 572 PH Meter
TE61 ETI 135 Panel Meter
TE62 E.A. Modulated Signal Injector
TE63 HE 103 Transistor Tester
TE64 HE 111 Ohmmeter
TE65 ETI 157 Crystal Marker

WE HAVE NOW BEEN APPOINTED OFFICIAL INTERSIL DISTRIBUTORS AND ARE CURRENTLY STOCKING SUPPLIES OF THESE FABULOUS PRODUCTS IN CONJUNCTION WITH ALL OUR OTHER COMPONENTS.

TIMERS
T1 ETI 650 STAC Timer
T2 ETI 564 Digital Wall Clock
T3 E.A. Universal Timer and Stopwatch
T4 ETI 540 Universal Timer

BIO FEEDBACK
BF1 ETI 546 G.S.R. Monitor (less probes)
BF2 ETI 544 Heart Rate Monitor
BF3 ETI 576 Electromogram

WARNING SYSTEMS
WS1 ETI 583 Gas Alarm
WS3 ETI 528 Home Burglar Alarm
WS4 ETI 702 Radar Intruder Alarm
WS7 ETI 313 Car Alarm
WS12 ETI 582 House Alarm
WS14 E.A. 1976 Car Alarm
WS15 E.A. 10 Ghz Radar Alarm
WS16 E.A. Light Beam Relay
WS17 ETI 247 Soil Moisture Indicator
WS18 ETI 250 Simple House Alarm
WS19 ETI 570 Infrared Trip Relay (including plug pack)
WS20 ETI 585 Ultrasonic Switch

MODEL TRAIN UNITS
MT1 ETI 541 Model Train Control
MT2 E.A. 1974 Model Train Control
MT6 E.A. 1978 Train Control

AUTOMOTIVE UNITS
A1 ETI 317 Rev. Monitor
A2 ETI 081 Tachometer
A3 ETI 316 Transistor Assisted Ignition
A4 ETI 240 High Power Emergency Flasher
A6 ETI 312 Electronic Ignition System
A7 ETI 301 Vari Wiper
A14 E.A. Dwell Meter
A15 E.A. Variwiper
A16 E.A. Tacho for Tune-ups
A17 E.A. Ignition Analyser and Tachometer
A18 E.A. Strobe Adaptor for Ignition Analyser
A19 E.A. 1975 C.D.I. Capacitor Discharge Ignition
A22 ETI 318 Digital Car Tachometer (less Metalwork)
A23 ETI 319A Variwiper Mk. 2 (no dynamic braking)
A24 ETI 319B Variwiper Mk. 2 (for dynamic braking)
A25 ETI 555 Light Activated Tacho
A26 ETI 320 Battery Condition Indicator
A27 E.A. Transistor Assisted Ignition
A28 ETI 324 Twin Range Tacho less case
A29 ETI 328 LED Oil Temp Meter less V.D.O. probe
A30 ETI 321 Auto Fuel Level Alarm
A31 ETI 332 Stethoscope
A32 ETI 325 Auto Probe Tests Vehicle Electricals
A33 ETI 333 Reversing Alarm
A34 E.A. Low fuel indicator

PHOTOGRAPHIC
PH1 ETI 586 Shutter Speed Timer
PH3 ETI 514B Sound Light Flash Trigger
PH4 ETI 532 Photo Timer
PH7 ETI 513 Tape Slide Synchronizer
PH12 E.A. Sync-a-Slide
PH14 ETI 558 Mast Head Strobe
PH15 ETI 553 Tape Slide Synchronizer
PH16 E.A. Digital Photo Timer
PH17 ETI 594 Development Timer
PH18 ETI 568 Sound or light operated Flash Trigger inc. optional parts
PH19 E.A. Sound Triggered Photoflash
PH20 HE 109 Extra Flash Trigger
PH21 E.A. Photographic Timer

SOUND EFFECTS
SE1 E.A. Sound Effects Generator*
SE2 E.A. Musical Tone Generator
SE3 E.A. Cylon Voice
SE4 E.A. Steam Whistle
SE5 ETI 607 Sound Effects
SE6 ETI 492 Audio Sound Bender
SE7 E.A. Electronic Sea Shell Sound Effects
*set as for Steam Train and Prop Plane noise

