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TEST GEAR VOL.3

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Project 147

Electronic dummy load

Jonathan Scott

With this unit you can test power supplies at currents up to 15 amps and voltages up to 60 volts. It can 'sink' up to 200 watts on a static test and you can modulate the load to perform dynamic tests.

THIS PROJECT is fundamentally a test instrument — but an unusual one. It is intended primarily for testing and 'setting up' power supplies of all varieties — from ordinary transformer-rectifier supplies to sophisticated regulated supplies. It can even be used to plot the discharge characteristics of storage batteries.

The unit employs four high power transistors connected as constant current 'sinks'. These dissipate power from the source to which the unit is connected. The characteristics of the load are controlled by controlling the base drive to these transistors. Self-destruction is avoided by the addition of protection circuitry which 'shuts down' the load if the rated current or power is exceeded. In addition, a relay will disconnect the unit if more than a safe voltage is applied.

The load can be *modulated* to vary the load current by means of an externally-applied signal. It can be modulated at frequencies up to 70 kHz. The resultant load current waveform can be monitored on an oscilloscope connected to the *current output* socket. The specifications of the unit are given in the accompanying box. We have also drawn up a graph showing the *operating area* of the unit.

Applications

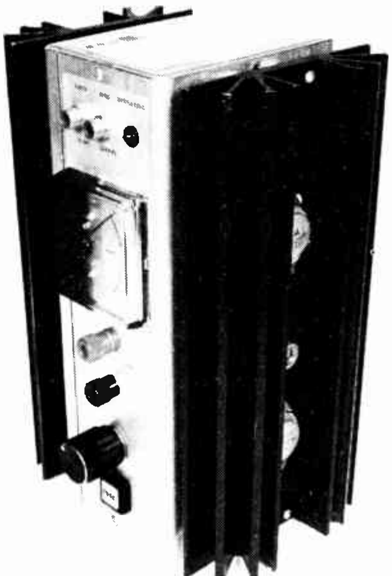
Regulated power supplies have a finite 'reaction time' following the application of a load or variation in load current. This project can be used to test the transient response, the reaction time, of a power supply as the load can be modulated. A low frequency square wave applied to the unit's *modulation input* will effectively vary the load resistance. The rise and fall times of the power supply under test can then be ascertained from an oscilloscope connected to the *current output*. Varying the level of the signal applied to the modulation input will vary the 'depth' of modulation. The load can be 'swung' from full current to zero current, or over a lesser range, and a good idea of how the supply reacts to this test can be gained.

The same technique can be used to check a power supply's regulation and to set the internal impedance.

Construction

We chose to use one of the larger Horwood rectangular boxes to house the project. The layout is not particularly critical and the unit could be assembled in a number of different ways. We chose the Horwood box as it proved convenient and inexpensive. It's convenient as the assembly is dominated by the 220 mm long heatsinks which have to be mounted vertically, and that's how we used the box — a little unconventional, but entirely practical. The box is designated type 34/9/DS and measures 240 mm x 100 mm x 70 mm. It comes in four pieces — the rectangular 'tube' is in two pieces and there are two end pieces. The heatsinks are mounted off the sides of the case on standoff pillars. This allows a free air flow around the vertically mounted heatsinks, ensuring good cooling efficiency.

There are several sources for suitable heatsink sections. Dick Smith Electronics stocks a 225 mm length, catalogue number H-3426. Rod Irving Electronics stocks a suitable style of

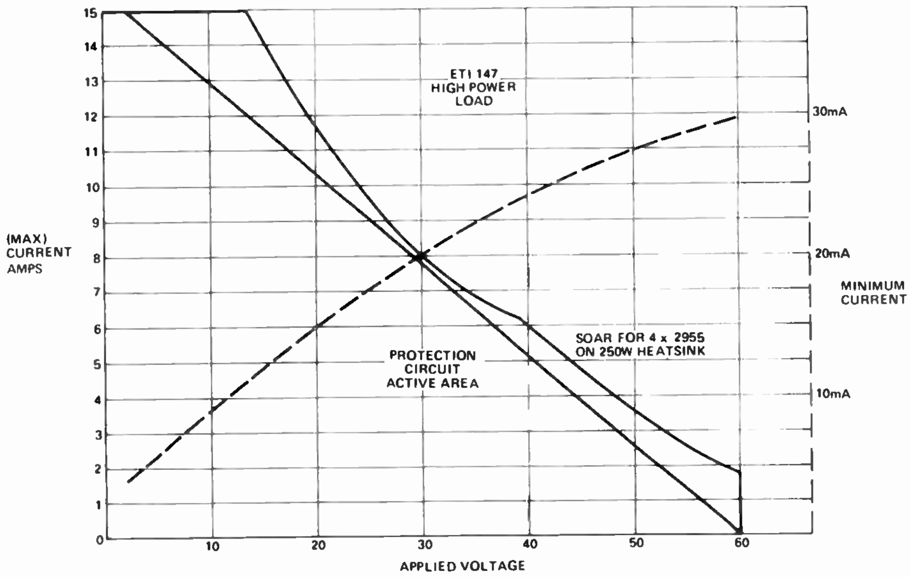


Side view showing Q9, Q10 and D2 mounted on the heatsink.

heatsink, manufactured locally, but you may have to ask for a length to suit.

First thing to do is tackle the metalwork. Carefully mark out and drill the heatsinks. One heatsink has two of the transistors mounted on it plus the BYX200R/21L diode, D2. This is a stud-mounting diode that is meant to 'press-fit' into a suitable hole in the heatsink. However, it is easier for home construction if you buy a bolt-on mount for it. These should be available from the supplier from whom you bought the diode. The transistors should be mounted well away from each other, but not too close to the ends of the heatsinks.

Having drilled all the holes in each heatsink, remove any burrs as these in-



ELECTRONIC DUMMY LOAD, PROTOTYPE PERFORMANCE SLEW RATE: 100mA/μS

terfere with good thermal contact. Bolt all the semiconductors to the heatsinks using thermal compound (such as Bevaloid GS13). No insulating washers are necessary, but solder lugs should be inserted under each of the transistor mounting bolts. Although all the transistor collectors are connected directly to the case, separate wires are run from each to the pc board so as not to *rely* on the mechanical connection and so that the unit may be tested or serviced with the case disassembled. The anodising on the heatsinks is actually a good insulator, and whilst toothed washers may be used where necessary to provide an electrical connection, we felt it better to provide a direct wire to the pc board. It's certainly more reliable.

Two standoff pillars, about 10 - 15 mm long, are used to support each end of each heatsink, as can be seen from the photographs.

Next, drill the case. Front panel layout is not critical and you can arrange it to suit yourself.

Mount relay behind the front panel using a small clamp fashioned from a scrap of aluminium. You can glue it on if you wish! It should be mounted quite close to the positive terminal so that a very short, heavy lead can run from the terminal to the relay contact pins.

The pc board is mounted on standoff pillars on the panel of the case opposite the front panel. It can be mounted in any convenient position. The panels on which the heatsinks mount have a large diameter hole (9 - 13 mm) drilled in them through which the wiring to the heatsink-mounted components passes. These holes should be grommeted to prevent possible shorts to the case. Transistor Q8, a TIP31 flatpack, is mounted on the case panel adjacent to the pc board. It is insulated from the case using an insulating washer and insulated mounting bush.

All the components that mount on the front panel can be assembled next. If

— text continues page 8. ▶

SPECIFICATIONS ETI-147 ELECTRONIC LOAD

Maximum dissipation	200 watts (see graph)
Maximum voltage	60 volts
Maximum current	15 amps
Minimum voltage	2 volts
Minimum current	3 mA
Modulation range	0 to full current
Modulation sensitivity	1 V p-p or better
Mod. frequency response	1kHz - 70 kHz
Protection	see graph

HOW IT WORKS — ETI 147

The ETI 147 dummy load is a passive constant current 'sink' which draws power from the supply to which it is connected. The load includes circuitry for protection from over-voltage, overcurrent, overpower, reverse voltage and secondary breakdown of the power devices.

For convenience of explanation, the circuit can be divided into five sections — the main power dissipator and drivers, the reference circuit, the reference comparison circuit, the protector circuit and the indication circuit.

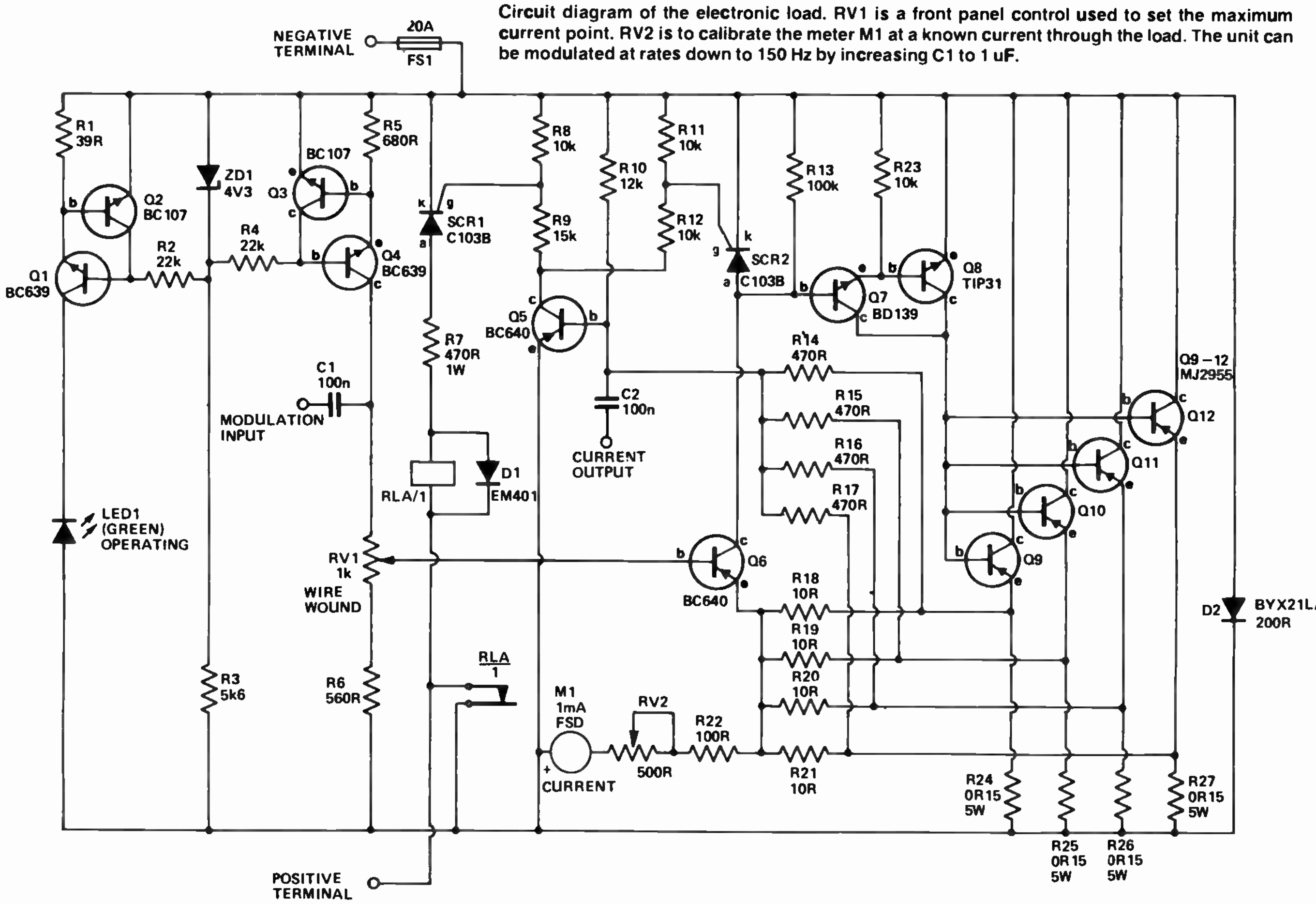
The power is dissipated in transistors Q9 - Q12. MJ2955 transistors have been chosen because, as they are PNP, their collectors can be connected to the heatsink without the need for an insulating washer. This decreases thermal resistance from the transistors to the heatsink. The resistors R24 - R27 ensure correct current sharing between the power transistors as well as forming the current sensing resistance for the protection circuit.

An internal reference is provided by passing a constant current — generated by ZD1, Q3 and Q4 — through R6 and RV1. Using a constant current generator allows the unit to operate over a very wide range of supply voltages, yet deliver a stable, low value reference voltage. The transistor Q6 compares the reference voltage from RV1 with the voltages across the resistors R24 to R27. These voltages are proportional to the current in the output devices and appear at the emitter of Q6 through R18 to R21. Q6 supplies current to the driver transistors, Q7 and Q8. The output transistors are turned on sufficiently to cause the voltage on the emitter of Q6 to be about 0.6 V above the voltage on its base.

The current sensing voltages appear on the base of Q5 through R14 to R17. R10 proportionally adds a component of the terminal voltage. Should either the current, the voltage or their sum exceed safe limits, Q5 turns on, tripping SCR2 and turning off the load. This 'sum-of-volts-and-current' circuit protects the unit from overcurrent, overpower and secondary breakdown. Because shutting down the load will not provide protection from overvoltage a relay is provided which operates when SCR1 conducts. SCR1 has been arranged to cut in if the current shutdown looks like being inadequate, i.e: if there is considerable voltage present. If the device protects only by current shutdown, turning RV1 to minimum will reset the circuit. If, however, the relay is operated it will be necessary to remove power to the unit before it will reset. Reverse polarity protection is provided by D2 and FS1.

The current through the load is monitored by M1 which senses the voltage at the emitter of Q6. The meter is calibrated by RV2. A LED indicating that the unit is operating is driven from a constant current source comprised of ZD1, Q1 and Q2. When the voltage is sufficient to operate the load the LED will light, giving an 'adequate voltage' indication. The LED will also extinguish if the relay drops out, indicating the need to remove power.

Finally, in order to make dynamic measurements, C1 provides the option of modulating the reference, and thus the current drawn, from anywhere between zero and full load. The actual current may be viewed with an oscilloscope connected to the output at C2. Capacitors are used here to avoid grounding these points, which would interfere with the operation of the unit. There is no reason why the dc voltage appearing on the meter could not be made available if so desired.



Circuit diagram of the electronic load. RV1 is a front panel control used to set the maximum current point. RV2 is to calibrate the meter M1 at a known current through the load. The unit can be modulated at rates down to 150 Hz by increasing C1 to 1 uF.

PARTS LIST — ETI 147

Resistors all ¼W, 5% unless marked

R1 .... 39R
R2, R4 .... 22k
R3 .... 5k6
R5, R6 .... 680R
R7 .... 470R, 1W
R8, R11, R12, R23 . 10k
R9 .... 15k
R10 .... 12k
R13 .... 100k
R14 - R17 .... 470R
R18 - R21 .... 10R
R22 .... 100R
R24 - R27 .... 0.15 ohm, 5W

Potentiometers

RV1 .... 1k wire wound
RV2 .... 500R trimpot

Capacitors

C1, C2 .... 100n greencap

Semiconductors *see text

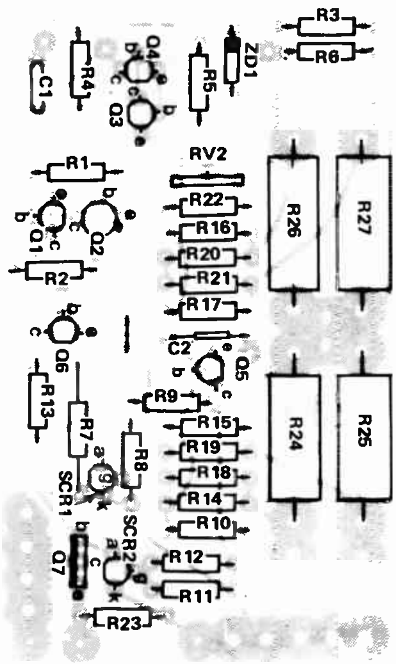
D1 .... EM401 or similar
D2 .... BYX21L/200R or similar 25A diode
ZD1 .... 4V3, 400mV zener diode
LED1 .... Green LED, TIL220G or similar
SCR1, SCR2 ...... C103B or similar SCR
Q1, Q4 .... BFY50,TT801, BC639*
Q2, Q3 .... BC107, BC547 or similar
Q5, Q6 .... TT800, BC640*
Q7 .... BD139
Q8 .... TIP31
Q9 - Q12 .... MJ2955

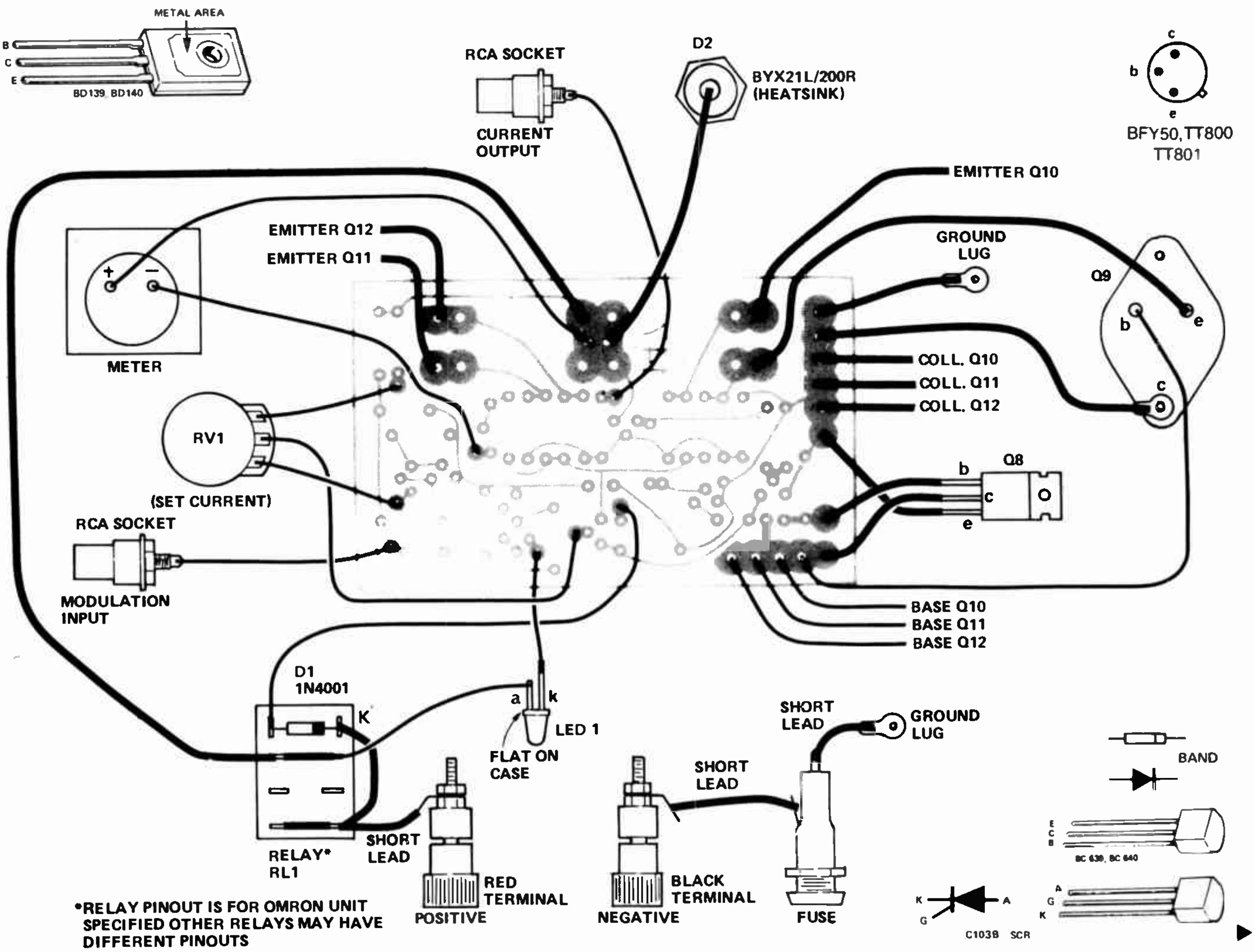
Miscellaneous

M1 .... 1 mA FSD meter, University TD48 or Minipa MU45 or similar

RL1 .... 24 V relay with 15 A contacts, see Shoparound on p. 114

ETI-147 pc board; fuse holder with 20 A fuse; two RCA sockets; two screw terminals; 10 x 12 mm standoffs; two lengths 225 mm-long flat-sided heatsink (see Shoparound p. 114); Horwood box, type 34/9/DS; 15 A hookup wire.

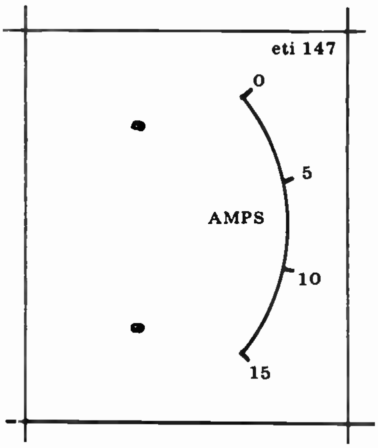


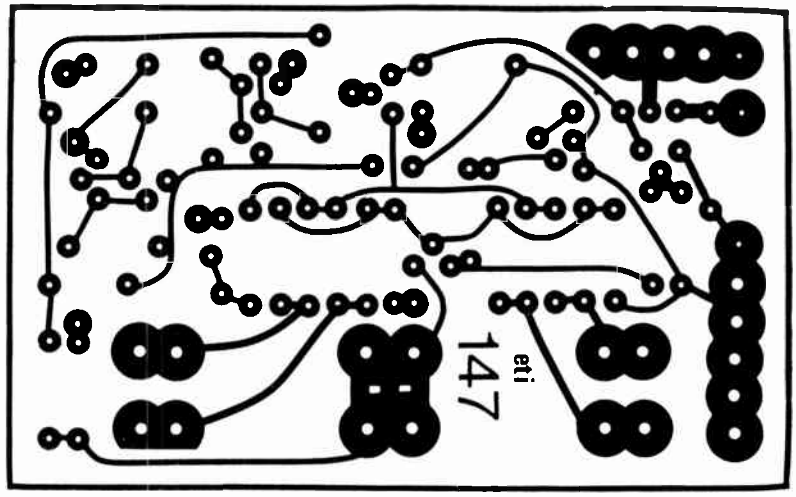


you are using a Scotchcal label, don't forget that it goes on first. Suppliers should have Scotchcal labels available — see Shoparound on page 114.

The pc board should be assembled next. Refer to the component overlay, taking care with the orientation of the transistor. If BC639 and BC640 transistors are used for Q1 and Q4, note that they have quite different pinouts to the other types, *so be careful.* The four 0.15 ohm, 5W resistors should be mounted 5 - 6 mm off the pc board to allow free circulation of air.

Check the pc board before wiring it to the case mounted components. Heavy duty, multi-strand hookup wire should be used to wire all high current carrying connections. This includes the collector and emitter leads to Q9, Q10, Q11 and Q12, the lead to the cathode of D2, the lead from the pc board 'ground' connection to the 'ground' lug on the case, wiring to the fuse and input terminals and to the relay contacts. Heavy lines on the wiring diagram indicate where to use heavy wiring leads. We suggest 32 x 0.2 mm cable as a minimum, preferably something heavier. Remember that it may have to carry as much as 15 amps. ●

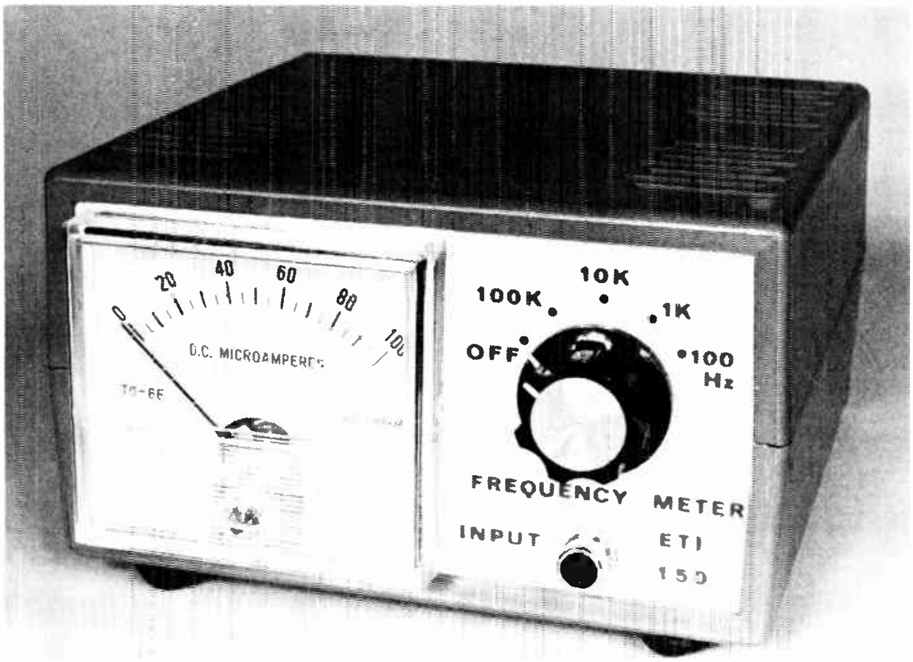




Simple analogue frequency meter features linear scale

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

Phil Wait



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

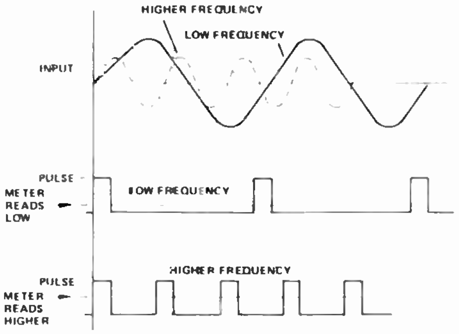
This project will enable you to measure frequency from around 100 Hz right up to 100 kHz with an accuracy of a few percent. It is inexpensive to build but performance is quite adequate to meet a large number of needs in any hobbyist's workshop. Accuracy is unaffected by the waveshape of the signal being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

The frequency meter may be powered from an internal No. 216, 9 V battery or from a Plugpack battery eliminator. A suitable dc socket may be installed on the rear of the cabinet.

All components are readily obtainable, the moulded plastic case in which we housed the prototype is an item supplied by A & R Soanar and is available from many suppliers.

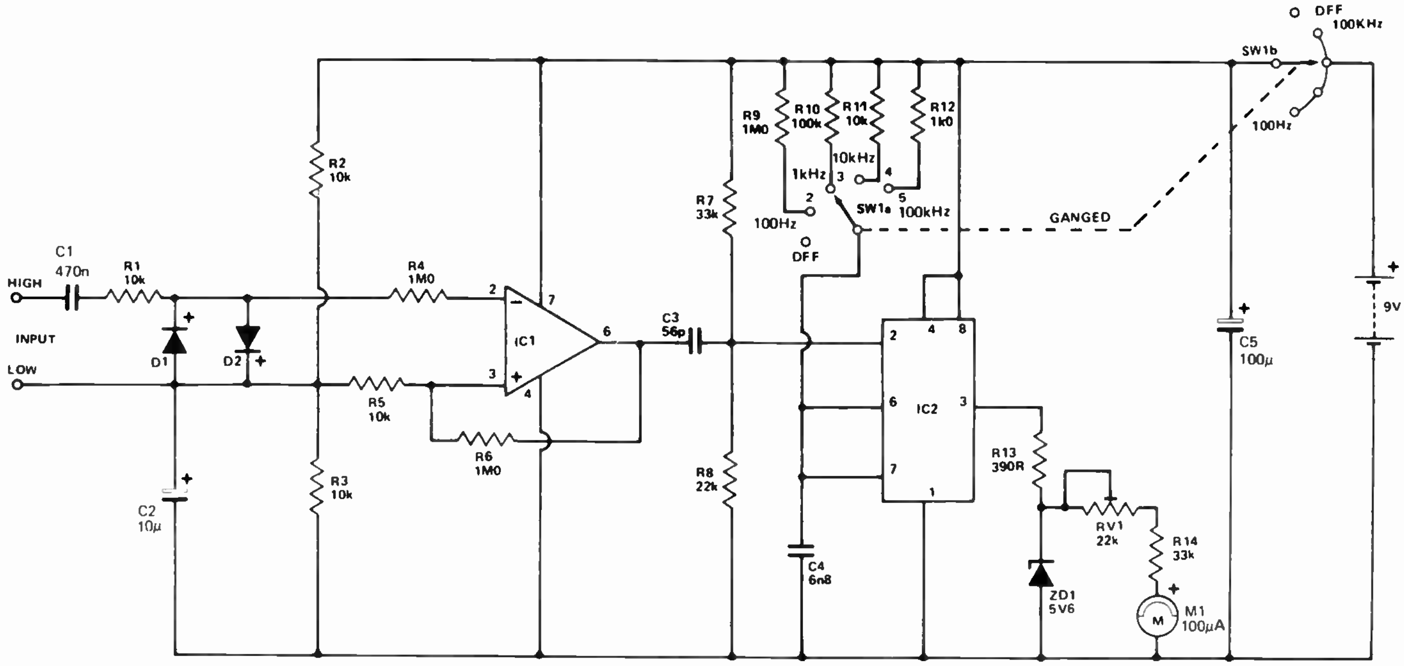
Circuit features

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



SPECIFICATIONS ETI 150

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



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

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

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

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

HOW IT WORKS – ETI 150

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

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

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

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

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

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

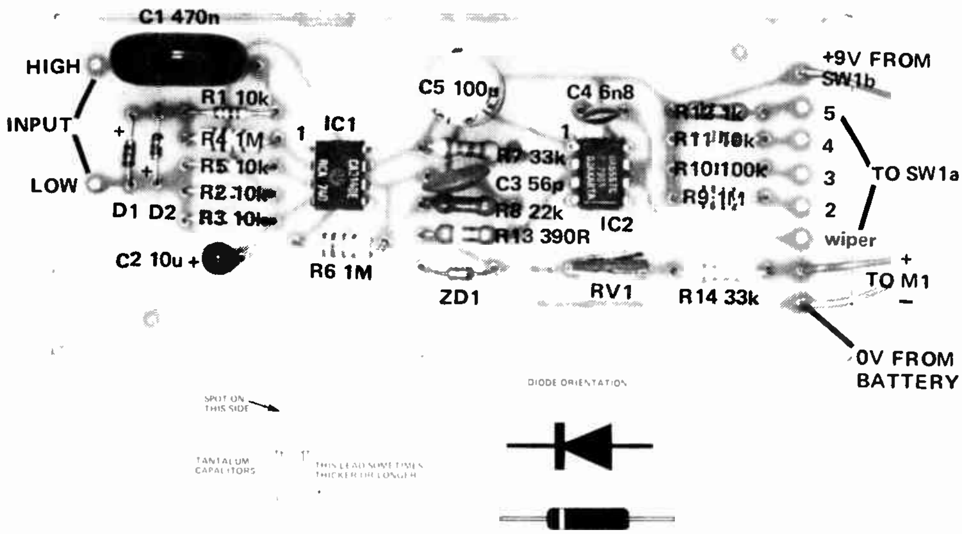
The output pulse from the 555 is clipped at 5.6 V by a zener diode, ZD1, to avoid inaccuracies caused by falling battery voltage (as the battery ages). The meter responds to the average value of the clipped pulses. As the frequency increases, the duty cycle (on/off ratio) of the pulse train increases,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

Construction

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

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

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



The pc board pattern is on page 34.

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

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

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

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

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

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

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

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

Calibrating it

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

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

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

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

Using your meter

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

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

PARTS LIST - ETI 150

Resistors	all ½W, 5%
R1–R3	10k
R4	1M
R5	10k
R6	1M
R7	33k
R8	22k
R9	1M
R10	100k
R11	10k
R12	1k
R13	390R
R14	33k
Capacitors	
C1	470n greencap
C2	10µ tantalum
C3	56p ceramic
C4	6n8 greencap
C5	100µ 25V electrolytic
Semiconductors	
D1, D2	1N914 or similar
ZD1	5V6,400mW Zener diode
IC1	3140 op amp
IC2	555 timer
Miscellaneous	
M1	100µA meter, University TD - 66 or similar
RV1	22k min vert mounting trim pot
SW1	two pole five pos wafer switch

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

Electronic ohmmeter features linear scale and high accuracy

Many workshop, laboratory and hobby applications require accurate measurement of resistor values or accurate matching of resistors of the same nominal value. This simple instrument fills the bill for the sort of measurement required.

THIS INSTRUMENT is a simple and inexpensive semi-precision ohmmeter that can be used to give accurate readings of resistance from a few tens of ohms to one megohm. The unit has four decade ranges covering 1k to 1M full scale and has a full scale accuracy of 2% if low tolerance range resistors are used.

Conventional moving coil ohmmeters have non-linear scales which typically cover two to four decade ranges of resistance value on a single scale. With such a range of resistance it is impossible to obtain an accurate reading, especially at the higher values. To measure resistance values with reasonable accuracy, the usual method is to use a Wheatstone Bridge, often very expensive and time consuming.

By contrast, this ohmmeter gives resistance readings on a linearly calibrated scale and covers only a single decade of resistance on each switched range. The instrument thus gives inherently more accurate readings of resistance than multimeter type ohmmeters.

The technique

The circuit consists of a voltage reference feeding an operational amplifier. The gain of the op-amp is set by the ratio of the range resistors, R3 to R6, to the feedback resistor, Rx. A moving-coil meter is connected to the output of the op-amp and the reading will be the reference voltage multiplied by the gain of the op-amp. Therefore, the reading is proportional to the gain of the op-amp which in turn is proportional to the value of Rx, the unknown resistor.

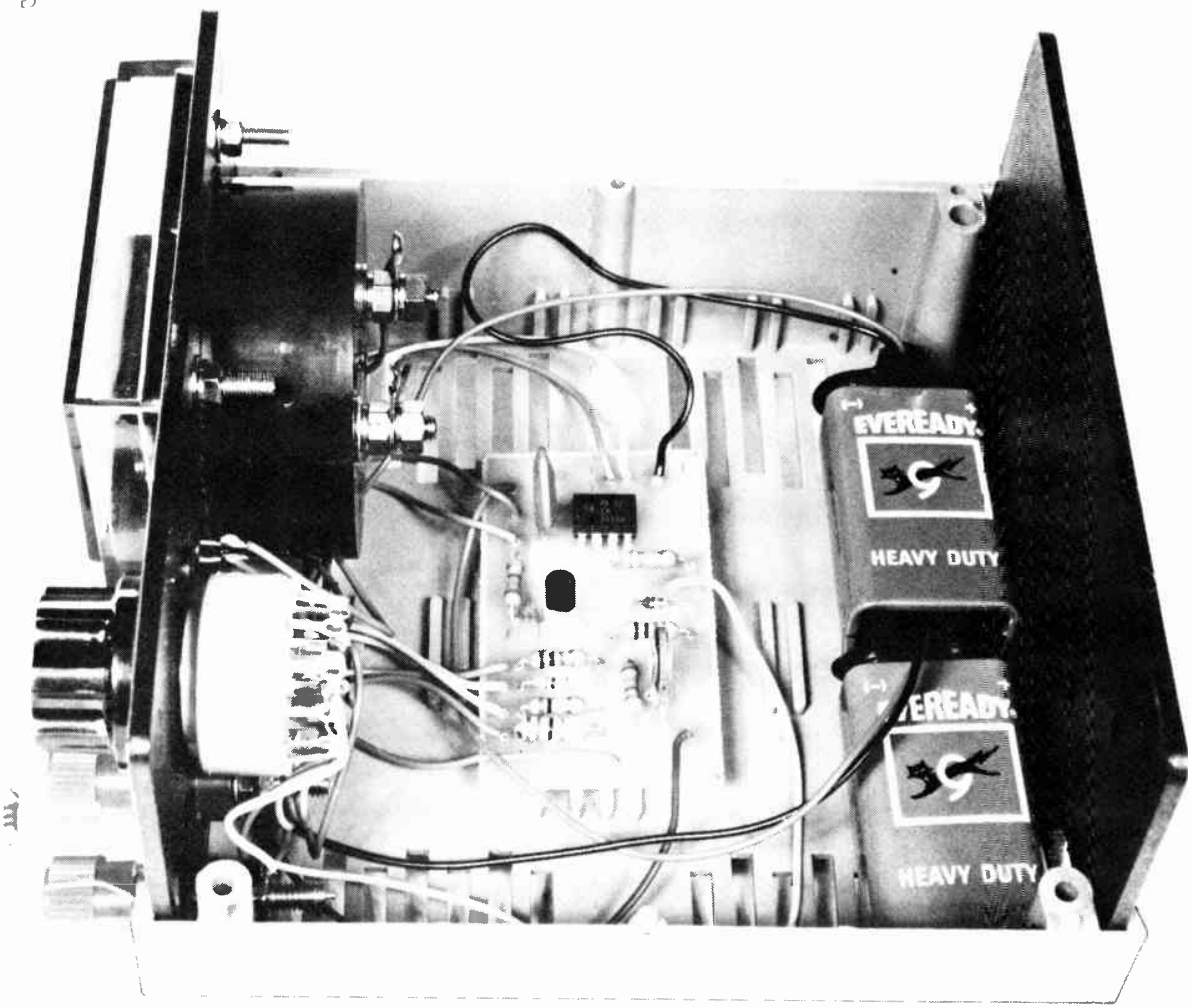
The op-amp we selected is a 301, used for its low input current. This ensures that the highest resistance range is not shunted by the input resistance of the op-amp causing inaccuracy at higher values. In fact a 10M range could be added but would not be accurate over about a few megs. The lowest resistance range is determined by the current capacity of the op-amp, reference supply, and the batteries.

Calibration of the instrument is achieved by adjusting the trimpot for correct reading with a known resistance.

Construction

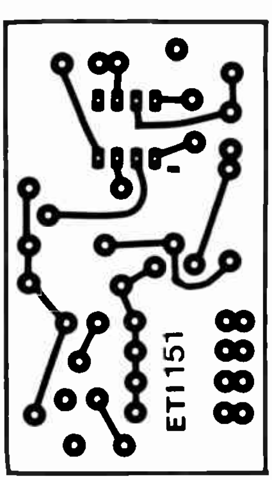
The ohmmeter can either be constructed as a completely contained unit, with its own moving-coil meter, as we have done, or it can be built as an add-on to an existing multimeter having a 1mA dc current range. As the meter is the most expensive part the latter method is by far the cheapest way of doing it.

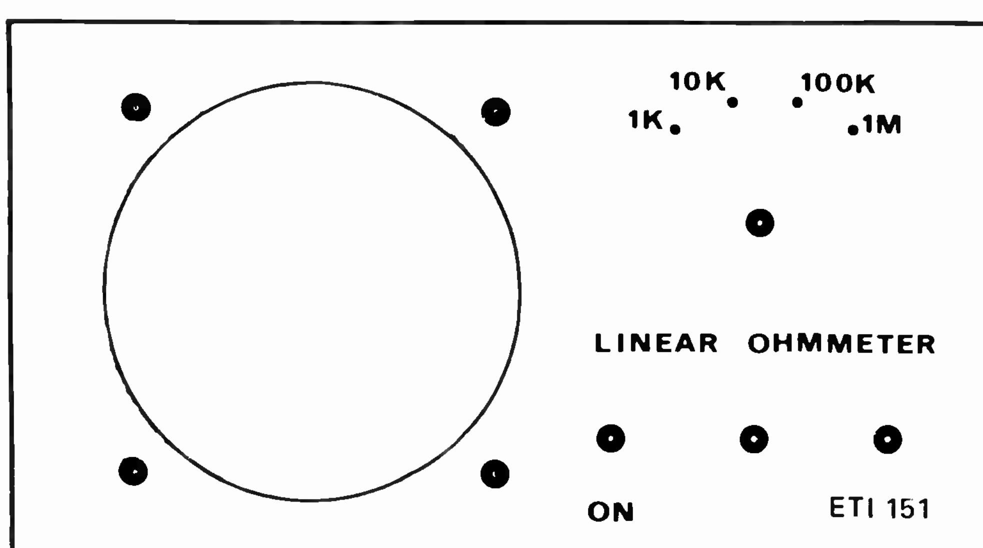
The construction is straightforward with all the minor components mounted on a pc board. Take care with the polarity of the zener diode. The 301 op-amp cannot be substituted by a



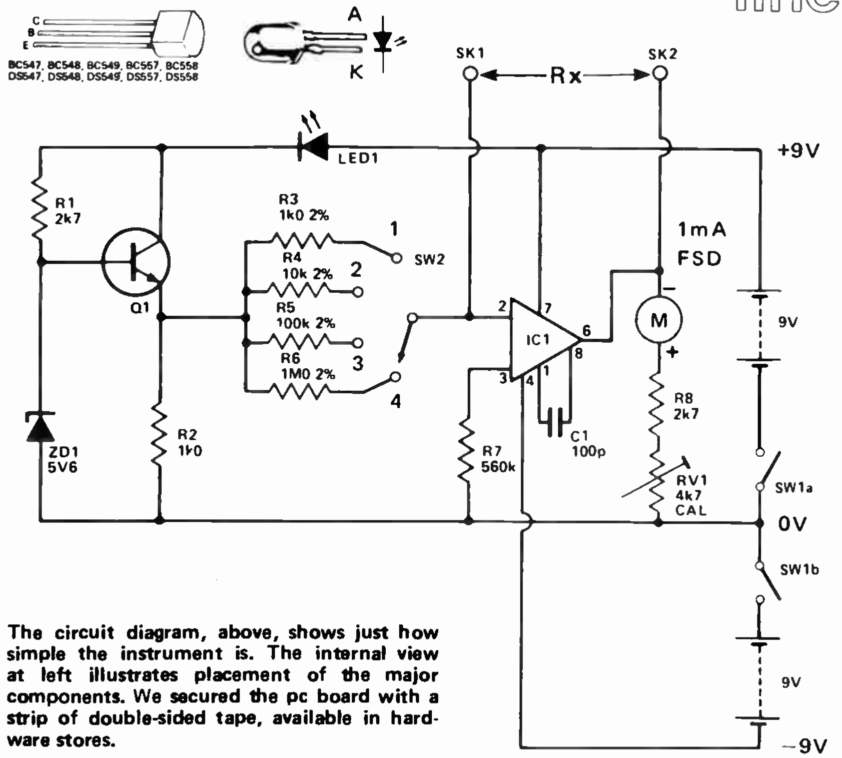
741 as it has been selected for its low input current. The overall accuracy of the instrument is determined by the tolerance of the range resistors (R3 to R6) and the accuracy of the meter. If 1% or 2% resistors are used the accuracy of the instrument will be about two percent. See Shoparound for a list of suppliers with close tolerance resistors.

When the pc board assembly is complete, fit the board into the box and complete the wiring to the major components. We used a common plastic case, identical to the one used for the Linear Scale Frequency Meter (page 9). If you are making an add-on version of the meter, fit a couple of screw terminals in place of the meter for





RIGHT: Front panel artwork. Scotchcal overlays will be available from Radio Despatch Service in Sydney.



The circuit diagram, above, shows just how simple the instrument is. The internal view at left illustrates placement of the major components. We secured the pc board with a strip of double-sided tape, available in hardware stores.

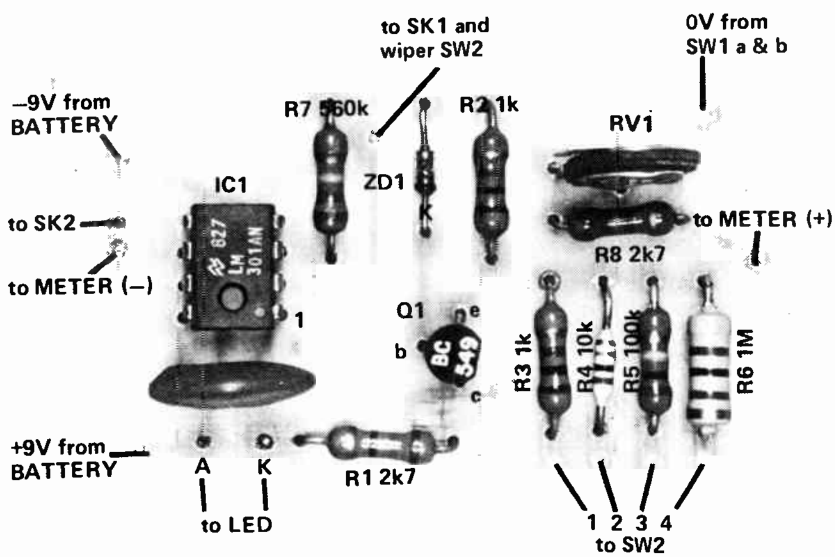
connection to your multimeter.

We used a 'Lorlin' range switch made by C&K. These switches start out life as a two-pole six-position switch and are easily changed to four position by moving round a small metal ring beneath the securing nut. Only one pole is used. In this way, C&K have come up with a single switch which can be changed to suit your own needs.

If your supplier stocks this switch he will show you how to adjust it. Any other single-pole four-position switch will do just as well.

Calibration

When construction is complete, switch the unit on and check that the LED lights up. If it doesn't, check the wiring and the polarity of the LED. When all is well connect an accurately known resistor (having a value within the range of the instrument) across the terminals and adjust the trimpot for the correct reading. The unit is then ready for use and should not require further calibration. You could purchase a 1k, 1% resistor specifically for this purpose. ●



HOW IT WORKS – ETI 151

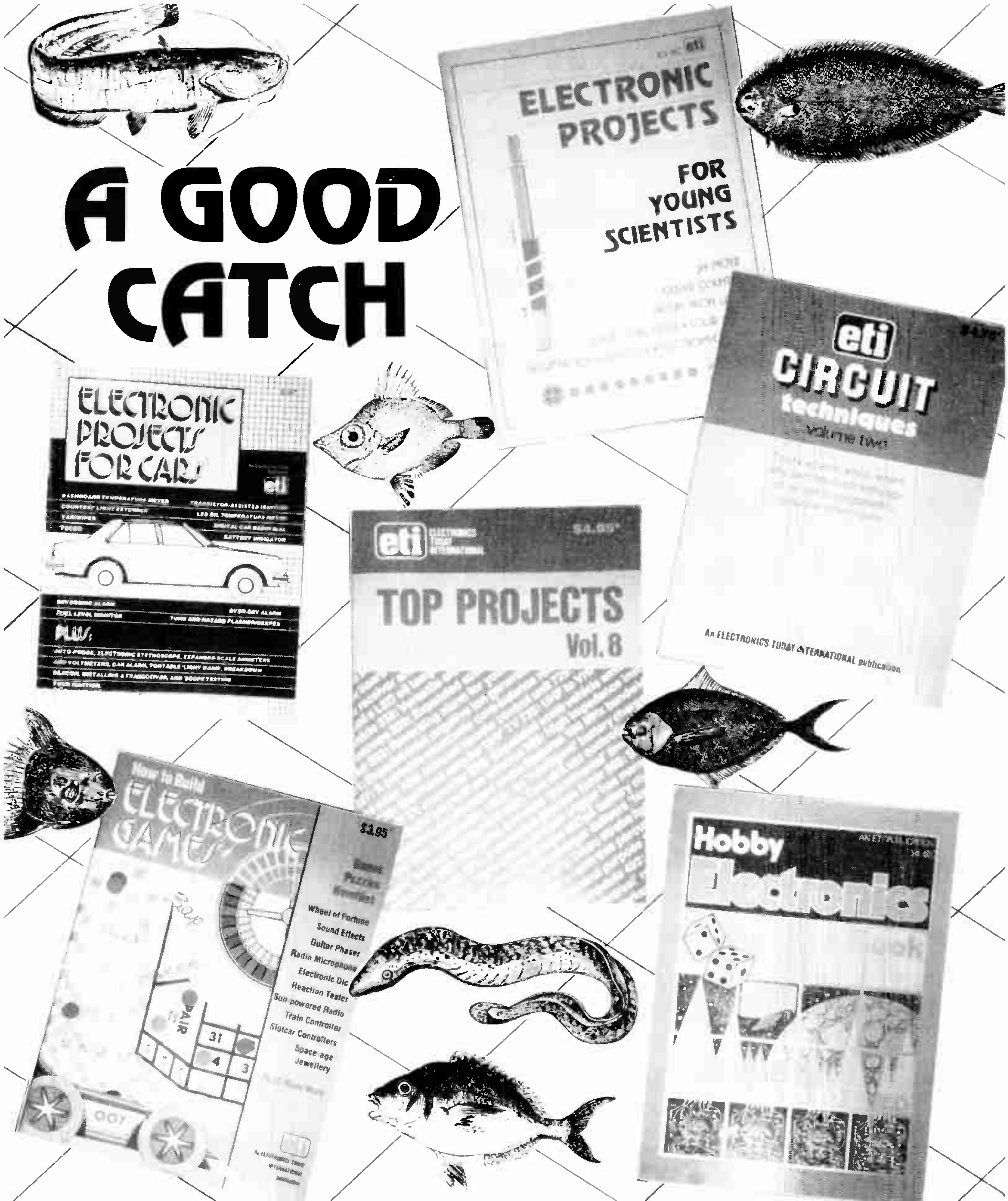
The linear scale ohmmeter circuit is divided into two parts: a reference voltage generator and a readout unit that indicates the value of the resistor under test. The reference voltage generator section of the circuit comprises zener diode ZD1, transistor Q1, and resistors R1 and R2. The action of these components is such that a stable reference of about 5V is developed across R2. This reference voltage is fed to the op-amp resistance-indicating circuit via range resistors R3 to R6.

The op-amp is wired as an inverting dc amplifier, with the 1 mA meter and R8-RV1 forming a voltmeter across its output, and with the op-amp gain determined by the relative values of ranging resistors R3 to R6 and by the negative feedback resistor Rx. RV1 is adjusted so that the meter reads full scale when Rx has the same value as the selected range resistor. Under this condition the op-amp circuit has a voltage gain of precisely unity. Since the values of the reference voltage and the ranging resistors are fixed, the reading of the meter is directly proportional to the value of Rx, and the circuit thus functions as a linear-scale ohmmeter and has a full scale value equal to the value of the selected range resistor.

PARTS LIST - ETI 151

Resistors (* See text)	all ½W
R1	2k7 5%
R2	1k 5%
R3	1k*
R4	10k*
R5	100k*
R6	1M*
R7	560k 5%
RV1	5k minimum vertical trim pot
Capacitors	
C1	100p ceramic
Semiconductors	
LED1	TIL220 red LED or similar
ZD1	5V1 400mW zener diode
Q1	BC109, BC549, or similar
IC1	301 op amp
Miscellaneous	
SW1	DPDT minimum toggle switch
SW2	one pole four position wafer switch
M1	1mA FSD meter 60 mm square, University TD66 or similar
SK1, SK2	screw terminals

ETI 151 pc board, two 9V batteries (type 216) and battery clips, plastic case 130 mm x 130 mm x 75 mm, knob.

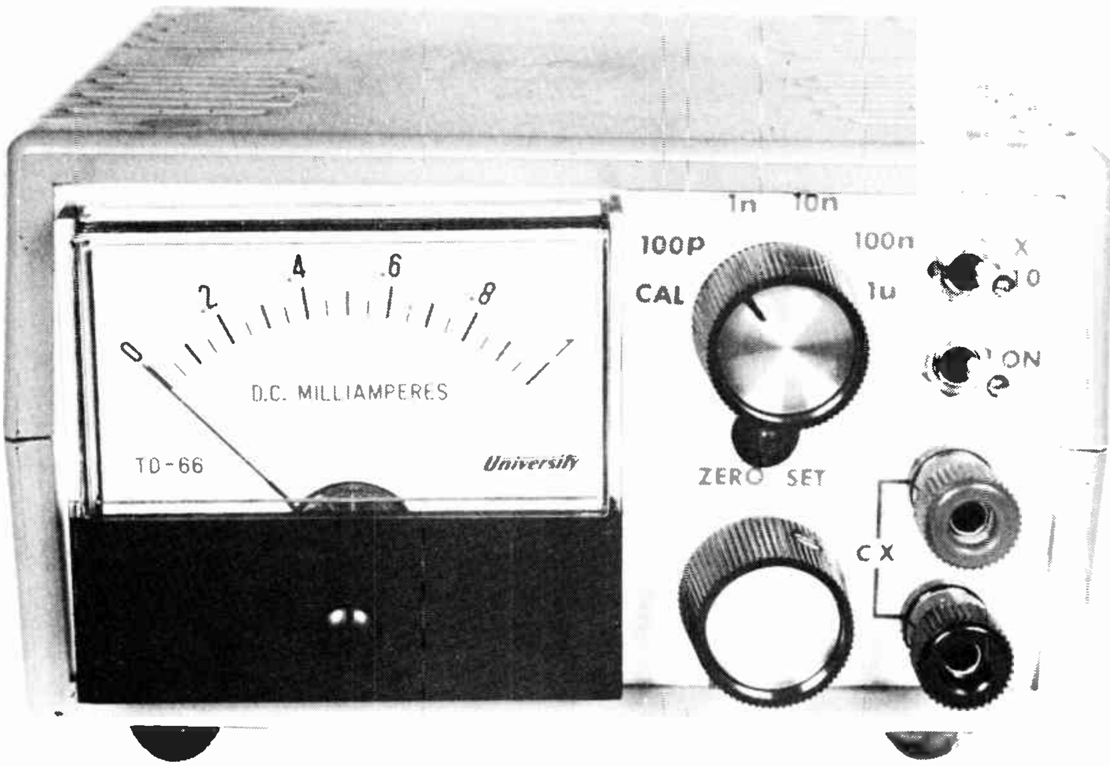


Available from newsagents, selected electronic suppliers or direct from ETI Magazine, P.O. Box 227, Waterloo NSW 2017. Please add $1.00 for post and handling if buying by mail order.