RECEIVERS/TRANSMITTERS
R1 ETI 711 Remote Control Transmitter Switch
R2 ETI 711R Remote Control Receiver
R3 ETI 711D Remote Control Decoder
R4 ETI 711B Single Control
R5 ETI 711C Double Control
R6 ETI 711P Power Supply
R7 ETI 707A 144 Mhz Converter
R8 ETI 707B 52 Mhz Converter
R9 ETI 708 Active Antenna
R10 ETI 760 Modulator
R11 ETI 780 Novice Transmitter
R12 ETI 703 Antenna Matching Unit
R15 E.A. 110 Communications Receiver
R17 E.A. 130 Communications Receiver
R18 E.A. All Wave I.C 2
R20 E.A. Fremodyne 4 Complete Kit
R21 E.A. Fremodyne 4 RF Section
R31 E.A. 27 Mhz Pre-amp
R32 E.A. 10-30 Mhz Pre-amp
R33 ETI 718 Shortwave Radio
R34 ETI 490 Audio Compressor
R35 ETI 721 Aircraft Band Converter (less XTALS)
R36 ETI 726 6 or 10 metre Power Amp
R37 ETI 475 Wide Band A.M. Tuner
R38 ETI 585 Ultrasonic Switch

VOLTAGE/CURRENT CONTROLS
V1 ETI 481 12 volt to - 40V D.C. 100 watt Inverter
V2 ETI 525 Drill Speed Controller
V6 E.A. 1976 Speed Control
V8 E.A. Inverter 12V D/C input 230V 50hz 300VA output
V10 E.A. Zero-voltage switching heat controller

COMMUNICATION EQUIPMENT
CE1 ETI 711 Remote Control Transmitter Switch
CE2 ETI 711R Remote Control Receiver
CE3 ETI 711D Remote Control Decoder
CE4 ETI 711B Single Control
CE5 Double Control
CE6 ETI 711P Power Supply
CE7 ETI 707A 144 Mhz Converter
CE8 ETI 707B 52 Mhz Converter
CE9 ETI 708 Active Antenna
CE11 ETI 780 Novice Transmitter
CE12 ETI 703 Antenna Matching Unit
CE15 E.A. 110 Communications Receiver
CE17 E.A. 130 Communications Receiver
CE18 E.A. All Wave I/C 2
CE20 E.A. Fremodyne 4 Complete Kit
CE21 E.A. Fremodyne 4 RF Section
CE29 E.A. Short Wave Converter for 27 Mhz
CE31 E.A. 27 Mhz Pre-amp
CE32 E.A. 10-30 Mhz Pre-amp
CE33 ETI 718 Shortwave Radio
CE34 ETI 490 Audio Compressor
CE35 ETI 721 Aircraft Band Converter (less XTALS)
CE36 ETI 726 6 or 10 metre Power Amp
CE37 ETI 475 Wide Band A.M. Tuner
CE38 E.A. Masthead Preamplifier
CE39 ETI 731 R.T.T.Y. Modulator
CE40 ETI 729 UHF TV Masthead Preamp (less external box)
CE41 ETI 735 UHF to VHF TV Convertor
CE42 HE 104 AM Tuner (less case)
CE43 HE 106 Radio Microphone (less case)
CE44 E.A. R.T.T.Y. Demodulator
CE45 E.A. Voice Operated Relay

MISCELLANEOUS KITS
M1 ETI 604 Accentuated Beat Metronome
M4 ETI 547 Telephone Bell Extender
M5 ETI 602 Mini Organ (less case)
M7 ETI 044 Two Tone Doorbell
M10 ETI 539 Touch Switch
M25 E.A. Digital Metronome
M37 ETI 249 Combination lock (less lock)
M39 E.A. Electronic Combination lock (including lock)
M46 E.A. Power saver for induction motors
M48 E.A. Lissajouis Pattern Generator
M53 ETI 247 Soil Moisture Alarm
M54 E.A. Electrochune Keyless Organ
M55 E.A. Pools/Lotto Selector
M56 ETI 256 Humidity Meter
M57 ETI 257 Universal Relay Driver Board
M58 E.A. Simple Metronome

STAGE
ST1 ETI 592 Light Show Controller (3 ch.) (1000 W/Ch)
ST2 ETI 593 Colour Sequencer (for use with ETI 592)
ST3 ETI 551 Light Chaser 3 channel 1000 watt/ch
ST4 E.A. Light Chaser 3 channel
ST5 E.A. Twin Tremolo for Organs/Stage Amps
ST6 E.A. Light Chaser
ST7 ETI 499 150 W Mosfet P.A. Module

Note: We do not stock sub-standard poor quality components

ALL AT NEW DISCOUNT PRICES

TRADE AND RESELLER ENQUIRIES WELCOME.