Capacitance meter features linear scale and low cost

This is the third instrument in our series of simple, inexpensive, look-alike test gear projects.

Roger Harrison



WE FIRST published a capacitance meter project over two years ago. The Linear Scale Capacitance Meter, Project 136, (ETI, March 1978) enjoyed a certain amount of popularity at the time it was published, but ran into a few snags. Unfortunately the edgewise mounting meter became difficult to procure as did, later, the case. Also, the meter required calibration by hand. Correspondence from a number of readers also suggested extending the range of the instrument to enable capacitors up to 10 uF to be measured.

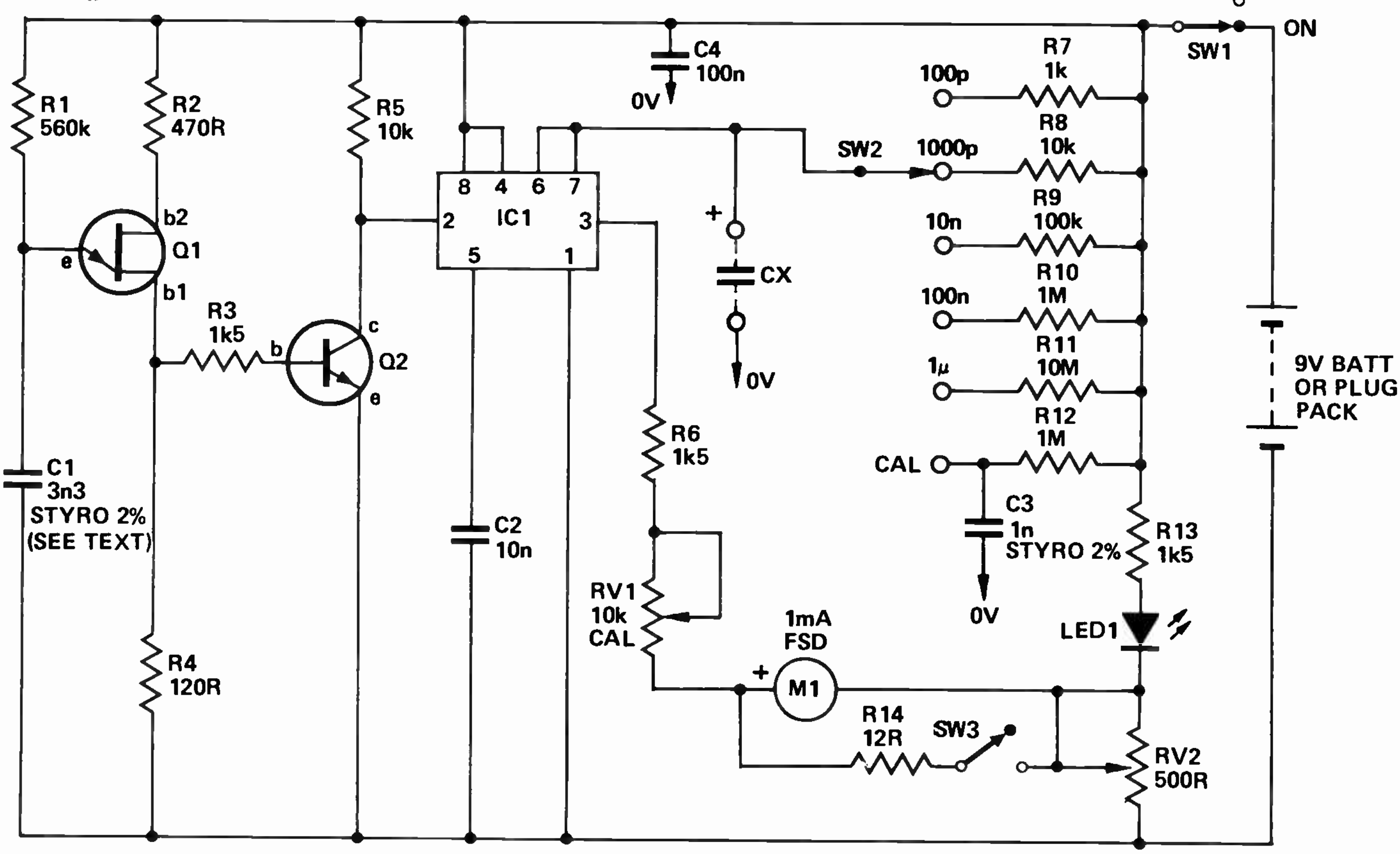
So, when we were considering our current range of simple, inexpensive test gear projects, the old linear scale capacitance meter was an obvious candidate for revamping to include in the series. Phil Wait took it in hand and here it is – the all-new, singing-dancing, lemon-fresh Linear Scale Capacitance Meter!

This unit has been constructed using the same type case, meter and range switch as the two previous projects in the series: the frequency meter, ETI-150, and linear scale ohmmeter, ETI-151. It can be powered from internal batteries or a small plugpack.

Since constructing the original project, the writer has been consistently amazed at how often it has been used. When considering the purchase or construction of test instruments, most people take resistance measurement for granted – but, in so many applications, capacitance measurement comes a good second. ▶

SPECIFICATIONS – ETI 152

Capacitance ranges (full scale)	100p, 1n, 10n, 100, 1u – to 10u on x10
Accuracy	5%, estimate to 2% on meter scale
Calibration	from internal capacitor, 2%
Supply voltage	9 Vdc from battery or plugpack



HOW IT WORKS – ETI 152

A unijunction transistor, Q1, is connected as a relaxation oscillator with a frequency determined by R1-C1. The frequency of oscillation in this instance is about 1 kHz.

Pulses of about 1 us duration are produced across R4 each time the UJT "fires". The resistance between b2 and b1 of the UJT reduces to a low value each time the emitter conducts. Much of the charge stored in C1 is "dumped" across R4 for the short duration that the e-b1 junction of Q1 conducts.

The narrow pulses across R4 drive the base of Q2 via R3, which serves as a base-current limiting resistor. The pulses cause Q2 to conduct for the same duration, that is, about 1 us, and negative-going pulses from the collector of Q2 drive the "TRIGGER" input of the 555 timer, IC1. This is connected to operate as a monostable in this circuit.

When IC1 receives a trigger pulse at pin 2, the flip-flop is set, releasing the short circuit across Cx and driving the output, pin 3, high. The voltage across the capacitor then increases exponentially for a period that depends on the value of the unknown capacitance Cx. The period is determined according to the formula:

$$t = 1.1\ RrCx$$

– where 'Rr' is the range resistor, and 'Cx' the capacitor being measured.

At the end of the period, the comparator inside the 555 resets the flip-flop which in turn discharges the unknown capacitor, Cx, and drives the output to its low state.

This cycle is repeated each time a negative-going trigger pulse appears at pin 2 of IC1.

Thus, as the range resistor value (Rr) is fixed, the ON/OFF ratio of the output voltage will be determined bv the value of Cx. The ON/OFF ratio is independent of the relaxation oscillator frequency and trigger pulse duration.

The current measured through the 'load' resistor on the output (R6) of IC1 will thus be directly proportional to the value of the unknown capacitor Cx.

The meter, M1, measures the current through R6, the meter inertia 'averaging' the current.

As the voltage at the output pin does not quite swing between the +ve supply rail and the 0V rail in its 'high' and 'low' states respectively, the dc offset is compensated for by returning the 'load' current through an offset voltage developed across RV2 via R13 from the supply rail.

Zero-setting is accomplished by making RV2 variable. A calibration control is provided by making a portion of the 'load' resistance variable – RV1 here.

The 'X10' switch simply reduces the sensitivity of the meter, allowing measurement of a high output pulse-on to pulse-off ratio.

Ranges

The unit will measure capacitance from 5 pF up to 1 uF in five ranges with a x10 facility to extend the top range to 10 uF. Full-scale values for each range are: 100 pF; 1 nF (1000 pF or 0.001 uF); 10 nF (0.01 uF); 100 nF (0.1 uF) and 1 uF – extended to 10 uF with the x10 switch.

The x10 switch actually works on all ranges and is handy when checking capacitors that over-range when a particular range is selected, so that the appropriate range can be readily found.

Different ranges can be provided by selecting different values for the range resistors R7 to R11. For example 47 pF to 0.47 uF (in five ranges), 4.7 uF with the x10 in, could be obtained by changing R7 to 470R, R8 to 4k7 etc. However, the meter scale would need to be recalibrated. As it stands, the scale reads capacitance directly.

The meter scale provides divisions of 5% and the actual capacitance value can be estimated to about 2% or so, once the unit is calibrated. Overall accuracy will depend on the meter and the calibration capacitor accuracy.

PARTS LIST - ETI 152

Resistors all ½W, 5% (except R7–R12)

R1	560k
R2	470R
R3	1k5
R4	120R
R5	10k
R6	1k5
R7	1k 2%
R8	10k 2%
R9	100k 2%
R10	1M 2%
R11	10M 2%
R12	1M 2%
R13	1k5
R14	12R

Potentiometers

RV1	10k min vert mounting trim pot
RV2	500R lin pot

Capacitors

C1	3n3 2% tolerance - see text
C2	10n greencap
C3	1n 2% tolerance - see text
C4	100n greencap

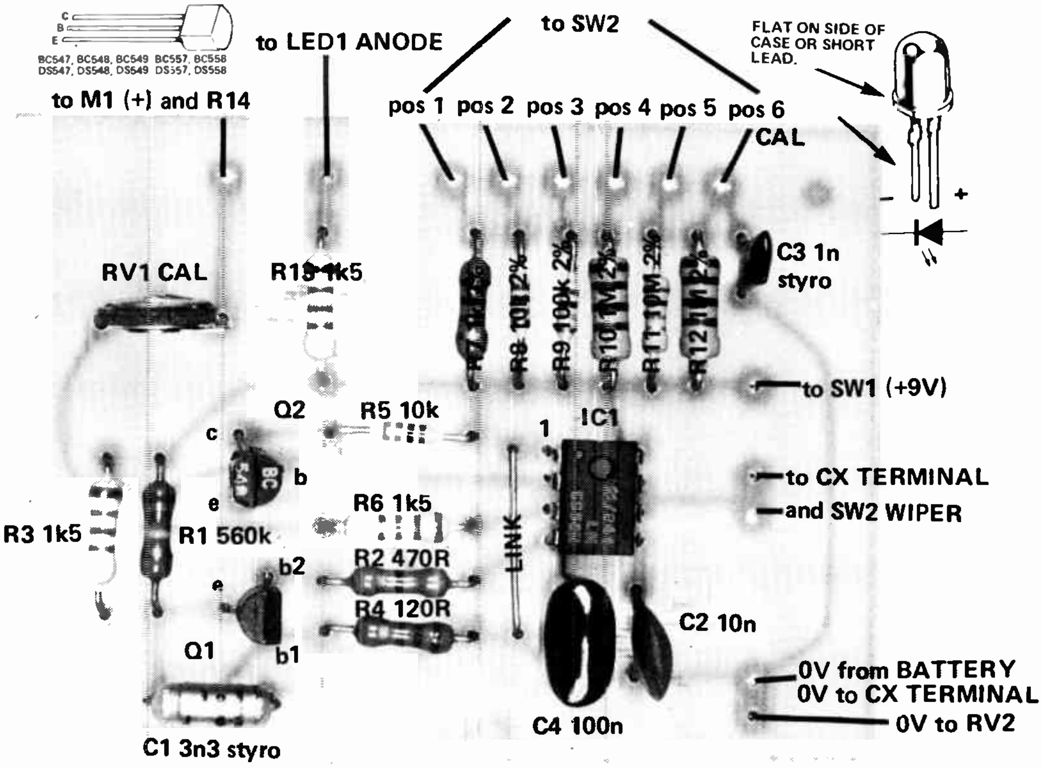
Semiconductors

LED1	TIL220R or similar LED
Q1	2N2646, 2N2647 unijunction
Q2	BC548, BC108
IC1	555 timer

Miscellaneous

M1	1mA FSD meter 60 mm square, University TD66 or similar
SW1	SPST miniature toggle switch
SW2	one pole six pos wafer switch
SW3	SPST miniature toggle switch
SK1, SK2	screw terminals

ETI 152 pc board, 9V battery (type 216) and battery clips, plastic case 130 mm x 130 mm x 75 mm, knobs.

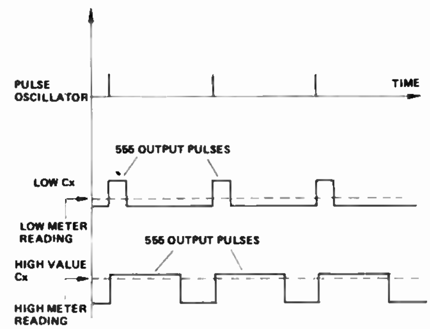


Design

A pulse oscillator, Q1, running at a pulse repetition frequency of about 1 kHz, triggers a 555 timer IC which is connected as a monostable multivibrator. The 555 in this configuration will produce a pulse at its output, pin 3, having a period determined by the values of the range resistor selected and the unknown capacitance. The lower the value of the unknown capacitance, the shorter the duration of the output pulse from the 555. Conversely, the higher the value of the unknown capacitance, the longer the duration of the output pulse.

The output pulse is passed through a moving-coil meter which will integrate the pulse waveform. The reading on the meter will thus be directly proportional to the ratio of the time the output pulse is on to the time it is off, resulting in a linear relationship of capacitance to meter reading. A low value of capacitance connected to the 'CX' terminals will produce a short duration pulse and thus a low meter reading; a high value of capacitance will produce a long duration pulse and a high meter reading, as illustrated on the accompanying diagram.

The output pulse of the 555 swings between values of about 2/3 of the supply voltage ('high') and 1/3 of the supply voltage ('low'). Thus, the meter needs to be returned to a voltage of about 1/3 of the supply, otherwise current would flow through it continuously. Conveniently, this voltage is set by a pot on the front panel which serves as a 'zero set' control. The meter is calibrated by varying the resistance in series with the meter, rather than having preset range resistors. This results in better accuracy and requires only one preset control. The CAL. position on the range switch is for occasional checking. Any significant variation in the calibration will generally indicate a low battery.



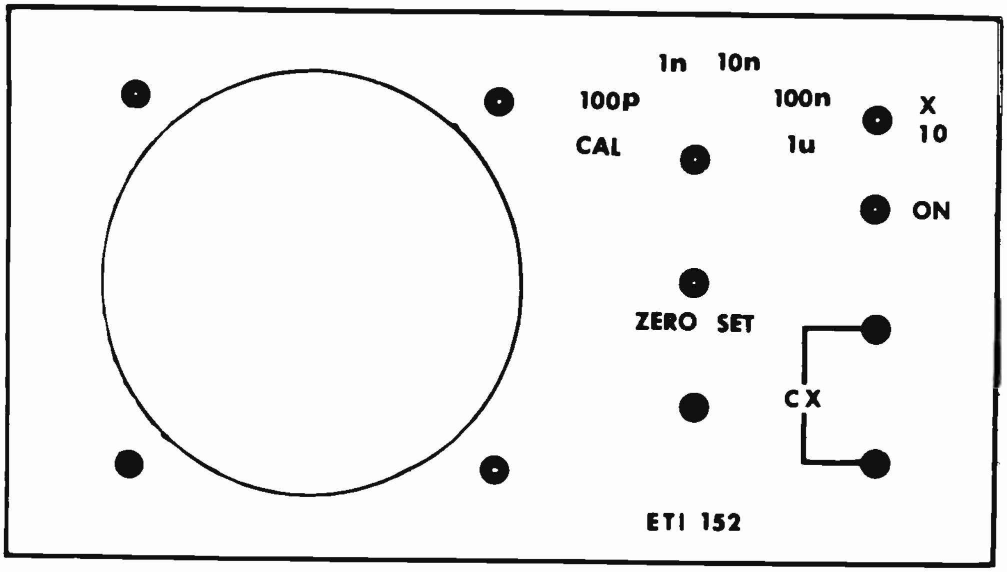
The unknown capacitance, Cx, determines the width of the output pulses from the 555 monostable. The meter integrates these pulses to produce a reading which is directly proportional to the unknown capacitor's value.

Construction

We mounted our meter in a matching case to our Linear Scale Ohm meter and Frequency Meter. The front panel layout is a little cramped but all switches and terminals are easy to use with plenty of finger room.

Start your construction with the pc board making sure that the integrated circuit is the right way around. Take care also with the transistor and UJT orientation. Capacitors C1 and C3 determine the overall accuracy of the instrument and should be close tolerance types. Some suppliers carry a range of close tolerance silver mica or styroseal capacitors. Alternatively, if you have a friend or employer with a capacitance bridge you can select one close to the required value (1n) from standard tolerance types. See Shop-around on page 114 for suppliers that stock suitable capacitors. The range resistors R7 to R12 should also be close tolerance (2%) types.

All other components, including



the x10 range resistor, are mounted on the front panel. Mount the smaller switches and terminals first, followed by the potentiometers and last of all the meter. The resistor R14 is wired from the positive meter terminal to one of the contacts on the range switch, SW3.

The printed circuit must be mounted so the lead length from the Cx terminals is as short as possible to avoid stray capacitance. Mount the pc board to the bottom of the case just behind the terminals and use tinned copper wire to make the connections making sure that the wires are well spaced from each other and well away from the rest of the circuit. Wire each connection from the board to the components on the front panel carefully to avoid errors.

When the construction is complete check all the wiring but don't assemble the lid to the box yet. Switch to the 1n range and turn the instrument on. Adjust the ZERO SET pot and see that the meter pointer varies about the zero scale marking. If it doesn't, check the pc board and panel wiring. If all is well, set the control so the meter pointer is on the scale zero mark. Then, switch to the CAL position and the meter pointer should move up the scale. Adjust the CAL trimpot on the pc board, RV1, so that the meter reads '1'. Switch to any range and you're ready to go!

You will find that stray capacitance affects the meter zero reading on the 100p scale. Simply adjust the ZERO SET control so that the meter reads zero before taking a measurement on this range. You'll find that once the instrument is zeroed on the 1n range, the higher ranges will not require further adjustment of the zero set.

In use, occasionally check the calibration. If grossly in error, your battery is about to go flat. A No.216 battery should give quite a long life as the unit draws less than 20 mA. For longer life a No.2362 battery is recommended. If you operate the unit from a plug-pack, one rated at 6 Vdc output should deliver more than 8V at this low load, which is perfectly adequate.

Remember that any devices used to grip the leads of capacitors being measured will add stray capacitance and you will need to compensate for this by readjusting the zero set control. However, this will only have to be done on the 100p and 1n ranges as the added capacitance will be negligible on the higher ranges.

The 'x10' switch is primarily intended to extend the 1u range to 10u, although it is useful on the other ranges – when a capacitor being measured over-ranges you can assess whether it is just above the range selected or many ranges up in value.

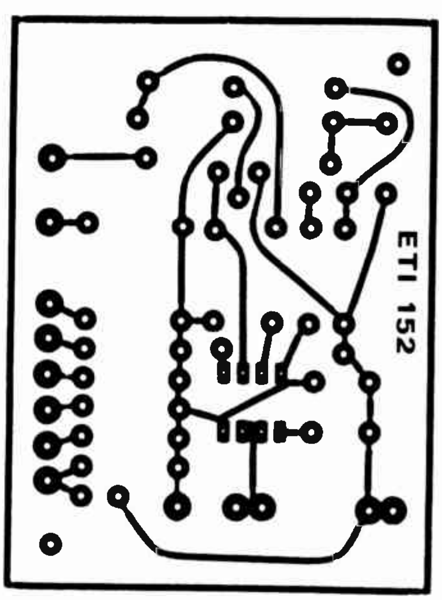
Well, there you go! I hope you find this instrument as useful as I have. ●

This project appeared in the February 1980 issue of ETI as part of a short series of look-alike test instruments. Several readers pointed out that the unit did not work properly in the 1μ/x10 mode (i.e: 10μ full scale) as the integration time was not long enough. This problem is cured by a simple modification.

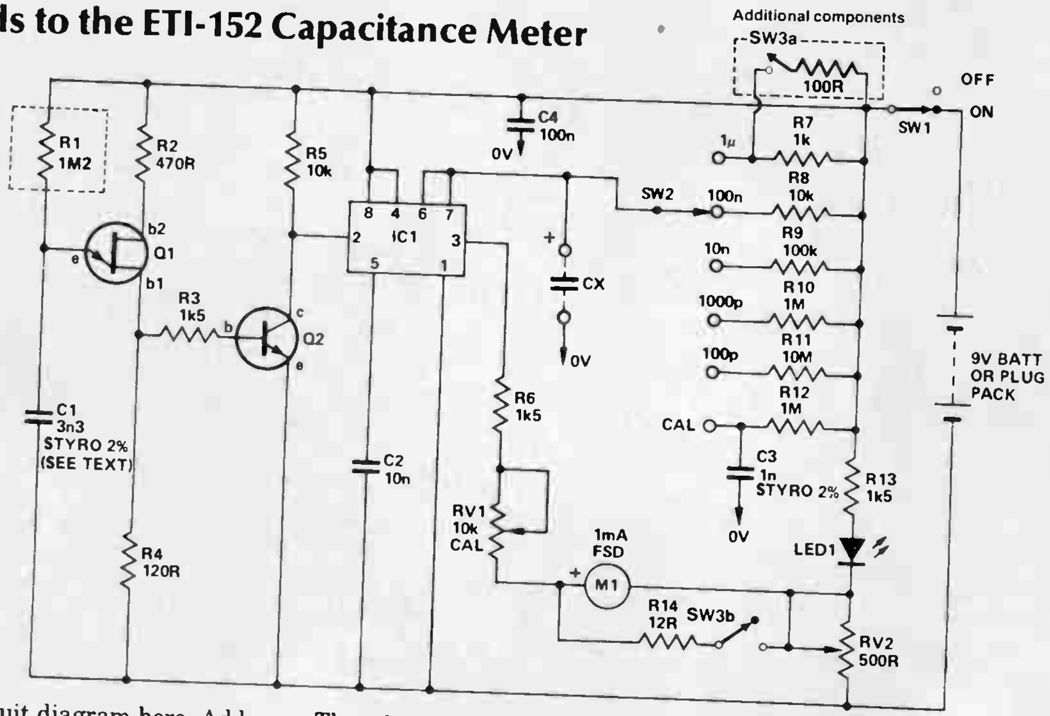
Firstly, SW3 should be changed to a double-pole, single-throw (DPST) type. Secondly, change R1 to 1M2, as shown

Above is a full-size reproduction of the front panel artwork. You may cut it from the book if you wish and use it directly.

Same-size reproduction of the pc board artwork. See Shoparound on page 114 for details on pc board suppliers.



Mods to the ETI-152 Capacitance Meter



in the new circuit diagram here. Add a 100 ohm resistor, switched across R7 by the other pole of SW3, as shown in the circuit diagram.

That should correct the problem.

Apart from that, some constructors found that RV2 (zero set control) was very close to one end of its range and difficult to adjust. This is probably brought about by LED1 having a fairly high voltage drop. To cure the problem, reduce R13 to 820 or 680 ohms.

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Project 325

'Auto-probe' for testing vehicle electrical systems

When it comes to probing faults or otherwise in a vehicle's electrical system, a multimeter has distinct disadvantages. This highly convenient probe is very useful in those awkward places so often encountered, plus simple to build and inexpensive.

Jonathan Scott

THE DIFFICULTIES of tracing a fault in a vehicle's electrical system using a multimeter are probably familiar to most readers. As that accursed Murphy's law generally has it, you have to contort yourself in to an awkward position before you can see where to put the test prod, or prods, and having done that, find that you can't twist yourself sufficiently to see the multimeter face.

Damned annoying, isn't it!

Then again, a multimeter can give you a false indication. No, not possible, you cry. It sure is though. If, for some reason, you're measuring the voltage on a particular point and it happens to be connected to the battery via a low, but significant, resistance how do you detect the presence of that low resistance?

A voltmeter measurement won't show it. If that low resistance is the fault, an ohmmeter measurement may well be impossible.

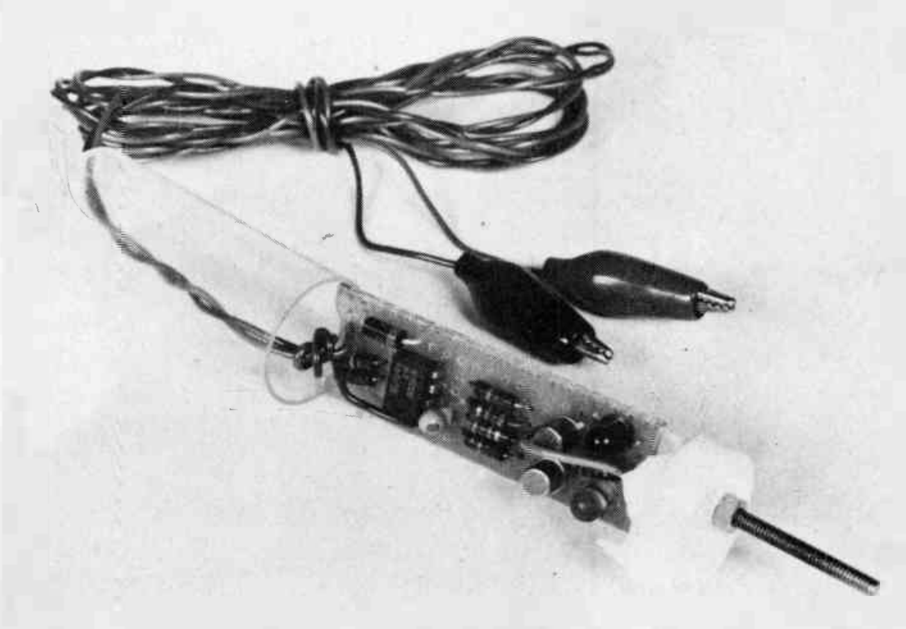
Sorting out the wiring can be a nightmare – especially on motorcycles.

This project gives clear indication of the six conditions one usually finds in an automotive electrical system. These are:

- Short to +ve supply
- Short to -ve supply
- Open circuit
- Connection to +ve supply via an intermediate impedance
- Grounded via an intermediate impedance
- Connection to a fixed, intermediate (low) voltage level

The Auto-probe is smaller, cheaper, easier to interpret and easier to use and read than a multimeter. It is the sort of device that can be left in the tool kit in the boot of your car or stored in the glove box. It is a worthwhile addition to any mechanically-minded handyman's array of gadgets.

The Auto-probe can be used on 6 V or 12 V systems, with minor changes to the circuit values.



The Auto-probe is housed in a common pill bottle. You can construct it either on matrix board, as shown here, or on a printed circuit board(see over the page). It's an amazingly handy gadget !

To get an idea of how it can be used, and how useful it is, let's take a look at a few typical problems encountered in vehicle electrical systems.

The problem

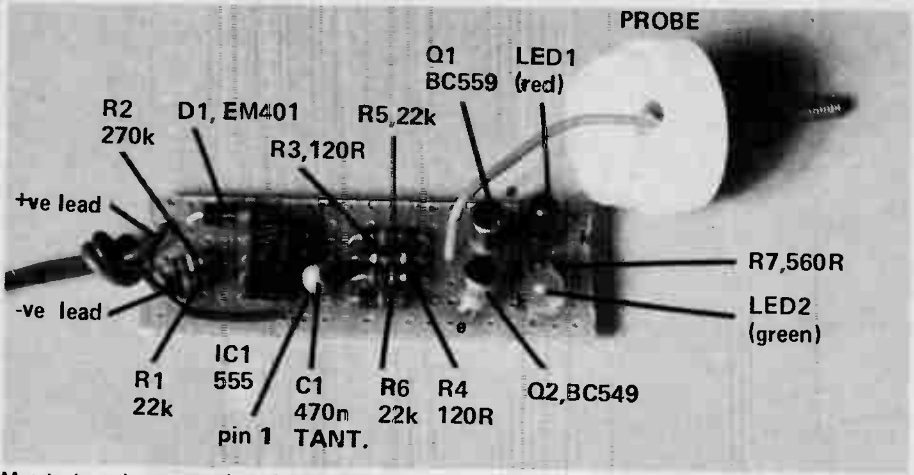
Let us consider the case of a car radio that has 'stopped working'.

Looking at the panel lights, you observe that they aren't lit up when the set's turned on. Obviously, it would seem to be a supply problem. Wriggling, upside down, under the dashboard, you check the fuse and find it intact. Taking the Auto-probe, you attach its supply leads to the rear connection of the cigarette lighter or the ignition switch. Both lights should blink on and off. If they don't then you'd have to reverse the connections and mentally castigate yourself for being a twit. No worries though, it's protected against twits.

Touching the probe on the radio's B+ connection, the red LED glows steadily. Aha! This shows the probe tip is connected to the supply. Touching the probe onto the radio's ground lead results in a blinking red LED. Hmm, it's connected to supply via an impedance. It seems the ground connection isn't grounded.

Some jiggling and scraping at the radio's ground lead earthing point results in a steady green LED and a burst of music . . . well, more likely, commercials.

Suppose you wish to know if your car has an ignition ballast resistor. This is a resistance inserted in series with the ignition coil primary during normal running, but is shorted out when the starter is operated so that the coil receives a voltage 'boost'. The resistor may be a heavy wirewound type mounted somewhere in the engine compartment, or (as is common in



Matrix board construction showing the component positioning and orientation. Note that we used the metal-can type transistors (BC109 etc) in this prototype. R3 and R4 are ½W GLP types.

PARTS LIST — ETI 325

Resistors .... all ¼W, 5% unless noted

R1, R5, R6	22k
R2	270k
R3, R4	120R, ½W, 5% (GLP type) see text
R7	560R

Capacitors

C1	0.47u Tantalum (35V)

Semiconductors

IC1	555
Q1	BC559, or similar
Q2	BC549, or similar
D1	EM401, or similar
LED1	TIL220R or similar, red
LED2	TIL222 or similar, green

Miscellaneous
Matrix board — 15 mm × 55 mm, or ETI-325 pc board; alligator clips; pill container; wire; 30 mm long 4 BA bolt and nut (for probe).

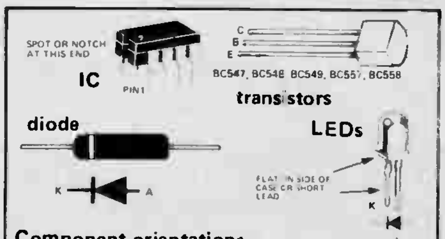
many late-model vehicles) a resistance lead is used — they're hard to spot.

In this case, the probe tip is touched on the coil primary terminal that is not connected to the contact breaker points. With the ignition on, (engine not running) no light will show on the probe, indicating it is connected via an intermediate impedance. When you touch the starter, the red LED should burst into lusty life, indicating the resistor is shorted, as you would expect.

Tracing wiring and switch operation can be a real hassle. Does this motorbike operate its horn by supplying power or a ground connection via the horn switch? If touching the two switch contacts in turn shows first a steady green LED then a blinking red LED, the first contact is grounded and the second is clearly connected to the positive supply via an intermediate impedance, i.e: the horn. If the green LED lights and then both LEDs blink when the probe is touched to the other switch contact, this would indicate that the horn is open circuit.

The circuit will cause both LEDs to blink when the probe tip is connected to an open circuit or to either side of the supply via an impedance greater than about 1000 ohms. In an automotive environment 1000 ohms is a high impedance!

Simple, and easy to use, isn't it?



Component orientations

Construction

This project may be constructed in either of two ways, depending on your preference: on matrix board, or on a pc board. Both methods are discussed here and overlay photographs are shown also.

If you elect to use matrix board, you will need a piece having holes spaced 0.1" (2.5 mm) apart. Cut the matrix board so that it measures 15 mm wide by 55 mm long — that's about seven holes wide by about 23 holes long (cutting through the 1st and 23rd rows).

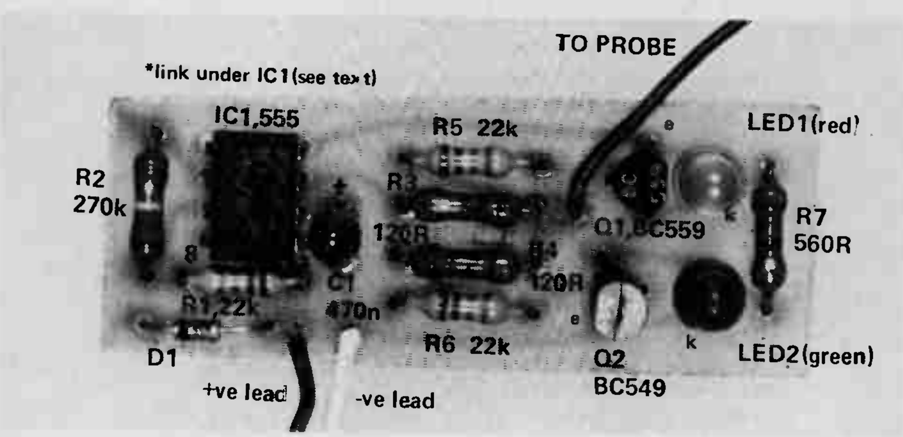
It is probably easiest to commence by mounting the two LEDs and the two transistors. You have to take some care when assembling a project on matrix board as the connections between the components are made under the board, using the component leads. Carefully study the overlay picture to see where the components are located and their orientation.

Make the connections between the components using the circuit diagram to guide you. Take care that no short circuits occur between adjacent leads.

Next assemble resistors R3 to R6, IC1 and C1 onto the board and make the appropriate connections. Take care with the orientation of C1. The positive lead is towards the *centre* of the board. Last of all, add R1, R2 and D1.

We'll get around to testing and assembling the unit into the pill bottle shortly, as this will apply to both sorts of construction.

Constructing the project on a pc board is much simpler. First thing to do is locate the position of IC1. A link is inserted between two pads located between the two rows of holes for the IC pins. Having done that, insert the IC. Take care that you have it correctly oriented. All the other components may now be assembled



Overlay for the printed circuit board model. Plastic pack transistors were used for this one.

READERS PLEASE NOTE
We do not sell kits or components for the projects described in this book. To find out who may be stocking kits or components for the projects featured, please refer to the 'Shoparound' page on page 114.

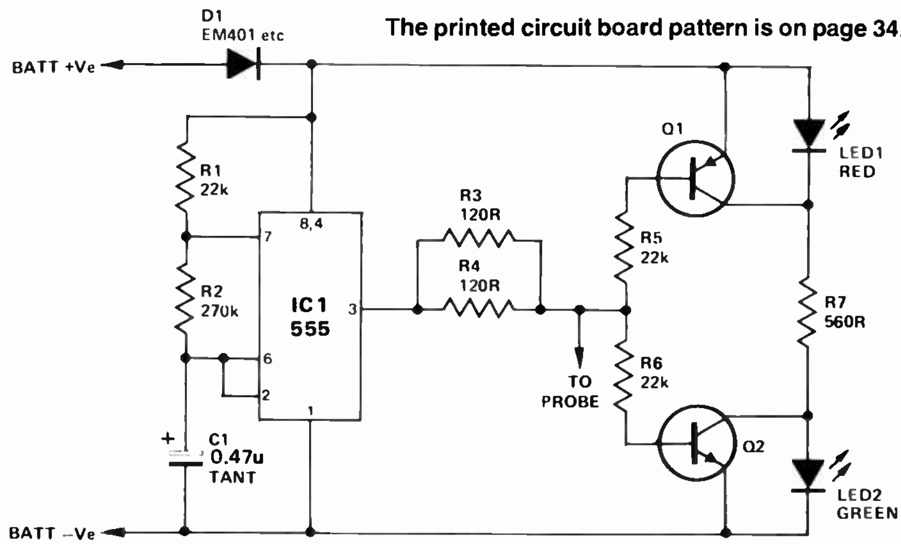
and soldered into the board. Watch the orientation of Q1 and Q2, the two LEDs and C1. Refer to the overlay picture.

Now comes the testing. This procedure applies to either form of construction. You will need either a 12 V battery or a power supply that can deliver around 12 V to 14 V dc. Temporarily solder battery leads and a probe lead to the board. Connect the battery leads to the 12 V supply. The two LEDs should flash. Shorting the probe lead to the negative of the supply should cause the green LED to flash.

If you cannot obtain the correct indications at this stage, look for incorrect connections or components around the wrong way. To check that IC1 is working, connect a multimeter — set to, say, the 30 V range — between the supply negative and pin 3 of IC1 (positive meter lead to the latter). The meter needle should rise and fall at about four times per second.

The pill bottle used to house this project measured 61 mm overall length (with the cap on) by 21 mm outside diameter. A 25 mm long 6 B.A. bolt was used for the probe. This was bolted through a hole made in the cap somewhat off-centre. The photographs show roughly where this needs to be. Just keep it out of the way of the board. A small solder lug under the bolt head is used to attach the probe lead from

The printed circuit board pattern is on page 34.



the board. The battery leads should be colour-coded to avoid confusion. The convention is: red for positive, black for negative. Twist together about one metre of each colour hookup wire.

Connect the appropriate leads to the board and tie a knot close to the board (see photograph).

Drill a hole in the end of the pill bottle, near the edge, and pass the battery leads through it. The knot prevents the leads being pulled out of the board. Attach alligator clips to the ends of the battery leads.

Two small cutouts will have to be made in the lip of the pill bottle's cap so that the LEDs may be seen easily. All these details are clearly shown in the photograph of the completed project.

Once you have the unit assembled, give it a thorough work out.

Once you have this little project working for you, you'll be amazed how quickly electrical problems in your vehicle are sorted out. ▶

MODIFICATIONS FOR 6 V OPERATION

Change R3 and R4 to 68 ohms each
Change R7 to 180 ohms
Change R5 and R6 to 10k

HOW IT WORKS – ETI 325

Consider first the 'idle' state of the device — i.e: with the probe open circuit. Diode D1 protects the whole circuit against accidental reversal of supply polarity. When the battery is connected correctly, the battery voltage (less about 0.7 volts dropped across D1) is applied to the electronics.

IC1 is the familiar 555 timer IC, connected as an astable multivibrator. When C1 charges up to 2/3 of the supply voltage, via R1 & R2, the 'high' level comparator (pin 6) detects this and sends the output high, which also shorts pin 7 to near ground. C1 thus commences to discharge via R2. When it reaches 1/3 of the supply voltage, the 'low' level comparator trips (pin 2) and C1 is allowed to recommence charging as before, since the output is sent low. This cycle repeats indefinitely, with a frequency of

$$F = 1/(0.692 \times C1 \times (R1 + 2R2))$$

With the values chosen, this is about 4 Hz. This may be varied by changing C1 or R2. The output on pin 3 of IC1 oscillates between nearly OV and V+ (less 0.7 volts). It can source about 200 ma.

Consider now the circuitry surrounding the LEDs. Assume at first that the voltage on the junction of R5 and R6 is about half the supply potential. Current will flow through the bases of both transistors via R5 and R6, hence both of these transistors will conduct. Each transistor will short out the LED connected in parallel. Thus neither LED will glow. If the voltage on the resistor junction (the probe connection) were to fall below 0.6 volts, or thereabouts, Q2 would be biased off and would no longer bypass the current flowing through R7 away from the green LED. Thus the green LED would light. Similarly, if the voltage on the probe were to rise to within 0.6 volts of the unit's supply rail (i.e: within 1.3 volts of the battery supply, due to the action of D1) Q1 would be biased off and the red LED would light.

Now let us put the picture together and see what happens in practice. The output of IC1 is connected to the probe and the resistor junction of the LED driver circuit via a 60 ohm resistance made up of two 120 ohm resistors in parallel. There are two resistors rather than one 1W or larger resistor for reasons of physical size.

With no connection made to the probe, the 555 drives the probe alternately to the +ve and -ve rails, with the result that the LEDs flash alternately.

Shorting the probe to either rail of course forces the appropriate LED to stay on continuously. If a resistance is placed between the probe and ground, say, three possibilities occur:

1) The resistance is so small that current from the 555 causes a drop of less than 0.6 volts across the resistance — this looks like a short and the green LED stays on.

2) The current develops sufficient voltage to turn Q2 on and the LED extinguishes on that part of IC1's cycle when its output is high. This allows the appropriate LED (green) to blink.

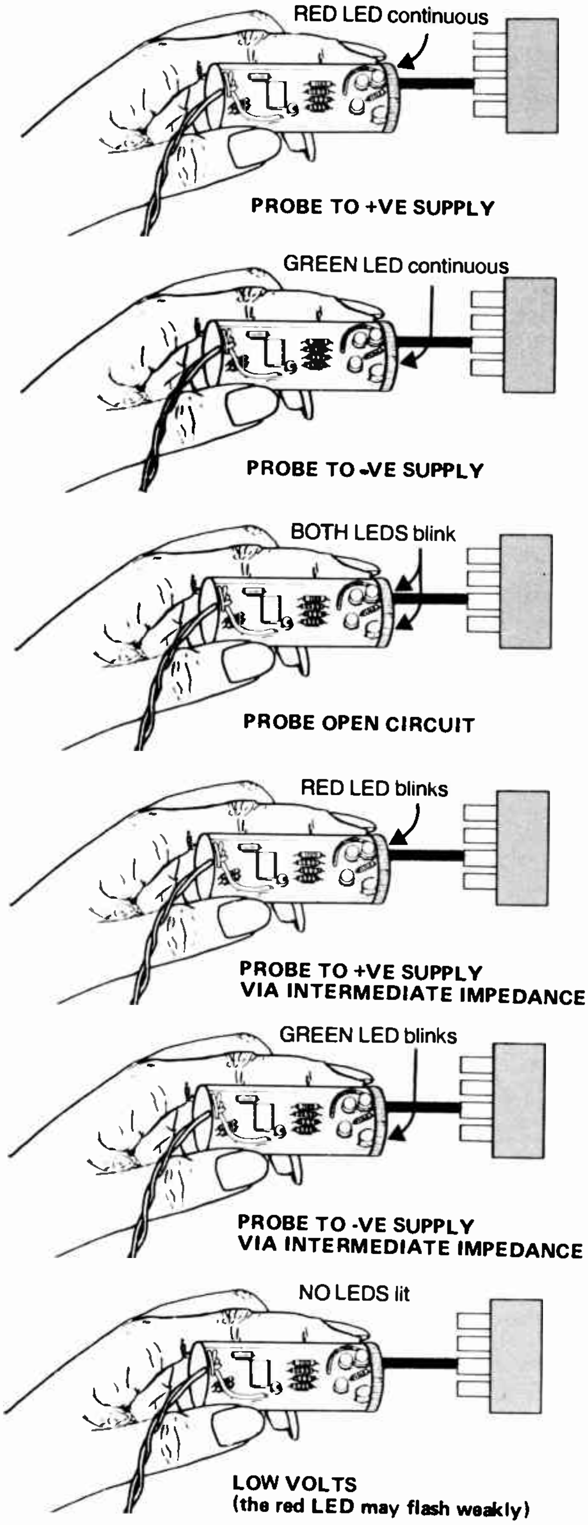
However, if the resistance is not high enough to allow the junction of R5/R6 to go far enough positive the red LED will not turn on. This gives green only blinking.

3) If the resistance is high enough (over 1k) both LEDs blink, giving the open-circuit response.

The same argument applies 'upside down' for a resistance to rail, but the voltage across it must be 1.3 V due to D1 being in the emitter circuit of Q1. If the voltage is fixed midway, neither LED can glow, as first assumed.

Resistor R7 fixes the LED current and R3/R4 limits the 555 output current to a safe level and defines the voltage 'turn-over' points.

ETI-325 AUTO-PROBE INDICATIONS



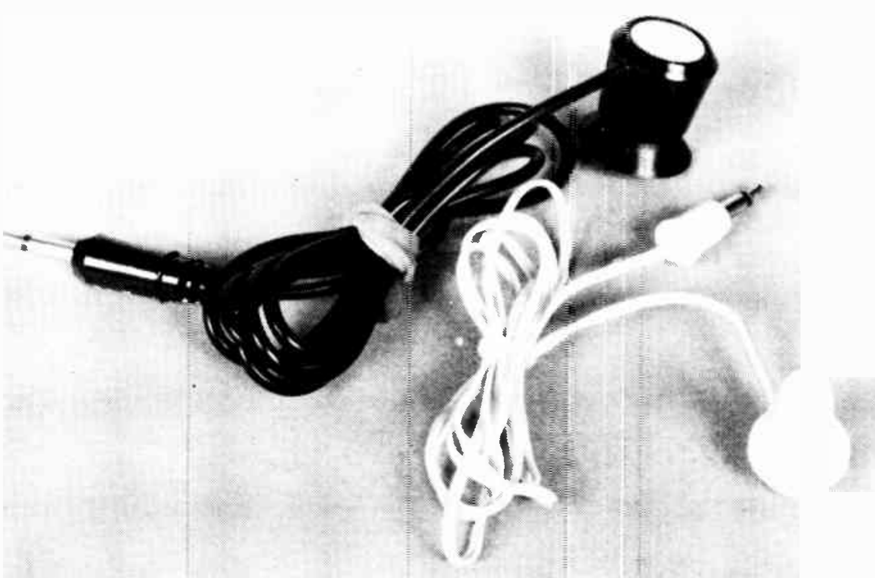
IMPEDANCE LEVEL CONDITIONS

Both LEDs blink	probe sees impedance larger than 1000 ohms
Red LED steady	probe to +ve via impedance less than 15 ohms
Green LED steady	probe to -ve via impedance less than 6 ohms
Red LED blinks	probe to +ve via imp. between 15 & 400 ohms
Green LED blinks	probe to -ve via imp. between 6 & 800 ohms

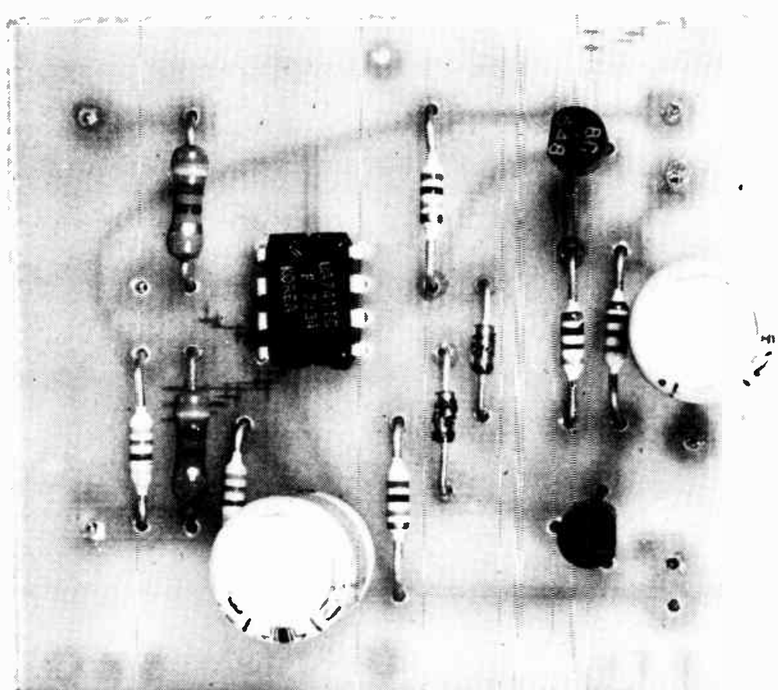
Mains cable seeker

Phil Wait

Finding mains cables hidden in wall cavities would require the X-ray vision of Superman or the divining skills of a 'dowser' . . . unless you had this project.



The sensor used for this project is a "telephone pickup coil" – the black object at the top. The inexpensive magnetic earpiece, below the pickup coil, indicates when you have located a cable.



Construction is very simple – just about foolproof if you use a printed circuit board; see over.

WHETHER YOU'RE engaged on extensive house renovations, or just want to bang in a picture hook, it's not only handy but a decided safety advantage to know where your mains wiring is located in the wall cavity.

After all, you don't want to drill straight into a mains cable and discover it by the shower of sparks . . . do you! It may well be the last thing you ever discover . . .

This simple device picks up the alternating magnetic field radiated by any cable connected to the 50 Hz mains. A simple, inexpensive "telephone pickup coil" is used as the sensor, the 50 Hz signal induced in this is amplified and applied to a small earpiece.

Commencing at any outlet or wall switch, you can trace where the cable runs by passing the pickup coil back and forth over the position where the 50 Hz hum is loudest, moving along the line of the loudest sound. The run of the cable may be marked with tape or whatever suitable method springs to mind.

Design

The design of the Mains Cable Seeker is extraordinarily simple. The pickup coil is a commercially-available unit that consists of a coil of many turns of fine wire wound on a small bobbin which is slipped over a soft-iron 'core'. This is encapsulated in a plastic container having a suction cap on one end. The suction cap enables the unit to be attached to a telephone. However, this feature is not used with this unit.

If the pickup coil is brought near any alternating magnetic field a current will be induced in the windings of the pickup coil and a small signal voltage will appear across the ends of the coil.

The pickup coil is connected to the input of a sensitive audio amplifier which raises the level of the signal such that it will drive an earpiece. ▶

Dowser — user of a "dowsing rod" or "divining rod"; a person who uses a rod, wire etc holding it in a particular way that gives an indication when the user approaches water, metal etc.

The amplifier design used in this project utilises an operational amplifier as a voltage amplifying stage, the output of which drives two transistors operated as a low power output stage. Feedback is applied directly from the output to the input. The resistance in the feedback path determines the gain, and thus the sensitivity, of the whole amplifier. A potentiometer is placed in the feedback path to allow you to vary the gain, depending on the strength of the 50 Hz field picked up from the cable you are tracing.

Construction

For simplicity, and to avoid wiring errors, we strongly recommend you construct this project using the printed circuit board design given here. You can make your own pc board, or buy one ready made. They should be widely available from a number of suppliers.

Commence construction by soldering the resistors and diodes in place. Take care with the orientation of the diodes. Refer to the overlay picture to make sure which way around they go. Next solder the two transistors in place – make sure you get them in their respective positions. Watch the lead orientation. Follow this with the IC making sure you get it the right way round also.

As the two electrolytic capacitors are a little cumbersome in comparison to the other components, they are soldered in last. These too, are polarised components, so watch which way you insert their leads. Refer to the overlay picture.

Once you have the pc board assembled and checked, you can connect the external components and give the project a trial run.

Run wires from the pc board to the input and output jack sockets, to SW1 and RV1 as indicated on the external wiring diagram shown with the pc board overlay picture. The battery connector has one red lead (the positive

HOW IT WORKS – ETI 560

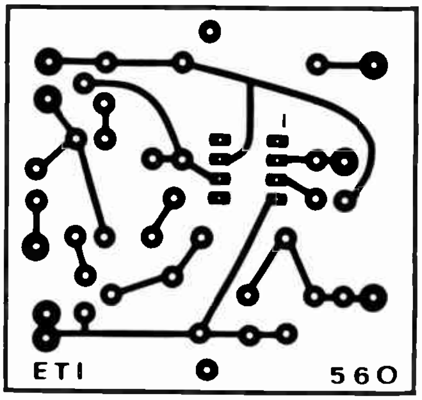
This Mains Cable Seeker works by detecting the weak alternating magnetic field of any current-carrying mains wiring. This signal is amplified to drive an earpiece. A pickup coil consisting of many turns of wire on an iron core is used to locate the field surrounding the mains cable.

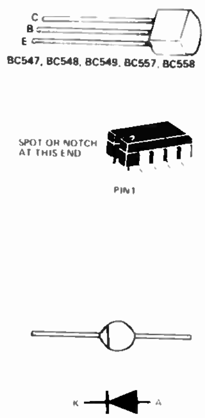
The weak signal induced into the pickup coil is first amplified by IC1, a type 741 operational amplifier (op-amp). This IC normally requires to be operated from a dual supply but, in this application, is biased to operate from a single 9 Vdc supply. The non-inverting input of the 741 (pin 3, marked +) is biased to half the supply via a potential divider consisting of R2 and R4. The junction of these two resistors is decoupled for ac by a 100u electrolytic capacitor, C1. The signal from the pickup coil is applied between the half-supply point and the inverting input of the op-amp (pin 2, marked –).

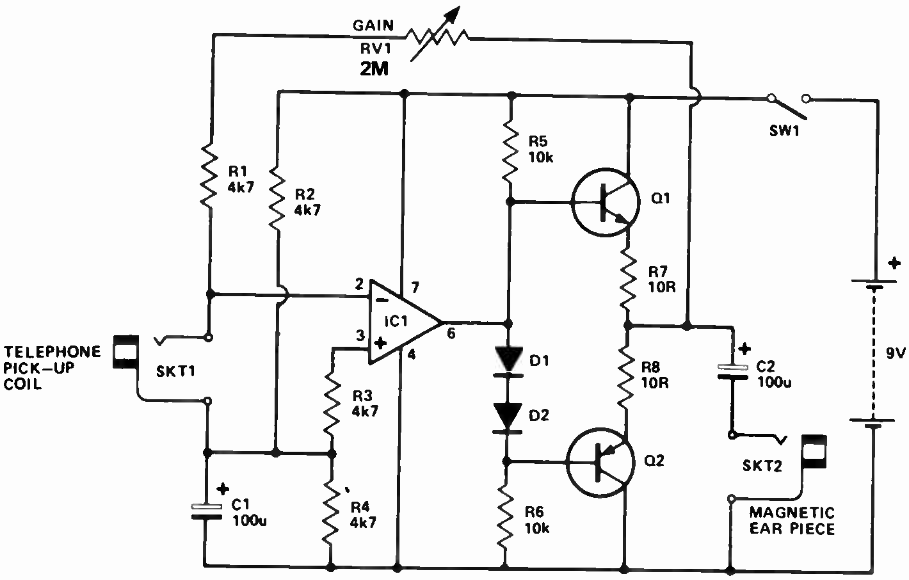
The op-amp, IC1, is arranged here as a variable gain inverting amplifier; that is, the output is out of phase with the input. The output of the 741 (pin 6) drives two output transistors, Q1 and Q2. These are connected as a complementary emitter follower current amplifier, driving the earpiece. Diodes D1 and D2 ensure that the bases of Q1 and Q2 are correctly biased, bias current being provided by R5 and R6. Resistors R7 and R8 are output current limiting resistors, the output being taken from their junction to the earpiece via a dc isolating capacitor, C2.

Feedback is taken directly from the output to the inverting input of IC1, via the gain control, RV1 and R1. The value of R1 sets the minimum gain (about unity).

Varying the feedback ratio, by varying R1, varies the gain of the whole amplifier.







connection) and one black lead (the negative connection). The *red* lead is soldered to the other pole of SW1 and the black lead is soldered to the '0V' connection indicated (on the pc board).

You are now ready to test the project. Plug in the pickup coil and the earpiece. Turn the unit on, you should hear a click in the earpiece. With an appliance plugged into an outlet and turned on, bring the pickup lead near the appliance's cord and advance the gain control. You should clearly hear the 50 Hz hum in the earpiece when you pass the pickup coil near the cord. Try tracing the hidden wiring a short distance.

If all is well, you can now think about mounting the completed project in a suitable box. One of the commonly-available plastic "zippy" boxes would be ideal. One of these measuring 130 x 70 x 40 mm will accommodate the pc board, the other components and the battery with ease. However, any similar box would suit, just make sure everything will fit.

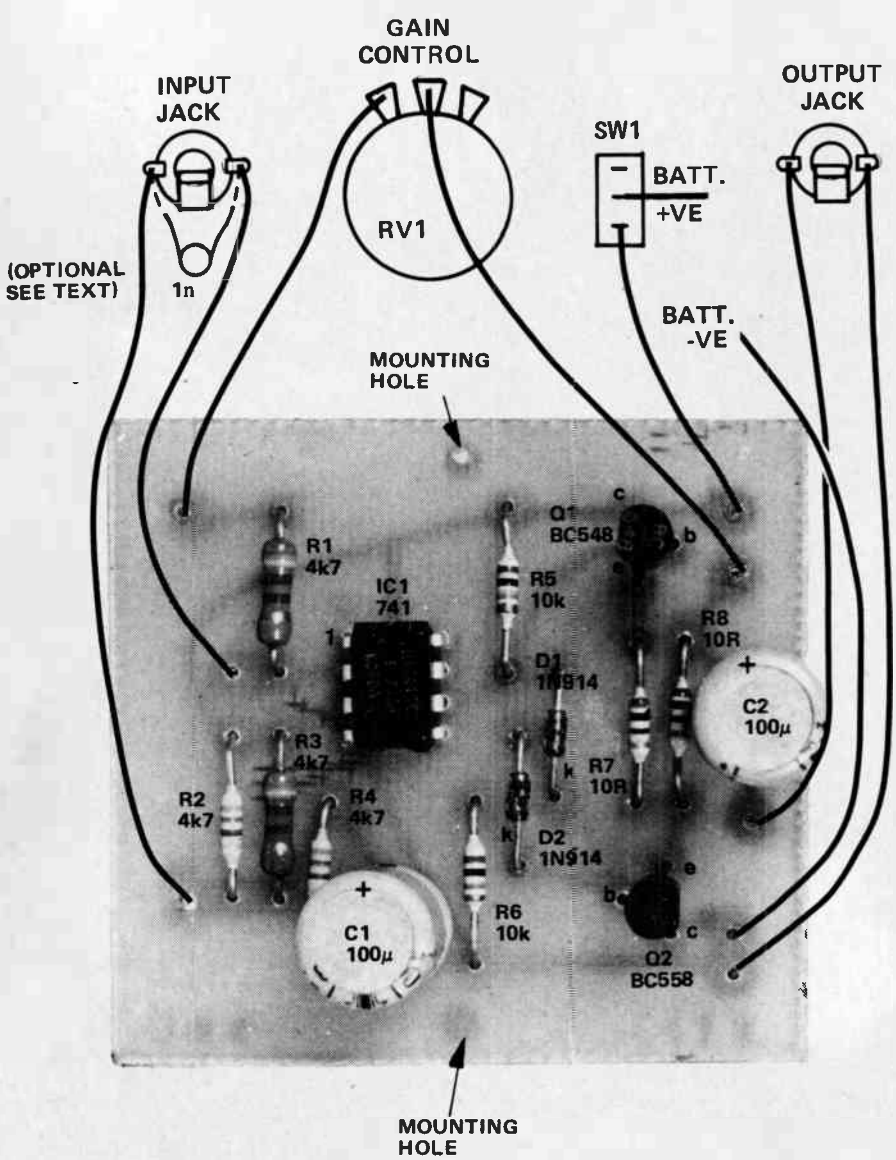
Suggestions

If you experience trouble with broadcast station pickup – where the pickup coil and input lead (and perhaps your body) act as an antenna – solder a 1n (1000 pF) ceramic or greencap capacitor across the input jack connections, as shown in the wiring diagram with the overlay picture.

You can wind your own pickup coil if you wish. We wound one on an 8 mm diameter by 30 mm long steel bolt. You must use a steel bolt. Being a ferro-magnetic material it concentrates the lines of force of a magnetic field in which it is placed, hence you will get greater induction in the pickup coil with a steel bolt than with any other type.

We first wound a layer of sticky tape over the thread of the bolt. A coil of about 300-400 turns of a light gauge enamelled copper wire was then jumble wound on this, then covered with a layer of sticky tape to hold it in place. The wire gauge is quite non-critical. Too heavy a gauge is difficult to handle and you won't fit the required number of turns on a bolt the size we used. Any gauge from, say, 26 to 32 gauge is OK – it doesn't matter if it's SWG or B&S. Any gauge lighter than 32 g tends to break very easily.

The coil/bolt assembly may be encapsulated for protection, or fitted into a small pill bottle or something similar. A length of shielded cable or a twisted-pair wire cable should be used to connect the pickup coil to the input jack. ●



Component overlay and external connection diagram for the project. Follow this carefully.

PARTS LIST — ETI 560

Resistors	all ½W, 5%
R1, 2, 3, 4	4k7
R5, 6	10k
R7 & 8	10R
Capacitors	
C1, 2	100u 16 V electrolytics
Semiconductors	
Q1	BC548, BC108 or similar
Q2	BC558, BC178 or similar
IC1	741 op-amp
D1, D2	1N914, 1N4148 or similar
Miscellaneous	
RV1	2M linear pot
SW1	SPST toggle switch
SK1, SK2	3.5 mm jack sockets
B1	Type 216 9 V battery

Zippy box to suit, battery clip, ETI-560 pc board, magnetic earpiece, telephone pickup coil or wire and bolt to wind your own.

Project 567

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.

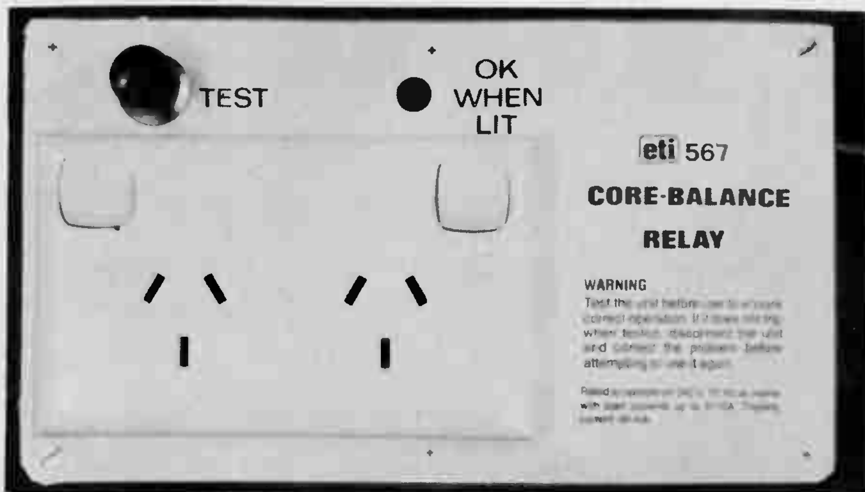
A FAULT in mains-operated equipment can place any external metal parts at mains potential — if you then happen to complete a path between the equipment and earth, you'll get a nasty surprise at the least or become another victim in the electrocution statistics. In some circumstances a fault may create 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 114 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.

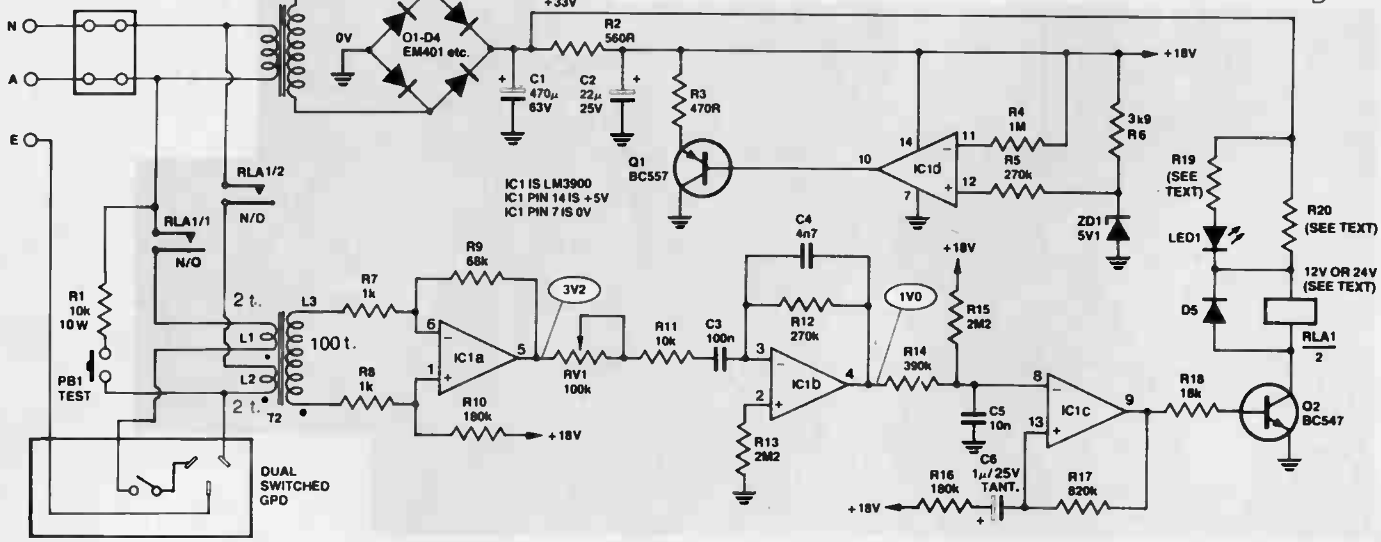
The Standard requires the unit's ratings to be marked on the front panel along with a warning notice. These have been included on our front panel artwork. In addition, the Standard requires any portable device to be double insulated (as per AS C100) between the external surface of the enclosing case 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 AS 3191), 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, 10 W 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.

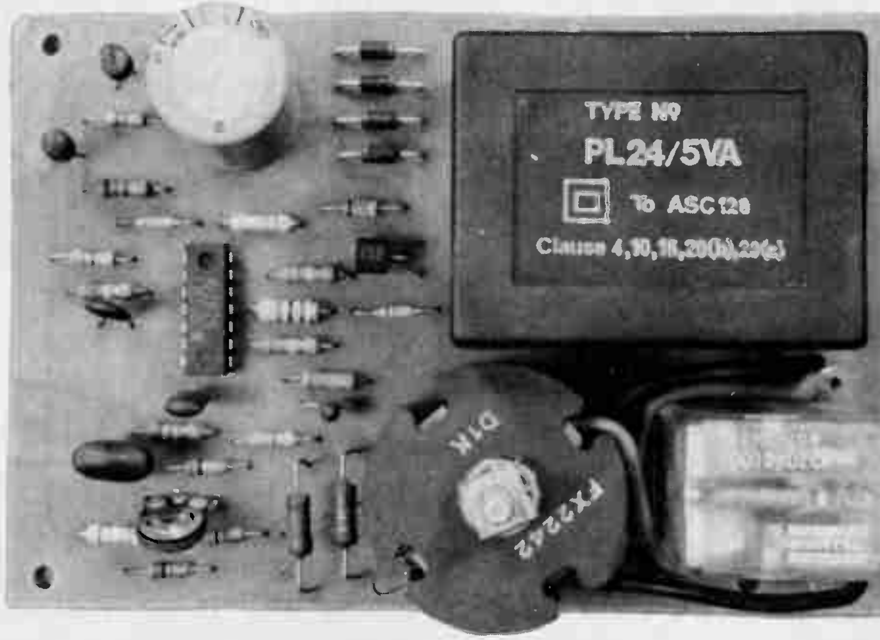
The printed circuit board should be drilled next, if you haven't got one that's pre-drilled. Locate the positions of the mounting holes for the potcore and the power transformer first.

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 34).

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.

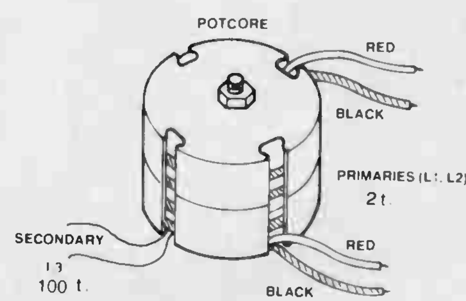
Mount the board in the bottom of the box using nylon nuts and bolts. Raise the board about 5-6 mm off the bottom of the box using fibre spacers.

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.

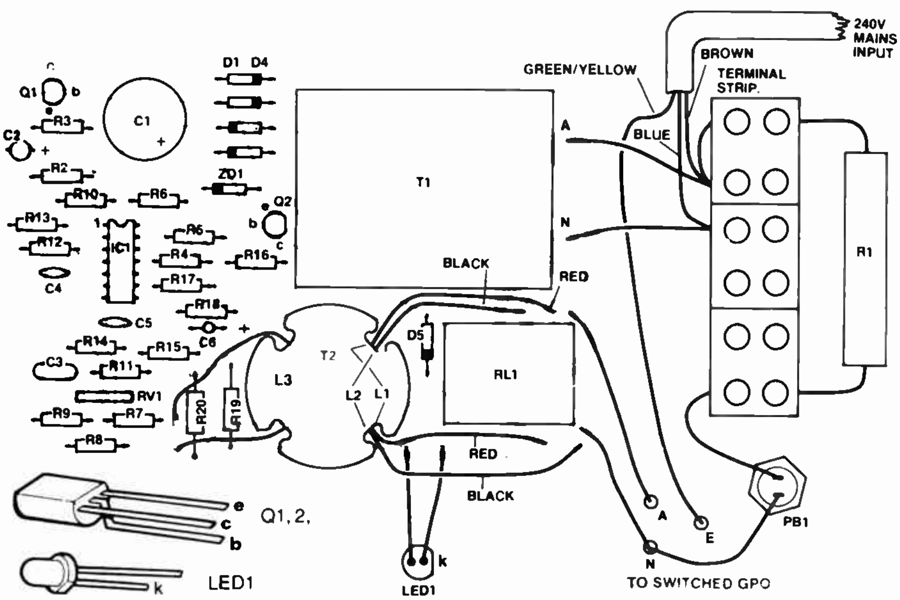


TRANSFORMER T1, WINDING DETAILS

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 34).

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

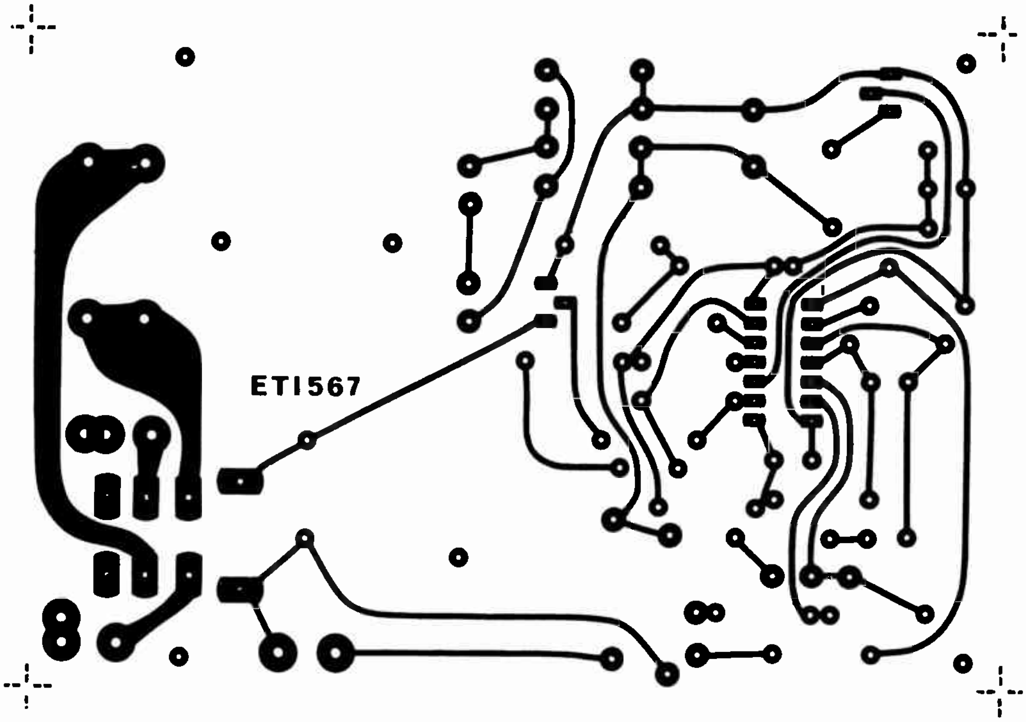
T1	PL24/5VA Ferguson transformer or sim.
T2	FX2242 pot core

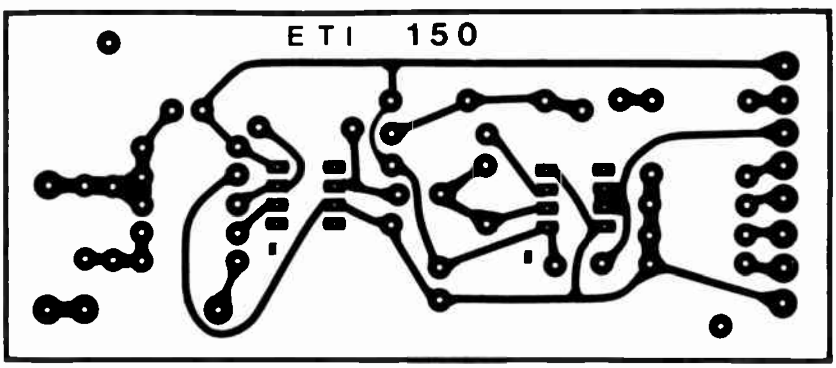
Miscellaneous

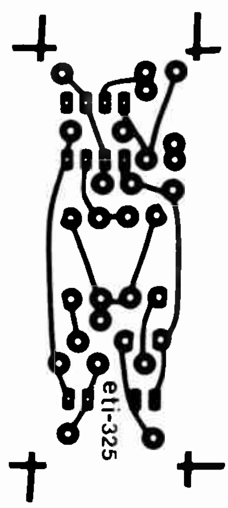
ETI-567 pc board; PB1 — 230 Vac rated momentary push button (push-on); plastic case to suit; relay (RL1) Fujitsu D024/02CK (24 V) or D012/02CK (12 V); wire, nuts, bolts etc; terminal block; 2m of 10 A rated mains lead.

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.

Two-tone generator for testing singlesideband systems

This project is an invaluable test instrument for the radio amateur or serviceman working with SSB transmitters.

WHEN SETTING UP a home-made SSB transmitter (such as one using our Project ETI-725 Polyphase Generator, published in ETI August 1979, testing a transceiver or setting up a homebrew linear amplifier, an appropriate audio signal source is absolutely essential. The most commonly used signal source for this sort of testing is a "two-tone" signal generator. Used in conjunction with even a simple oscilloscope, any single-sideband transmission system can be adjusted for best linearity – and thus, least distortion – eliminating "splatter" which can cause interference to other transmissions nearby. The two-tone generator is also invaluable for determining peak envelope power (PEP) of a transmitter.

The completed project was housed in a convenient 'zippy' box.

Why?

The input-output relationship of a single-sideband transmitter must be reasonably linear or intermodulation will cause distortion products that can extend well outside the SSB channel. The amount of distortion tolerable in an SSB rig is difficult to estimate. Of course, it is important to ensure that products outside the channel are kept as low as possible, but distortion that occurs inside the channel is another matter. Gross distortion must be avoided – but often, changes in distortion level may make very little difference to the perceived transmission quality. Furthermore, in attempting to eliminate some small vestige of distortion inside the passband, other parameters may be degraded. Most likely to suffer will be efficiency, with an associated increase in current flowing in the output stage causing increased thermal dissipation, and possibly a shortening of the output device's life-span.

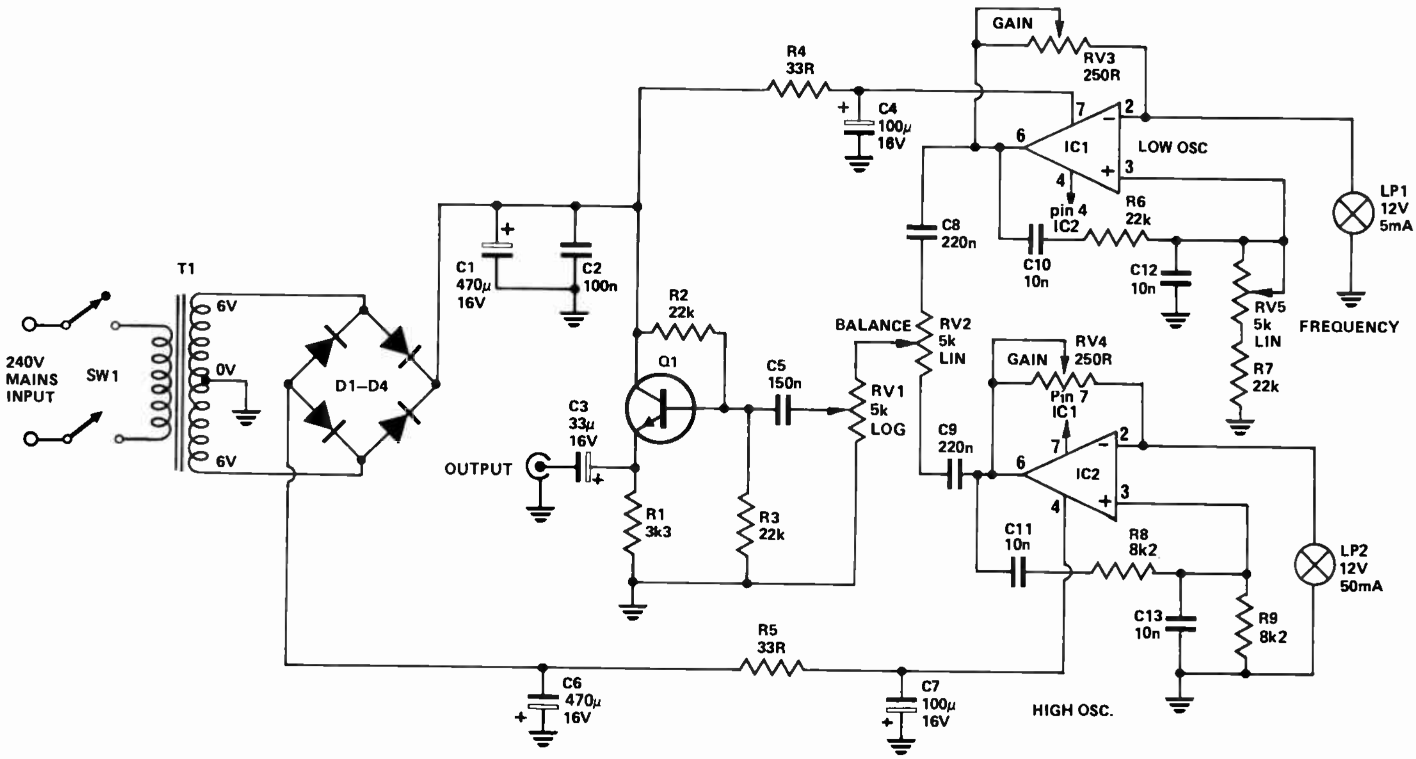
The major causes of distortion in output stages are clipping and cross-over distortion. Clipping occurs at high power levels. An increasing input voltage will eventually overdrive the amplifier, when it is not possible for the output voltage (or current) to follow the input accurately. It is easily cured by ensuring that the output stage is not overdriven. A two-tone generator is used to establish the maximum input level that will not produce clipping.

Cross-over distortion in push-pull designs is related to bias adjustment and becomes the dominant form of distortion at low signal levels. The cure is not as simple as is the cure for clipping. The output stage idle current can be increased but this will decrease efficiency. Often, filtering is used to reduce distortion products due to cross-over and here again, the two-tone generator is used to get an idea of the amount of cross-over distortion present.

The test generator is used with a CRO connected to the output of the transmitter, either directly or via an RF probe. The generator is connected to the microphone input and the resultant wave shape observed on the CRO. The presence of distortion products will change the waveform so that a clean sine wave shape will indicate a good clean transmitter. Increasing the input level until the output 'flattens' on the peaks will indicate the input level at which clipping occurs (this is called "flat-topping").

The generator

The generator simply mixes two sine waves together so that the transmitter is modulated by the beat frequency of the two tones. It is important that the tones are not harmonically related and that one of the tones can be adjusted slightly in frequency to make it easier for inexpensive CROs to sync on the ▶



output waveform. A balance control has been fitted to the unit so that the level of the two tones can be made equal if filtering in the transmitter audio pre-amplifier attenuates one signal more than the other.

The sine wave oscillators consist of op-amps in a Wien Bridge circuit. The frequency of the basic oscillator is given by the equation:

$$f = \frac{1}{2\pi R8\, C11} \text{ Hz. Where } R8=R9, \text{ and } C11=C13.$$

This gives frequencies of 1850 Hz for the fixed oscillator and 600 to 700 Hz for the variable frequency oscillator.

The problem with this type of circuit is that the gain must be closely maintained or the sine wave will be clipped severely. The necessary gain stability is achieved with the use of a light bulb in the negative feedback loop. The resistance of the light bulb varies with temperature, increasing with increasing temperature. If the oscillator amplitude were to increase, the larger current through the filament would increase its temperature, increasing its resistance,bringing about a rise in the amount of negative feedback and a consequent decrease in oscillator amplitude. The circuit works very well and once the oscillators are set up, thev will operate quite reliably. The light bulb used was a standard 12 volt "lilliput" bezel globe rated at 50 mA. A variety of globes can be used, although the value of the feedback presets might have to be changed, if the bulb chosen has a very different current rating from the one specified.

The outputs of the two oscillators are fed to either side of RV2 which serves as the 'balance' pot, and then via RV1 to an emitter-follower stage around Q1. This provides the generator with the necessary low output impedance. If it is found that the output voltages are unnecessarily high a series resistor (≈ 47k) can be placed between the wiper of RV2 and the 'top' of RV1 — replace the link between the wiper of RV2 and the pc board with the resistor.

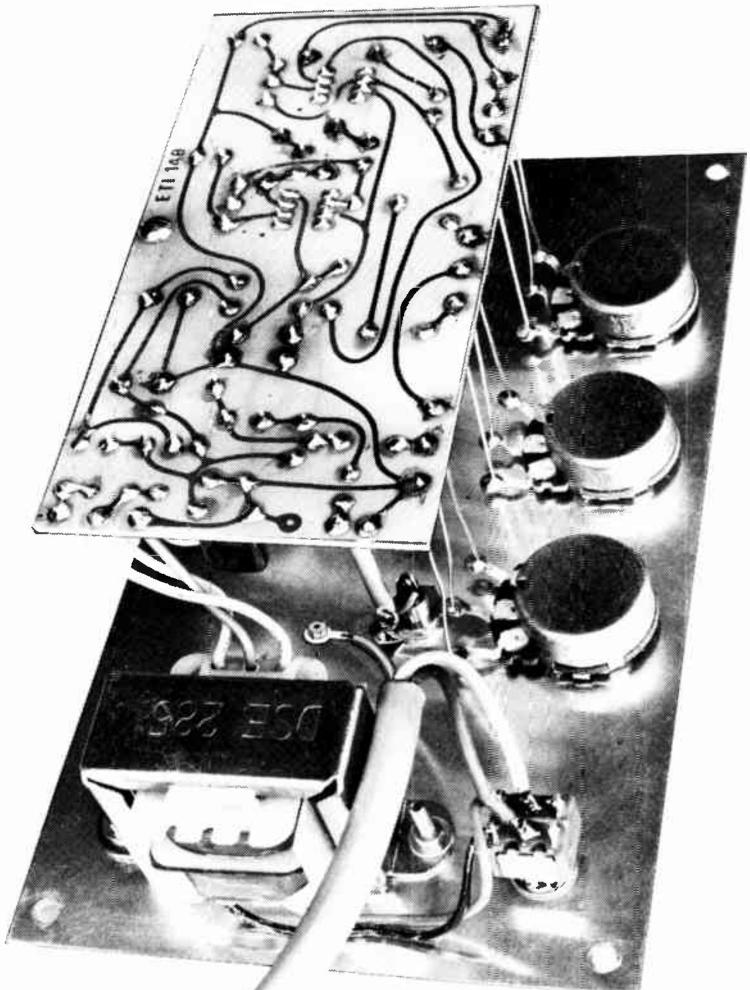
HOW IT WORKS

IC1 and IC2 form Wien Bridge oscillators at the frequency determined by C10, C11, C12 and C13, R6, R7, R8, R9 and RV5. The potential dividers formed by RV3, RV4 and the two light bulbs maintain the amount of overall gain to prevent distortion. Capacitors C8 and C9 couple the outputs of the oscillators to the balance pot RV2. Capacitor C5 couples the output of the volume control to Q1. The bias for this stage is determined by the potential divider R2, R3. The output is taken across R1 via the 33µ tantalum capacitor. The power supply is constructed on the same printed circuit board, diode D1 to D4 forming a full wave bridge rectifier, C1 and C6 being smoothing capacitors.

Construction

The construction is reasonably simple since it is mostly confined to the pc board. The order the components are placed on the board is not really critical, but it is probably wise to leave the ICs until last as they are the most difficult to unsolder should they be accidentally overheated while soldering other components around them. The light globes are soldered onto the pc board by first soldering wires to the globe. Short lengths of wire cut from the resistors already on the board are ideal for this. Care must be taken not to overheat the globe when soldering to the bottom connection, as the bulb is likely to unsolder itself internally with the heat applied from the soldering iron.

The prototype was constructed in a plastic 'zippy' box but any suitable ▶



View of the internal construction showing placement of the major components and wiring to the potentiometers. The mains earth lead should be grounded to the front panel. Use a cable clamp where this lead enters the case.

PARTS LIST — ETI 149

Resistors

R1 .... 3k3
R2,3,6,7 .... 22k
R4,R5 .... 33R
R8,R9 .... 8k2

Potentiometers

RV1 .... 5k log
RV2,RV5 .... 5k lin
RV3,RV4 .... 250 ohm vertical mounting mini trimpots

Capacitors

C1,C6 .... 470u, 16V electro
C2 .... 100n greencap
C3 .... 33u, 16V tantalum
C4,C7 .... 100u, 16V electro
C5 .... 150n greencap
C8,C9 .... 220n greencap
C10,11,12,13 ..... 10n greencap

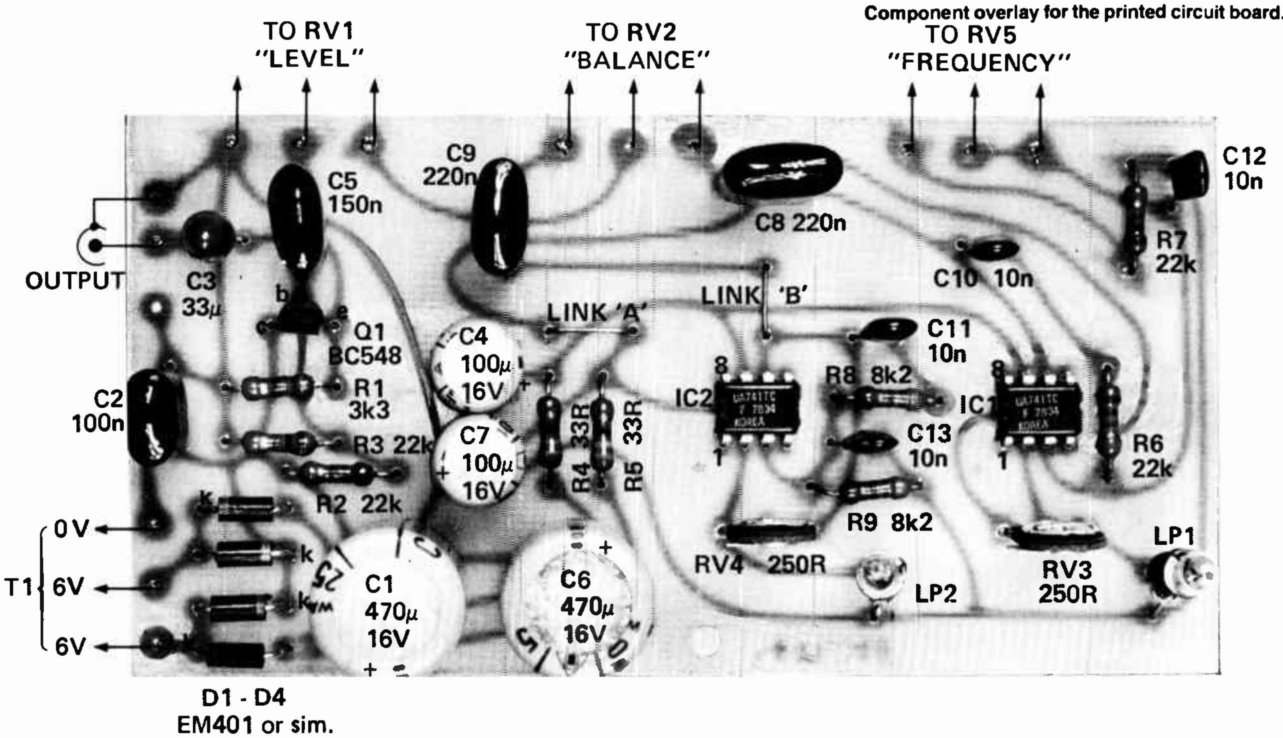
Semiconductors

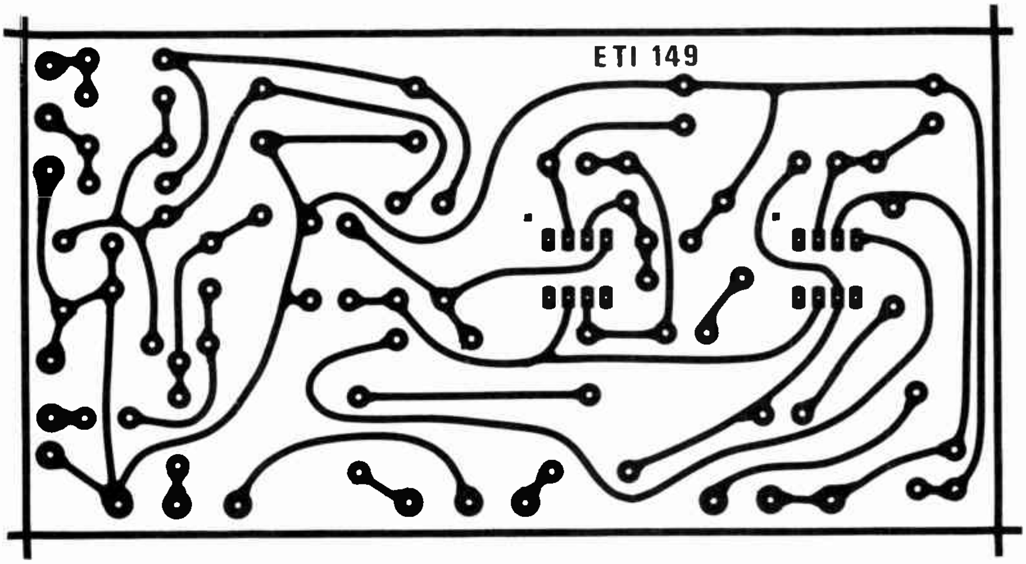
Q1 .... BC548,BC108 or similar
IC1,IC2 .... 741 op-amp
D1-D4 .... EM401, 1N4001 or sim.

Miscellaneous

LP1,LP2 .... 15 V/50 mA light bulbs
T1 .... 6.3 - 0 - 6.3 V, 150 mA transformer (M-2851 or similar).
SW1 .... DPST 240 Vac switch
RCA phono output socket; zippy box — 200 x 115 x 60 mm; ETI-149 pc board; three knobs; Scotchcal front panel (see "Shoparound" this issue); power cable, cable clamp and plug.

Component overlay for the printed circuit board.





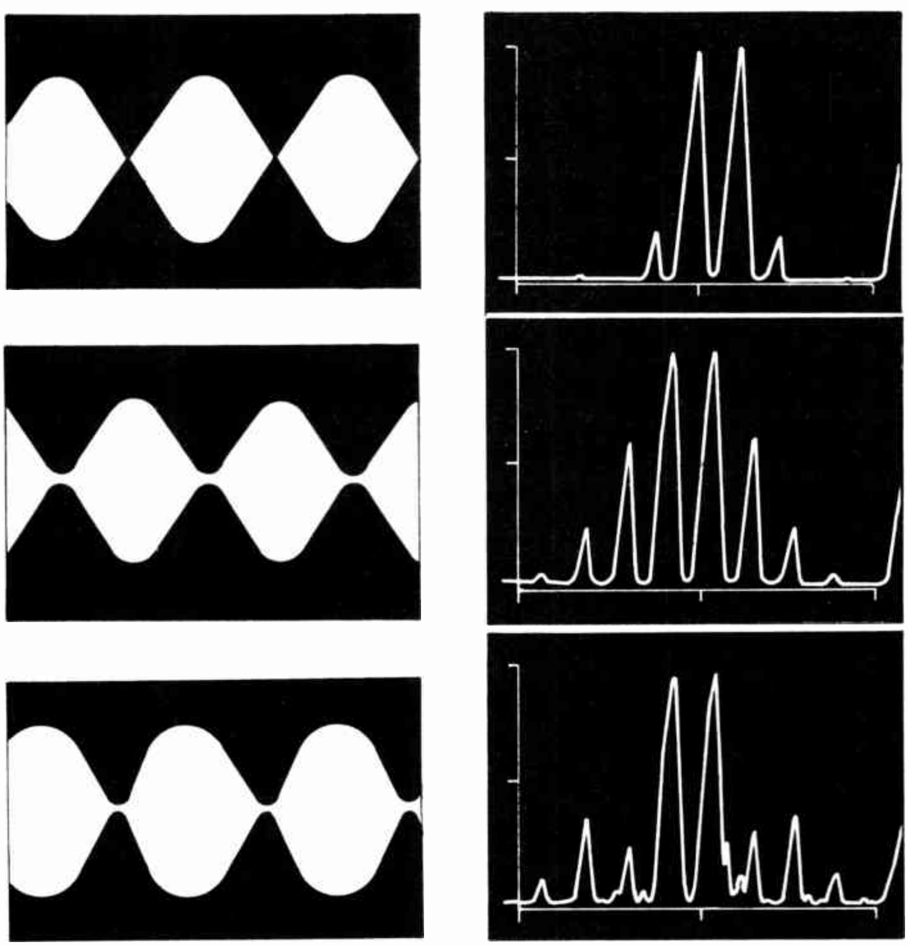
sized box could be used. The printed circuit board was mounted onto the front panel by one bracket bolted to the rear of the board (see photo) and the wire connections to the potentiometers. If this method of construction is chosen it is necessary to ensure that the pots are mounted in the correct position on the front panel.

Shielded cable should be used to connect the output of the board to the RCA socket; this will prevent hum being induced into the output from the power transformer. Make absolutely certain that all 240 volt connections are secure and that the earth wire is soldered to a lug and bolted firmly onto the front panel. The mains flex should enter the case via a clamp grommet.

Powering up

Before connecting to the supply, check all the 240 Vac wiring and the pc board. If all is correct, connect a CRO to the output and turn the balance control fully to the side connected to the fixed oscillator. Adjust the preset control RV4 so that oscillation starts. Determine the range over which the circuit will oscillate, ensuring that the waveform does not clip, and set the preset in the middle of this range. Now wind the balance control to its other extreme and adjust RV3 in exactly the same way.

That's it! And may your extraneous sidebands be vanishingly small. ●



◀ A properly adjusted transmitter should produce a CRO pattern as at left and a clean analyser trace, as on the right. The two signal tones predominate and distortion products (the two small 'pips') are well down. Note the clean 'crossing points' on the CRO display.

◀ If the bias on one stage of the linear amplifier system is set too low, particularly the PA bias, these sort of patterns result. The crossing points on the CRO pattern are clearly rounded while the analyser display shows the distortion products have increased dramatically.

◀ A classic case of 'flat topping'. The CRO display has flattened peaks and the crossing points are obviously rounded. The analyser display shows the distortion products have moved away from the main signal. A signal like this causes 'splatter' well away from the transmitting frequency. In general, it is caused by overdriving linear amplifier stages.

Typical oscilloscope patterns you will obtain with corresponding spectrum analyser displays, when using the two-tone generator to adjust an SSB transmitter.

Digital pH meter is simple and accurate

A pH meter has many applications in widely varying fields of interest; in chemical analysis, in soil analysis (gardening!); swimming pool chlorination; care of tropical fish, etc. This project features a 3½-digit liquid crystal display, simple construction and straightforward operation.

Peter Eliot
Phil Wait

FROM TIME TO TIME readers write or 'phone us with a project suggestion that, at first sight is attractive and practical, but on further investigation runs into what seems insuperable difficulties — generally with the supply (or lack!) of a critical component.

We first looked at this project in response to a spate of reader enquires. They generally pointed out that a pH meter was something we have never done but there were plenty of commercially available models — generally at prices well beyond the hobbyist or student. The electronics for such a project could be designed in several ways and this seemed to present few problems. So, we went looking for a suitable pH electrode.

That's where it all started to come apart at the seams. Our early efforts turned up imported probes costing in the vicinity of $100 for the least expensive model. We figured the electronics for an analogue readout instrument (using a moving coil meter) would cost around $30 or so and for a digital readout instrument around $40 or so. With probes at three times or more the cost of the electronics, a project started to look decidedly unattractive. It almost fell by the wayside.

However, during a conversation one day with Peter Eliot of the Amalgamated Instrument Company, who make and market a range of digital panel meters and portable digital instruments for industrial applications, the editor enquired where he obtained the pH probes for his digital pH instruments, and what did they cost? Peter was using Australian made probes chiefly because they cost less than half the equivalent imported types, and what's more they were readily available. Quick as a flash, we were talking to the man from Starcross Scientific, who distribute the range of 'Ionode' probes made in Queensland. A suitable probe was priced at around $40 so we figured a project would be timely and popular. What's more, having already done much of the required development work, Peter Eliot volunteered to provide us with a circuit and some material to suit our requirements. With some pc board and packaging work from the project staff, this project is the result. ▶

Project 572

Principles

The pH electrode or probe consists basically of an electric cell which, when immersed in a solution, will generate a voltage proportional to the hydrogen ion activity of that solution. The voltage generated is a measure of the pH of the solution. Measure the voltage generated by the electrode, display it, and you've got a pH meter. Simple enough, but there are a few difficulties.

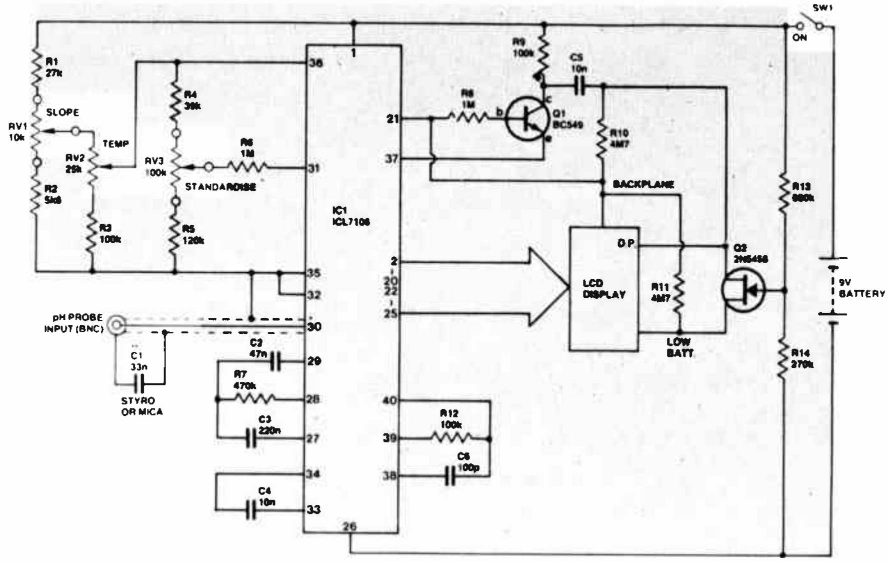
First problem is the internal (or source) impedance of the pH probe. It is generally around 10^9 to 10^{10} ohms! This means that whatever instrument you use to measure the voltage output of the pH probe needs to have an input impedance at least an order of magnitude (i.e: 10 times) higher.

The second problem that has to be tackled has to do with the "slope" variation with temperature of the pH electrode. The output of an electrode is typically 60 mV per pH unit, i.e: for a change in pH of a solution from, say, 7.5 to 8.5, the probe's output voltage will vary 60 mV. The electrode generates a *positive* voltage for pH values less than pH 7 and a *negative* voltage for pH values greater than pH 7. The electrode output is zero at pH 7.

If you plot a graph of probe output versus pH, where pH is represented on a log scale, you get a straight line as illustrated by the unbroken line in Figure 1. However, that line is only correct for one temperature. At another temperature, a line having a different "slope", indicating that the probe's nominal "mV per pH unit" output has varied, results as illustrated by the broken line in Figure 1. In general, a probe's sensitivity (mV per pH unit) increases with increasing temperature and vice versa.

The slope of a probe also varies with the age of the unit. Regular calibration checks remove any error that this may bring to the reading.

There are two general ways to correct for slope variations with temperature: by means of a manual control in the circuit, or automatically. For obvious reasons, the first method is the simplest and that's what we've elected to do.



* PIN 30 DIRECTLY CONNECTED TO SCREENED CABLE
** C1 CONNECTED DIRECTLY AT BNC CONNECTOR

Fortuitously, the input impedance of an ICL7106 analogue-to-digital conversion IC is around 10^{11} to 10^{12} ohms which is just what we need, apart from providing an appropriately scaled digital output to drive a display. Consequently, most of the circuitry for the pH meter is contained within two ICs; the ICL7106 and an LAD204 LCD display. The external circuitry is used to provide the appropriate scaling (so that the display reads directly in pH units) as well as slope and temperature compensation controls.

As this is a battery operated instrument, we thought it would be convenient to have some indication of when the battery was getting low. Surprise, surprise — the LCD display we chose incorporates a little "low batt." warning display in the top left hand corner. This is activated with a little extra circuitry once the battery voltage falls below 8.5 volts.

The pH probe

The pH probe we obtained for our instrument comes from Starcross Scien-

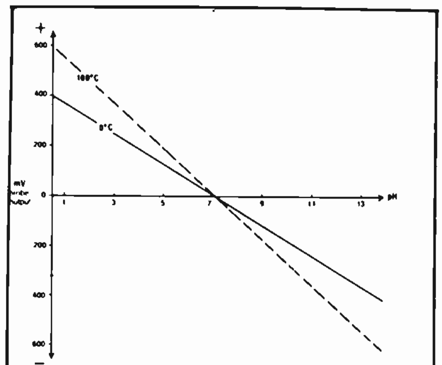


Figure 1. Illustrating how the "slope" of a pH electrode's sensitivity varies with temperature.

HOW IT WORKS — ETI 572

The instrument employs a single-chip analogue-to-digital (A/D) converter IC, type ICL7106, driving a liquid crystal display. Virtually all of the instrument is contained within the A/D converter chip and display. Operation of the 7106 is explained in a separate box. The reference voltage for the A/D converter is varied by three controls to provide the appropriate 'scaling' of the input so that the instrument reads directly in pH units, corrected for "slope" and temperature variations.

Input to the 7106 is applied between the IN LO pin (30) and COMMON pin (32) as the input is negative-going and we require a display which reads positive. The IN HI pin (31) has a portion of the reference voltage applied to it via a resistive divider involving R4, RV3 and R5. This sets the display to read (positive) 7.00 when the input is zero i.e: when the probe is in a pH 7.00 solution.

The A/D converter reference is developed between pins 35 and 36, derived from a resistive divider pick-off between the positive supply rail and the COMMON pin (32).

Varying the reference voltage by a small amount is used to provide temperature and "slope" compensation. The SLOPE control is part of the reference voltage divider and provides a 'vernier' control over a reasonable range, so making the control easy to adjust. The TEMPERATURE control forms part of a resistive divider from the wiper of the SLOPE control, RV1. Again, this provides a vernier adjustment. The voltage appearing on the wiper of RV2 is applied to the REF HI input of the 7106. The whole arrangement minimises interaction between the controls.

The internal clock of the 7106 is run at 50 kHz for maximum mains hum rejection, as explained elsewhere. The LCD display is driven by a square wave signal between the backplane and the numeral segments. This is provided by the 7106 from pin 21. The decimal point requires a drive signal in anti-phase to this and Q1 is arranged as an inverter to provide the appropriate drive to the decimal point.

The LOW BATT. indicator is activated by Q2. The gate of this FET is biased by a voltage divider using R13 and R14. When the battery voltage falls below about 8.5 V, Q2 turns on and applies the anti-phase backplane signal (from the decimal point drive) to the LOW BATT. pin on the display.

Hum filtering at the input is provided by a 33n capacitor connected directly across the input socket.

tific, P.O.Box 151, Frenchs Forest, NSW 2086. They are available by mail order. At the time this book was published the price was around $50.00. The probe, designated G101NFE, comes complete with a plastic protector cap, a wetting cap for storage and a comprehensive booklet plus two 200 ml containers of buffer solution, one of pH 6.88, the other pH 4.00. A BNC plug is fitted to the coaxial cable connection. The probe is a "non-flow" or sealed type and will have a long life without needing replenishment of the internal electrolyte.

In addition, Starcross have available accessories such as 100 ml plastic beakers and plastic wash bottles. They can also supply spear point electrodes suitable for soil analysis.

Construction

The pH meter is housed in a plastic box measuring 150 x 80 x 50 mm, although a 'zippy' box of similar size having an ▶

ABOUT THE 7106

The ICL7106 is manufactured by Intersil of the USA and contains all the circuitry for a digital panel meter employing the 'dual-slope integration' technique all housed in a 40-pin dual-in-line package. It is designed to drive any multiplexed 3½-digit liquid crystal display. A companion chip, the ICL 7107 is designed to drive any suitable 3½-digit LED display.

The internal circuitry of the 7106 can be divided into several areas: firstly there's the precision dual-slope integration type analogue-to-digital converter, then display decoder/driving circuitry and display multiplexing.

The precision dual-slope A/D converter is the most important, so let's take a close look at that.

In this method of A/D conversion the analogue input voltage is first converted to a time period which in turn is converted into a binary number by a timer/counting system. Referring to the block diagram here, and the associated timing diagram, the system commences the measurement when the switch connects the analogue signal input to the integrator which commences to 'ramp up'. At the same time the counter begins, from zero, to count the clock pulses. When a predetermined number of pulses, 1000 with the 7106, appear in the counter, the integrator is electronically switched over to the reference voltage. At this point, the integration capacitor, C, has then charged linearly from the input, rising as a ramp voltage to a level decided by the average input signal value over the counter time period (T). As the switch changes to the reference, the counter is reset to zero and commences counting again. The reference, which is of opposite polarity to the input signal, now causes the charged integration capacitor (C) to ramp downward with a fixed slope. When the output of the integrator reaches the zero threshold the counter is stopped and its contents displayed on the digital readout. The count displayed is the ratio of the counts during the 'downward' ramp (over time 't') to the counts during the upward ramp. Thus, for a limit of 1000 counts during the upward ramp, a direct reading of input voltage is obtained if the reference voltage is chosen appropriately.

The absolute value of the integration capacitor and the clock frequency are of little significance provided they are stable for the duration of the conversion period.

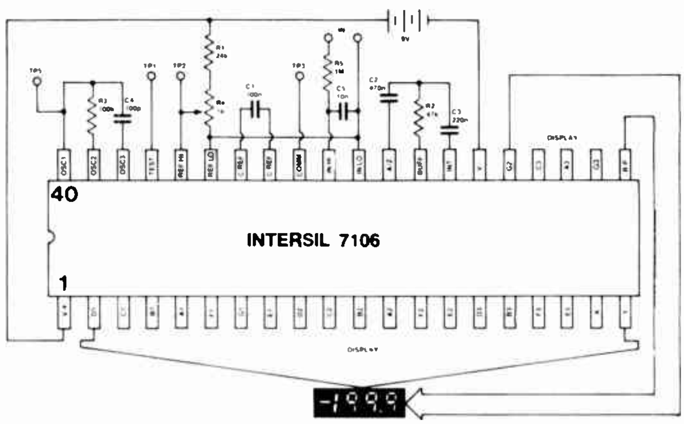
The relatively long analogue-to-digital conversion period has an inherent advantage in that it ignores noise. When noise is integrated over an extended period, its amplitude tends to zero. Thus, dual-slope integration results in excellent accuracy.

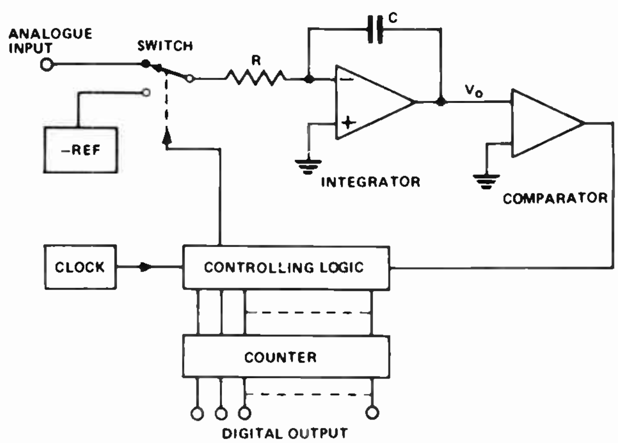
The 7106 has an on-board clock oscillator, the frequency of which is determined by external RC components — R3 and C4 in the circuit here, connected between pins 38 and 39. The clock frequency has been set to 50 kHz for the pH meter project. The oscillator frequency is divided by four internally to give a clock period of 80 us. As the integration period is 1000 clock periods long, the analogue input is integrated over a period of 80 ms. This results in pretty nearly optimum mains hum rejection as any 50 Hz ripple on the input will be integrated over four cycles and will thus have a dc value approaching zero.

Clock input is to pin 40 (TP5 in the circuit here) and the 7106 may be driven from an external clock if so desired. It requires a square wave drive of 5 V amplitude, positive with respect to the **common** pin. For external clock drive the clock RC network (R3-C4) is not required.

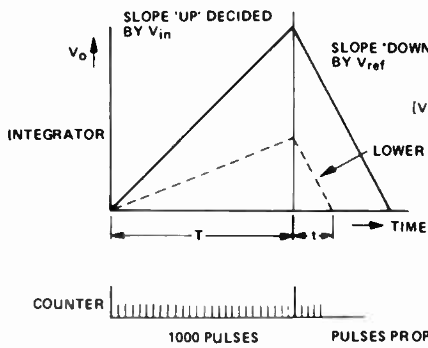
The A/D converter reference voltage is developed between pins 35 and 36 (REF LO and REF HI respectively). Pin 35 is set internally to be always 2.8 V lower than the positive supply rail applied to pin 1. The full-scale sensitivity of the 7106 can be 'programmed' by setting the value of the voltage between the REF LO and REF HI pins. For 200 mV full-scale sensitivity (reading of 1999 on the display) the voltage between pins 35 and 36 should be set to 100 mV, for 1 V sensitivity it should be 500 mV and so on.

Input current drawn by the 7106 is extremely low, typically one picoamp (1 pA or 10^{-12} amp as it has an input impedance measured in Giga-ohms (10^9 ohm)! For this reason, the unit can be used to measure voltage sources having a source impedance up to 10^{11} ohms — making it ideal for application in a pH meter. A useful spin-off from the 7106's high input impedance is that only quite small value capacitors are required in parallel with the input to provide good hum rejection. In addition, the input impedance is readily defined by using an appropriate value parallel resistor or simple attenuator on the input.





Block diagram of the 'dual-slope integration' technique of analogue-to-digital conversion commonly used in digital meters.



Timing diagram for the dual-slope A/D conversion technique.

PARTS LIST — ETI 572

Resistors all ½W, 5%

R1	27k
R2	5k6
R3, 9, 12	100k
R4	39k
R5	120k
R6, 8	1M
R7	470k
R10, 11	4M7
R13	680k
R14	270k

Capacitors

C1	33n styroseal or mica
C2	47n greencap or polycarbonate
C3	220n greencap or polycarbonate
C4, 5	10n greencap or polycarbonate
C6	100p ceramic or mica

Semiconductors

Q1	BC549, BC109 or similar
Q2	2N5485, 2N5484 or similar
IC1	ICL7106 see text
LCD Display	LAD204 see text

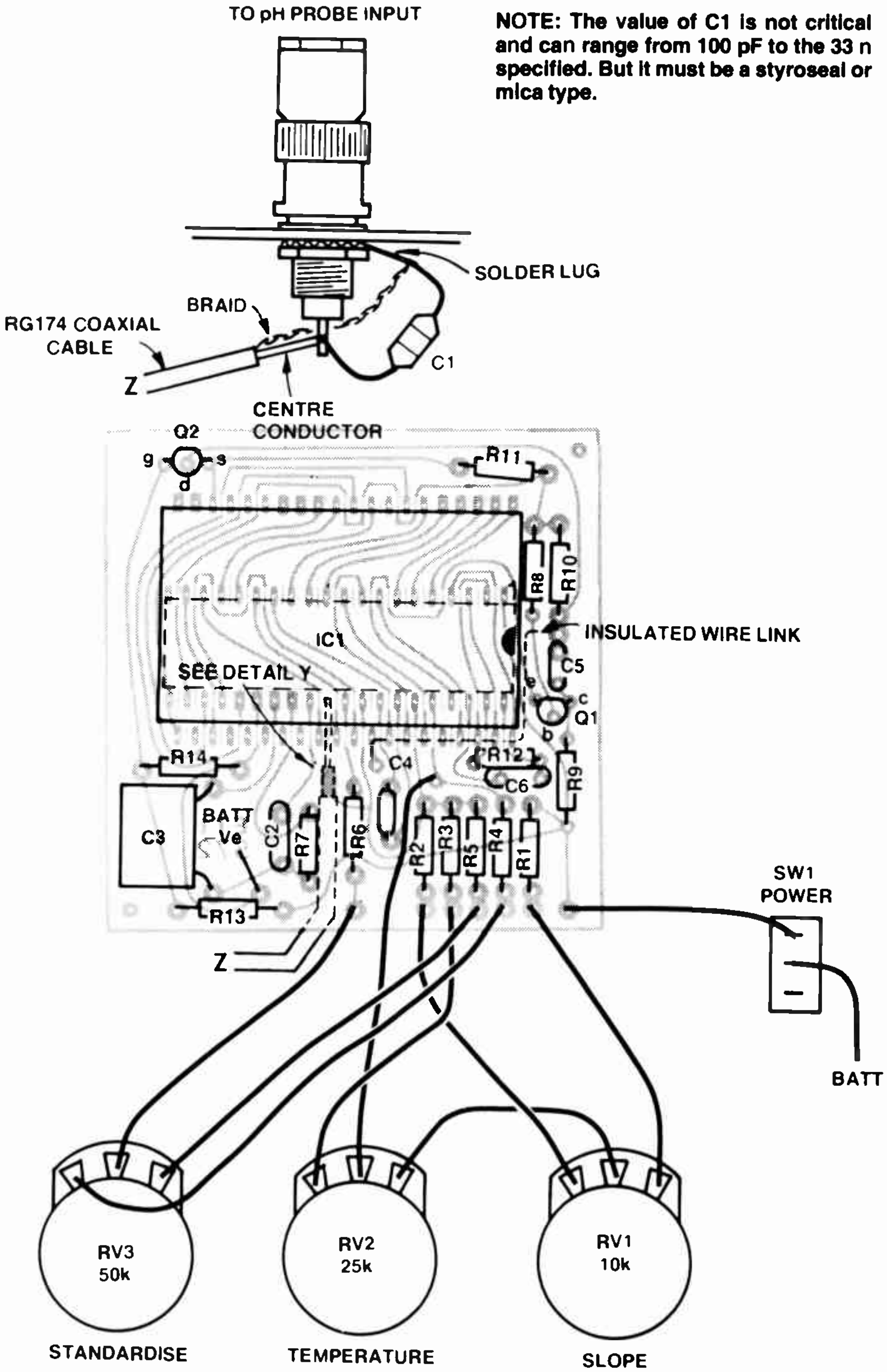
Potentiometers

RV1	10k linear
RV2	25k linear
RV3	50k linear

Miscellaneous

SW1	SPST miniature toggle switch

ETI 572 pc board; plastic box 150 mm x 80 mm x 50 mm; battery clip and No. 216 nine volt battery; length of 4 mm diameter coaxial cable, RG174 or similar — not shielded audio cable; BNC socket (teflon insulated and not second hand); three collett knobs; 40 molex pins; nuts, bolts etc.

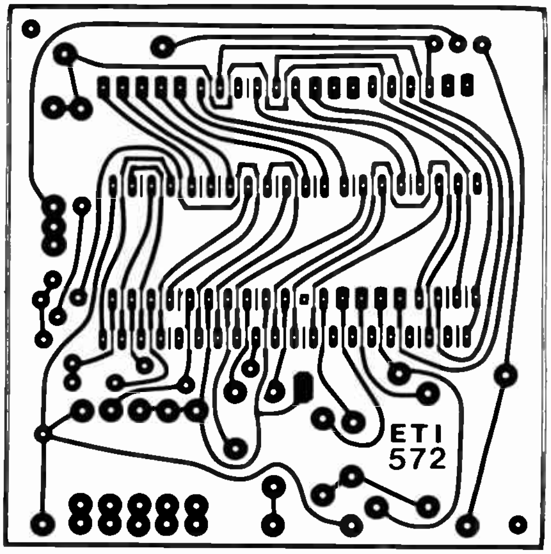


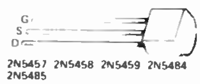
aluminium front panel would also suit. The pc board is mounted behind the front panel, positioned such that the display may be viewed through a cutout. The three control potentiometers are also mounted on the front panel. The input connector is a BNC coaxial socket which has PTFE insulation. This was chosen as it has very high insulation resistance. We mounted the socket on one end of the case and it is connected via coaxial cable. The battery was mounted on the bottom of the case, held in place with double-sided adhesive tape.

Since the input impedance of the 7106 is extremely high, as explained previously, the input pin (pin 31) must be connected directly to the coaxial cable, without touching the fibreglass board. To do this a 1.5 mm diameter hole was drilled through the pc board immediately beneath pin 31 of the 7106, allowing the pin to pass straight through the board where the cable to the input connector can be terminated directly to it. If you look at the pc board artwork, you will see this drill hole marked by a small square pad with a drill centre marked on it.

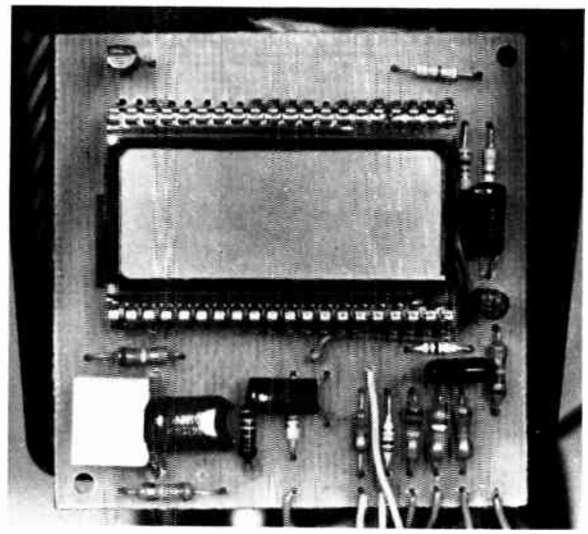
First step in the construction is to drill the lid of the case for the potentiometers, power switch and display cutout. This is best done by using the front panel artwork as a template. Scribe around the inside of the cutout, then mark a parallel line about 2 mm inside this. Drill a series of 3 mm diameter holes using this inside line as the drill centre line, and then pop out the centre of the cutout. Use a flat file to smooth off the edges to the first scribed line.

Mark the centres of the potentiometer holes and centre punch them. These holes are drilled to 10 mm diameter. The hole for the power switch should be

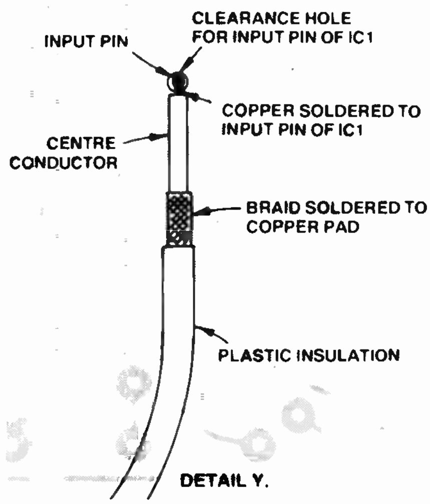


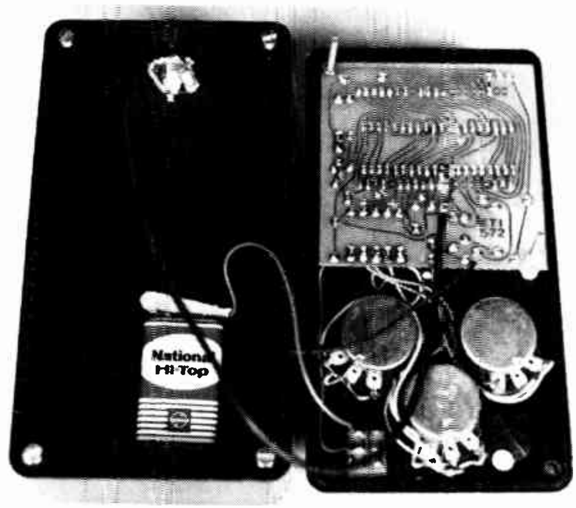


NOTE: The pinout of these FETs varies from manufacturer to manufacturer and with date of manufacture. The gate (G) and drain (D) leads may be transposed to that shown here. Check with your supplier or a recent data book. Note also that with these FETs the drain and source leads may be interchanged for convenience and the device will work equally well in this application.



Top right: view of the printed circuit board, showing the liquid crystal display.





Right: showing the rear of the pcb, with connections to the probe and potentiometers.

marked in the same way and drilled to 6 mm diameter. Next, mark and drill the hole for the BNC input socket (also 10 mm diameter).

The front panel transfer should not be attached yet. The pc board is mounted behind the front panel using two countersunk-head bolts and nuts either side of the board to position it. Using the unloaded pc board as a template, mark and drill the holes for the bolts that are to hold it. Countersink the holes on the *upper side* of the panel.

The pc board may be tackled next. All the smaller components should be mounted first. The capacitors are bent down onto the board so that they will be lower than the display. Capacitors C2, C3, C4 and C5 can be greencap, polycarbonate or mylar capacitors. If you have bought an Intersil ICL7106EV digital panel meter evaluation kit, some of the components may be used in the project. The clock capacitor, C6, can be either an NPO ceramic type or silver mica. The evaluation kit uses a 100p silver mica type for this capacitor.

Next mount transistor Q1, and the FET Q2, pushing them hard down on the pc board so the tops of their cases will sit below the display (when it is mounted). The FET has an unusual pinout configuration so be extra careful that you insert it the right way round.

Mount the 7106 IC as shown in the overlay diagram, being careful to orient it correctly. Forty pin ICs are very hard to get out again!

We mounted the display directly above the 7106 on two rows of Molex pins. This permits quite a compact pc board and elevates the display somewhat above the surrounding components on the board. It may also be unplugged, which might be necessary as we explain shortly.

Insert the two rows of Molex pins, but only solder those pins which are actually used. Those pins not having pc board tracks attached are not used. When the pins are in place, bend back the steel connecting strip between the pins with a pair of long-nose pliers until the strip breaks off. The unused pins will come away with it.

Some displays do not have pin 1 designated, but if you turn the display edge-on to the light you should be able to see the numerals faintly. Alternatively, you have a 50-50 chance of getting it right (or wrong — but we're optimists!) if you take a guess.

Mount and wire the three potentiometers and the power switch next. Connections are indicated on the wiring diagram. The potentiometer terminals are positioned at odd angles so that they can be fitted in the available space. This necessitates the use of collet knobs so that the pointer can be positioned correctly in relation to the shaft. Some small grub-screw knobs will work, but you may have to shop around. Or use press-on knobs with adjustable pointers — just as good as collet ▶

knobs. Wire the battery clip and power switch last.

At this stage you can check to see if you have the display inserted the correct way round. Temporarily plug in a battery and turn the unit on. If all is well, you will see numbers come up on the display. If not, no numbers will appear. Unplug the display and reverse it if this is the case.

With all the components mounted, the pc board can now be mounted to the front panel. Adjust the position of the board so that the display sits firmly behind the cutout in the panel, but don't strain the board.

Finally, solder the coaxial cable from the input socket to the pc board as indicated in the accompanying diagram. Make sure that you use good quality coaxial cable such as RG174 (4 mm dia.), not ordinary 'shielded cable' as its insulation resistance is not good enough for this application. Also ensure that the PTFE insulation on the BNC socket is clean and free from flux. If necessary, wash the socket in alcohol.

Terminate one end of the cable on the socket being careful not to leave any flux on the socket's insulation, or heat the coaxial cable insulation too much. Use a good hot iron with a clean tip and solder quickly. Use a large solder lug under the socket's nut for the braid connection or solder the braid to the edge of the nut. Capacitor C1 mounts directly across the input socket and it must be a styroseal or mica type.

Cut the cable to about 150 mm length and terminate the other end to the input pin of the 7106 as shown in the drawing on page 43. Don't let any flux flow down onto the hole in the pc board or allow the solder bead at the joint to touch the board.

Now you can plug in the battery and your pH probe and give the unit a try. If all is well, the front panel artwork can be mounted. Scotchcal panels will be available from the usual suppliers.

Using the instrument

Before making a measurement, the instrument should always be 'buffered'. Remove the wetting cap from the probe and attach the plastic protective cap — that little bulb on the end is *very* fragile. Set the TEMPERATURE control to room temperature (say, 25) — the scale on this control is marked in degrees centigrade (°C). Clean the electrode with distilled water if you have used it recently.

You will need two buffer solutions, one having a pH near 7 and the other a pH near 4. The two most commonly available have a pH of 6.88 and 4.00. Put the probe in the pH 7 solution and adjust the STANDARDISE control for the correct reading according to the marked pH of the buffer. Allow about two minutes or so for the reading to stabilise before finally adjusting the control. Remove the probe and wash it again in distilled water.

Now put the probe in the pH 4 buffer and allow the reading to stabilise. Then adjust the SLOPE control for the correct reading according to the marked pH of the buffer.

Go through the procedure again to ensure correct adjustment. Only then can you take a reading in the solution or solutions to be tested. Wash the probe before making a measurement and between successive measurements.

If the temperature of the solution, or solutions, to be measured differs substantially from the temperature of the buffers, set the TEMPERATURE control to approximately the temperature of the solution to be measured. This control only has a minor effect and its operation is very 'broad'.

There you have it, your own digital pH meter with an Australian-made probe to boot! ●

THE CARE & FEEDING OF YOUR pH ELECTRODE

To ensure the maximum life and best response from your pH electrode, the following procedures are recommended.

1) When not in use the pH electrode should be stored with its tip soaking in distilled water. It is important that the porous glass membrane and salt bridge are *not allowed to dry out*. If for some foolish reason this does occur the electrode will require soaking in distilled water for 24 hours before it can next be used.

Store the pH electrode with its tip soaking in distilled water, use the protective shield and rinse with distilled water between measurements.

NEVER clean a pH electrode on a rag, or on your sleeve, or under a running tap.

2) For long term storage, cover the glass bulb with a 'wetting cap' containing distilled water. (Note that plastic wetting caps are supplied with the Australian-made Ionode pH electrodes).

3) When in use, the electrode should be rinsed thoroughly with distilled water (preferably applied with a fine-nozzled wash bottle — see the accompanying illustration) between successive readings and between buffer calibrations.

4) If the electrode is used with non-clean or organic solutions the electrode may require extra cleaning from time to time. The most common method used is to soak the electrode for 24 hours in a '0.1 normal' hydrochloric acid solution. Alternatively, simply soaking the electrode in a mild solution of household detergent and distilled water will generally emulsify the contaminants and restore the electrode to normal.

5) *Always be careful not to touch, scratch or damage the porous glass membrane.* It is advisable to use a plastic protector cap as shown in the accompanying illustration. (These are supplied with the Ionode electrode).

6) Generally, a sluggish response from the electrode will indicate that it needs cleaning.

For troubleshooting other problems it is best to consult the instruction booklet supplied with the electrode or the supplier from whom you purchased the electrode.

The 'Mainsmaster'

Jonathan Scott

An essential piece of equipment for the keen experimenter's workshop, service bench or test lab.

WHEN TESTING an item of newly-developed mains-operated equipment, or servicing a unit of commercial manufacture, the need often arises where the circuit's response to variations in mains voltage has to be examined. The performance of regulated power supplies is a typical case in point.

The traditional method is to use a "variac". This is a type of continuously variable autotransformer — constructed somewhat like an enormous wirewound potentiometer. A large dial moves a contact over the single winding — the output being taken between the contact and one end of the winding. The main drawback of the variac, for most hobbyists, experimenters — even servicemen, is cost. Secondly, it may do more than is necessary for most people's applications.

Boost or buck

The simple and inexpensive, solution is to connect a suitable step-down transformer as an autotransformer with switching arranged to 'boost' or 'buck' the mains voltage by a small, fixed percentage. This will do the same job as a variac, but over a limited range, and allows scope for a few useful additions — such as monitoring the load voltage and current.

Thus, we have the 'Mainsmaster'.

This project uses a very common stepdown transformer having a 25-0-25 volt secondary. This is switched in series with the output socket so that, when the whole secondary is connected *in phase* with the mains, it will *add* 50 volts increasing the output by about 20%. When only *half* the secondary is connected in phase, the output voltage will increase by about 10%.

Similarly, when the whole secondary is connected *out of phase* with the mains, the output will *decrease* by 20%; with *half* the secondary connected out of phase the output will decrease 10%.

As the transformer secondary is rated at 2A, loads up to about 500 W may be run from the Mainsmaster.

To monitor the output voltage and current a series of resistors and diodes provide rectification and voltage and current scaling for a commonly available 1 mA meter movement. A new scale has been provided, marked with the appropriate voltage and current scales.

Standard, inexpensive, mains-rated toggle switches are used to arrange the boost and cut, meter switching and switching of the output direct to the mains.

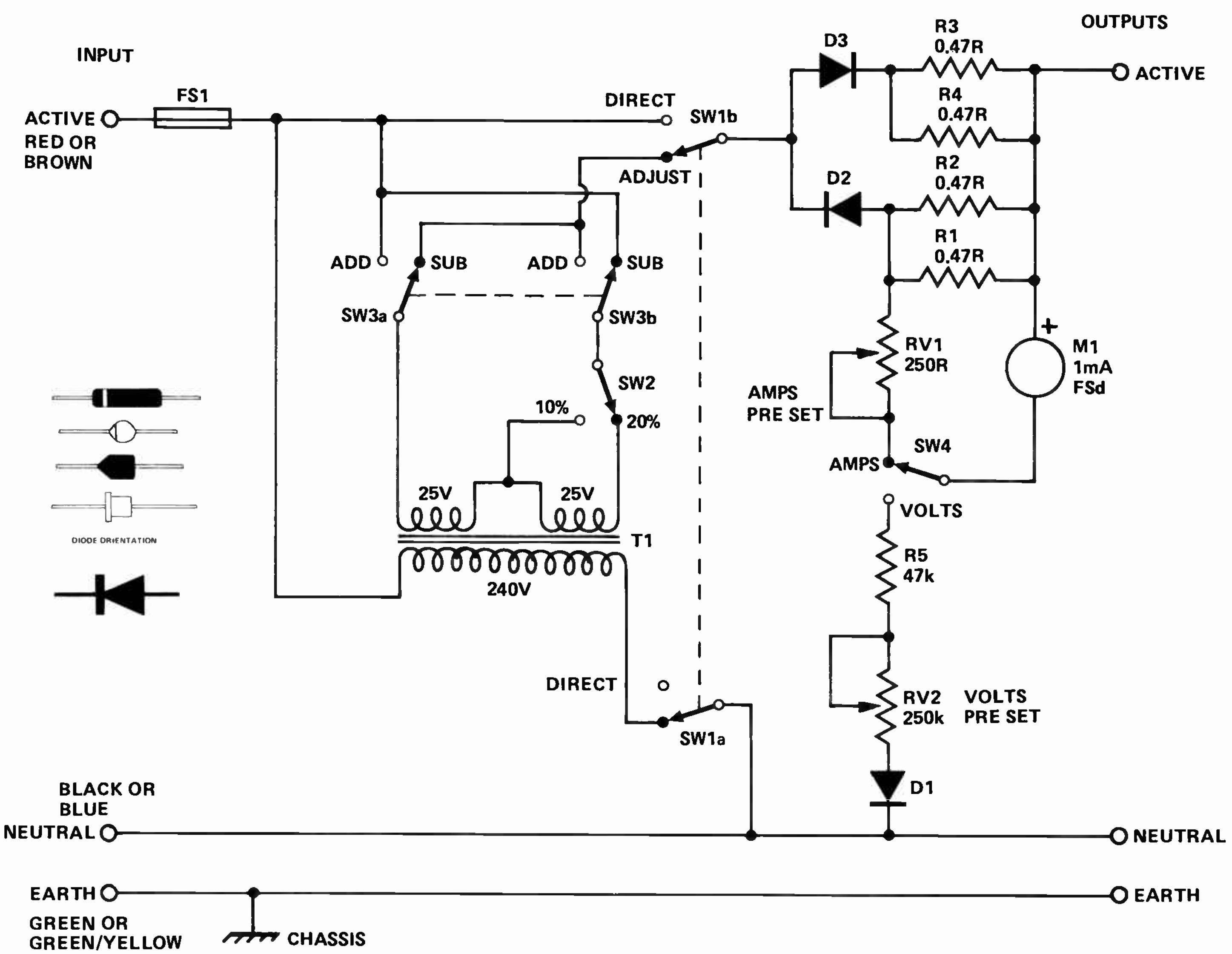
Construction

Since the whole circuit is at active mains potential we recommend that the three-pin plug be fitted last of all!

Unless you are competent to do so, it would be wise not to deviate from our design in any detail.

Construction is relatively simple, with only the meter, diodes and transformer needing to be connected a particular way around. All switches need to be 240 V rated. We used DPDT switches for SW1-SW4 though only two need to be DPDT rather than SPDT. This was because we could not readily locate 240 V AC switches of identical appearance in both DPDT and SPDT. It is advisable to use the pc board shown as it forms a solid, reliable mount for the trimpots.

A number of sensible construction practices should also be included. Firstly, use a proper cord clamp for the mains cord. Earth the transformer and front panel. (Our transformer is bolted to the front panel and both earthed). ▶



It is advisable to use a robust box, an all-metal diecast one being the best, though expensive. Use proper 240 V AC rated hookup wire (known as 23 x .0076).

After the interconnections have been completed according to the diagram the calibration of voltage and current ranges remains. Do not attempt to adjust the trimpots with the unit plugged in. These should be adjusted in small steps, each adjustment being made with the unit disconnected. The meter should be set to agree with a multimeter or reference instrument measuring across a purely resistive load, such as 200-300 watts worth of incandescent lamps. Remember that the unit is only rated to 2 A, so only 500 W can be drawn continuously. The fuse will limit the output current to 3 A. ●

MAINS WIRING

Constructors should keep in mind a number of simple rules when doing any 240 Vac mains wiring.

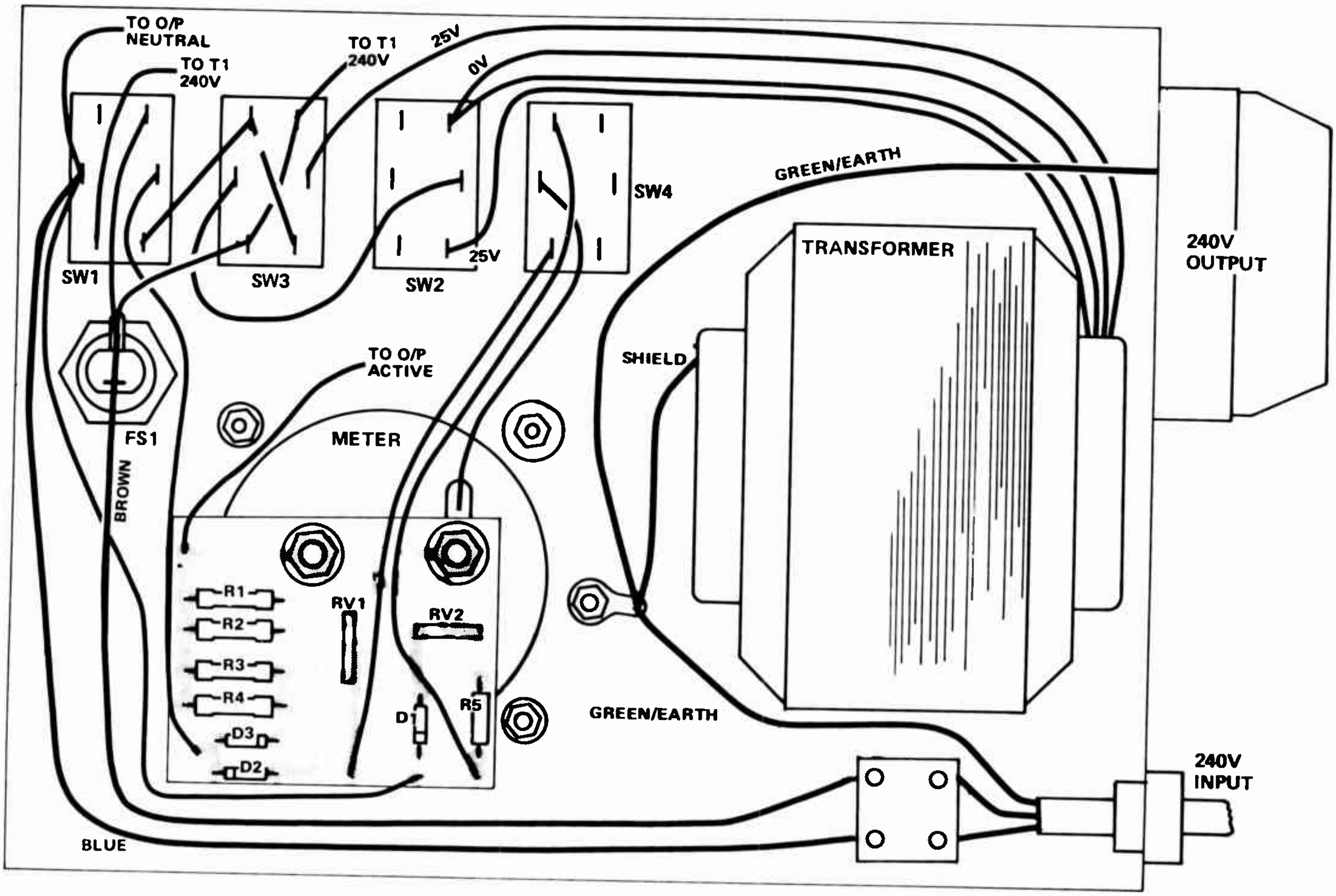
Firstly, the input cord should be standard, approved three-core flex. Not "figure-eight" flex. It should be secured to the case of the equipment with either a clamp-type grommet or passed through a standard rubber grommet and secured inside the equipment by a proper cable clamp. Knotting the cable is not good enough — and dangerous.

The active and neutral wires must be terminated, immediately inside the equipment, to a terminal block. The earth wire must be longer and earthed via a lug under a bolt and nut used for that purpose alone so that, if the clamp fails under any circumstances, the earth lead will be the last to break. If any subsequent wiring passes through a metal partition or chassis it should be sleeved or a small grommet inserted in the chassis hole.

Do not pass mains wiring over any circuitry within a piece of equipment. Route it around, keeping well clear of components. Use cable ties. Keep mains wiring well separated from low voltage wiring, preferably at opposite ends of the chassis of a piece of equipment. This also reduces the likelihood of hum pickup in sensitive circuits, such as high gain amplifier stages.

Use electricity authority approved transformers (see ETI, September 1979, page 13) and three-pin plugs.

Follow these directions and you should live to enjoy your hobby for many years.



PARTS LIST – ETI 146

Resistors
all ½W 5%
R1-R4 . . . . . .0.47R
R5 . . . . .47k
RV1 . . . . . .250R
RV2 . . . . . .250k

Semiconductors
D1-D3 . . . . .EM4004 or sim.

Switches
SW1, SW3 . . .DPDT 3A, 240 Vac switch
SW2, SW4 . . .SPDT or DPDT 3A 240 Vac switch

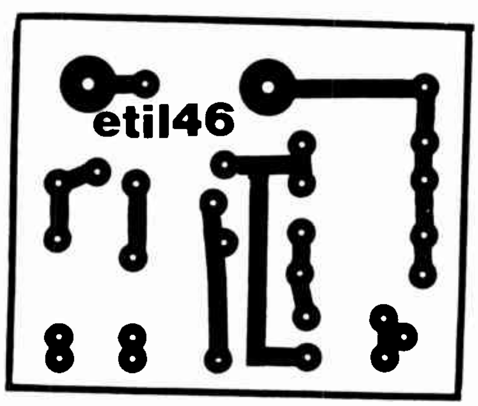
Miscellaneous
FS1. . . . . . . .3 A (3AG) fuse and fuse holder
T1. . . . . .Ferguson PF3259, 25-0-25V 2 A transformer or similar.
M1 . . . . .1 mA, 65 mm square panel meter

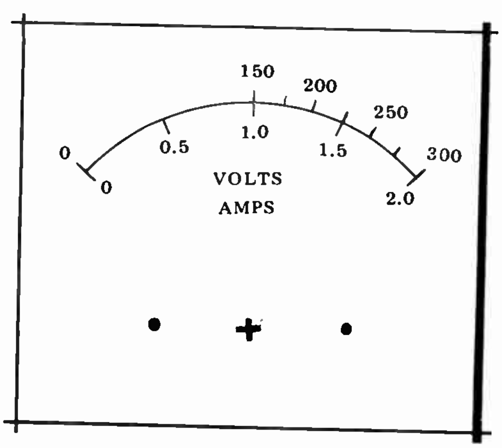
Diecast box 200 x 125 x 100 mm, 3pin mains panel mount socket, ETI 146 pc board, cable clamp, mains cord and plug, rubber feet.

HOW IT WORKS – ETI 146

The circuit may be divided clearly into two parts: the voltage switching part, and the metering part. The switching part works simply by switching either half or all of the secondary of T1 in series with the mains supply – either in phase to add, or 180° out of phase, to subtract. This is controlled by SW1, SW2 and SW3. SW1b removes the 240V AC from the transformer when the direct connection is used. The whole circuit (and load) is protected by F1.

The metering part measures volts and amps. Diode D3 rectifies the voltage across the load. R5 and RV2 set the meter range to 300V AC FSD. R1-R4 with D1-D2 form a (symmetrical) 2A shunt for the meter which allows it to pick off DC (since the meter sees only the current in R3/R4). RV1 sets the current sensitivity.





Project 156

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).

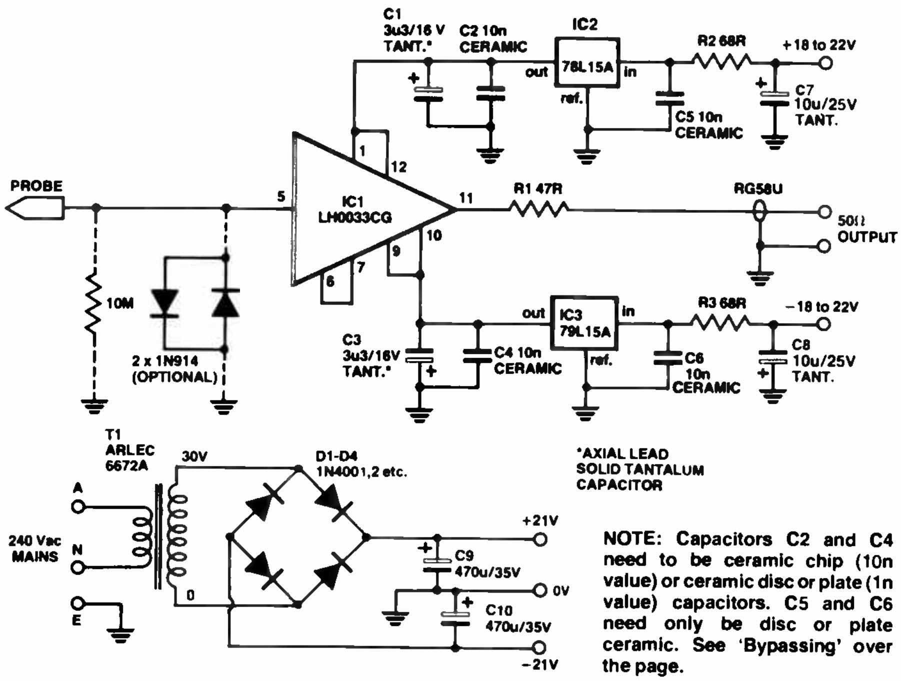
Design

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

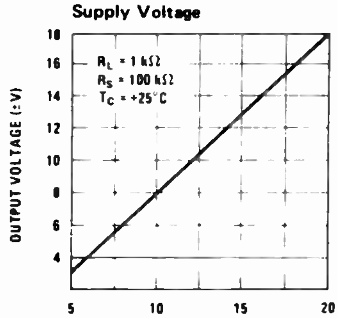
Output offset voltage	12 mV
Voltage gain	0.98
Input impedance	10^{11} ohms
Output impedance	6 ohms
Output voltage swing	±13 V
(V_S = ±5 V)	(6 V p-p)
Supply current	21 mA
(V_S = ±15 V)	
Power consumption	630 mW
(V_S = ±15 V)	

ac characteristics (LH0033C/LH0033CG) — typical

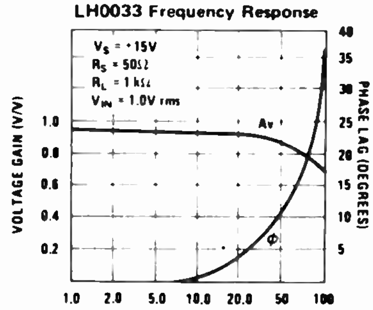
Slew rate (V_{in} = ±10 V)	1400 V/µs
Bandwidth (V_{in} = 1 V_{rms})	100 MHz
Phase non-linearity (1 - 20 MHz)	2°
Rise time (△V_{in} = 0.5 V)	3.2 ns
Propagation delay (△V_{in} = 0.5 V)	1.5 ns
Harmonic distortion (f›1kHz)	‹0.1%

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.

LH0033 Output Voltage vs Supply Voltage



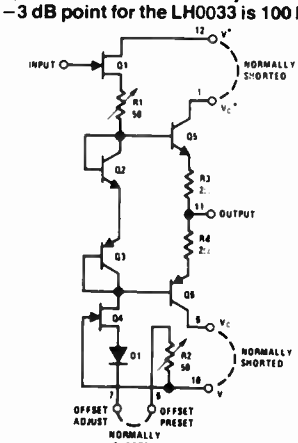
LH0033 Frequency Response



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.



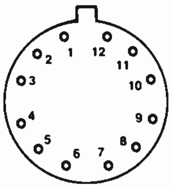
As the device is direct-coupled, dc levels will be maintained between input and output.

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

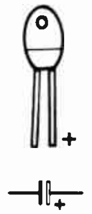
To provide regulated plus-and-minus 15 V rails for the IC, two three-terminal regulators are employed, a 78L15A for the positive rail and a 79L15A for the negative rail. These can supply up to 100 mA and have a very low output impedance up to several hundred kilohertz, which is exploited for low frequency 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.

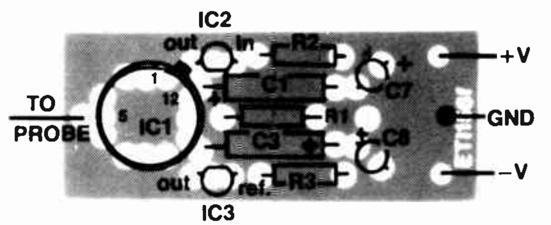
COMPONENT OVERLAY, TOP OF BOARD



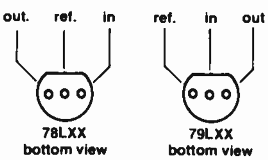
LH0033CG
top view



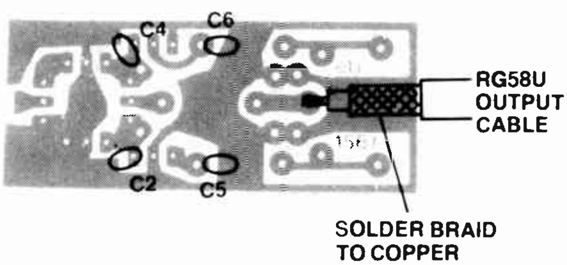
TANTALUM CAPS.

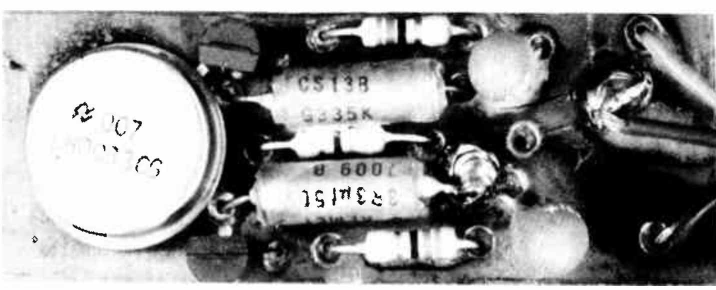


COMPONENT OVERLAY, BOTTOM OF BOARD



IC2, IC3 PINOUTS





The completed pc board, prior to assembly in the probe housing (pcb pattern is on page 52).

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.

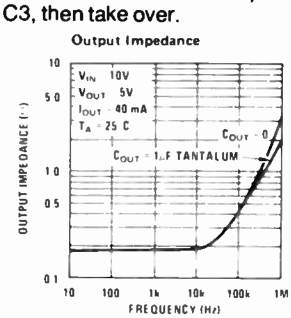


Figure 1. **Output impedance characteristic of a three-terminal regulator.**

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.

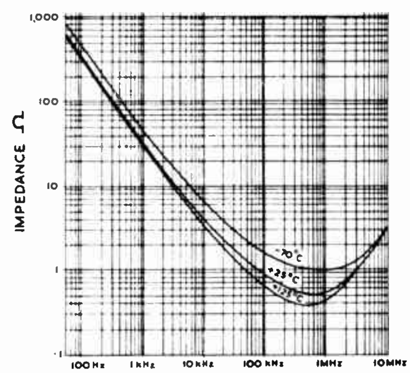


Figure 2. **Impedance characteristic of axial lead solid tantalum capacitors.**

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.

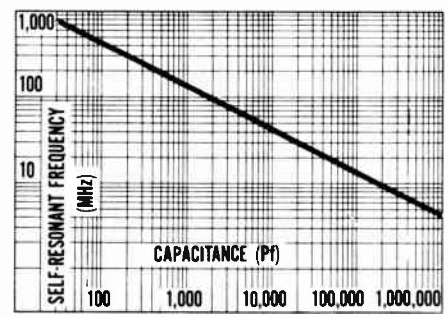


Figure 4. **The self-resonant frequency versus capacitance of a typical ceramic chip capacitor.**

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.

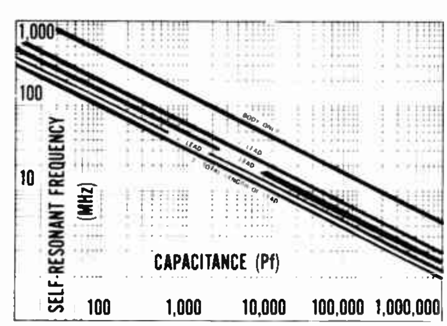
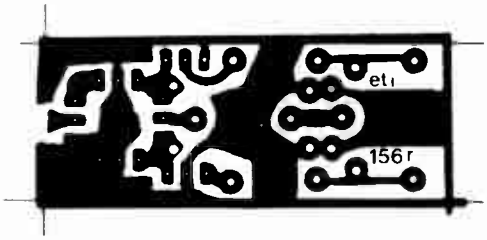


Figure 5. **The self-resonant frequency versus capacitance of a typical 5 mm disc or plate ceramic capacitor with differing lead lengths (from lower curve, up — 25 mm lead length, 22 mm, 13 mm, 6 mm and none).**


eti
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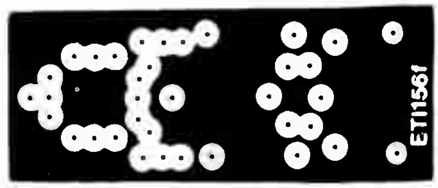
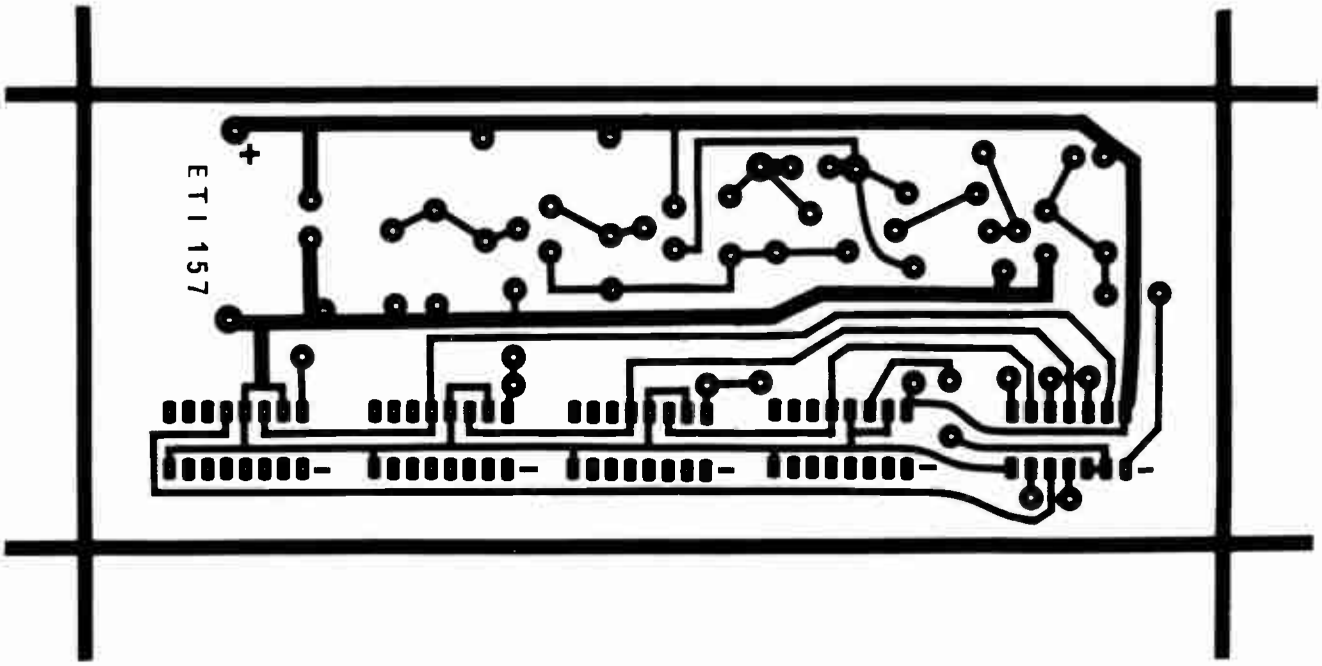
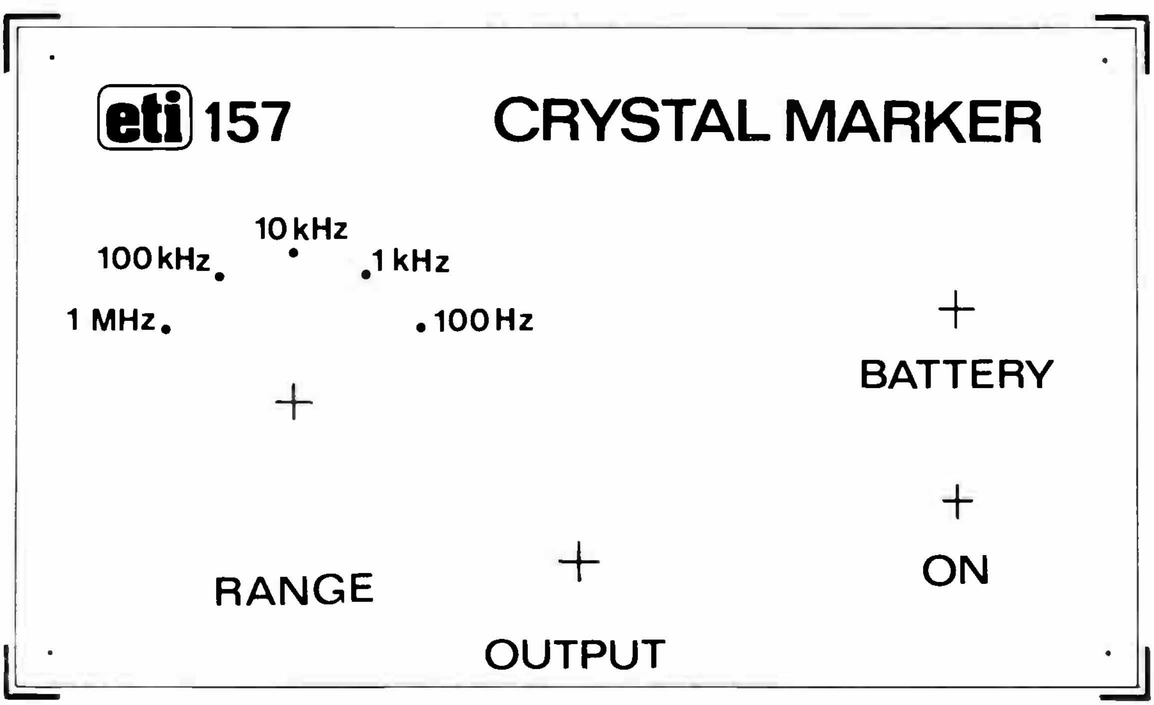

ETI156f

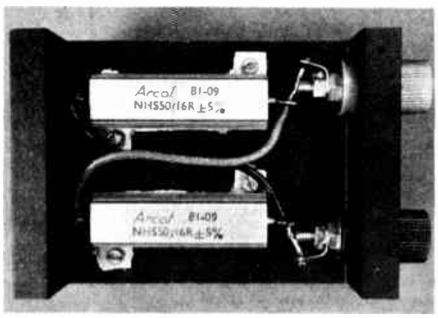

ETI 157


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

High power 'dummy loads' for audio amplifier testing

Apart from a multimeter and perhaps an oscilloscope, a resistive dummy load of 4, 8 or 16 ohms impedance capable of dissipating up to 100 watts is just about the most useful item of test equipment the audio enthusiast could have. Here are several ways to build one.

Andrew Kay
Roger Harrison



ETI-155b 8 ohm, 100 W dummy load using non-inductive resistors.

WHEN IT COMES to designing electronic equipment — from the very simple to the very complex — if one asked several designers how they would go about a certain design problem undoubtedly you'd get a different answer from each. Here again, we see a fine example illustrating that old saying — "... there's more than one way to skin a cat."*

The project staff at ETI have spent some considerable time over the past two years developing a variety of amplifiers. The fruits of these labours have been duly published and enjoyed by many readers. However, we've always lacked a *decent* dummy load for such work and have sort of *made do* with such contraptions as a string of one ohm 5W resistors dangled in a tub (plastic!) of water, lengths of electric jug element, etc, etc. Whilst jury-rigging such things is in the finest traditions of electronic design and development, the (more than) occasional mishap is not just a frustrating interruption but often a decided nuisance giving rise to dark mutterings, steam from the ears and shouts of "we'll have to get a *decent* dummy load?!!"

As no doubt many of our more intrepid readers, and/or do-it-yourself audio fanatics, have discovered, such things are hard/difficult/impossible (... delete whichever not applicable) to come by.

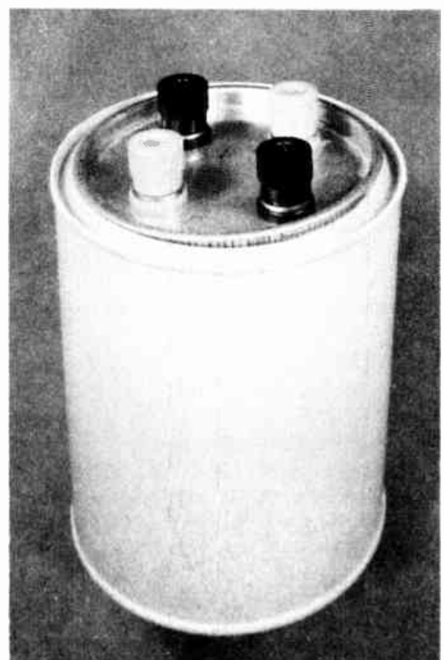
Then, Everest Electronics came to the rescue. Eagle-eyed readers will have seen the item we ran in News Digest in the ETI March '81 issue concerning the *Arcol* range of metal-clad power resistors carried by Everest. When the information arrived, quick as a flash we organised some non-inductive types for a dummy load. Several weeks later two 16 ohm 50 W non-inductive Arcol resistors arrived on the Editor's desk. An hour later we had a working dummy load! Naturally, everybody thought it would make a good project...

In the meantime, a freelance associate of ours, Andrew Kay, had desired exactly the same thing. Andrew, however, went about solving the problem a different way. He purchased a batch of one watt 1% resistors and made a 50 W dummy load. But, he figured, why not have a little more versatility and make two the same, allowing parallel and series connection to obtain a 4 ohm, 100 W dummy load or a 16 ohm 50 W dummy load as well as a twin 8 ohm 50 W dummy load enabling testing of both channels of a stereo amplifier at the same time! Frankly, we don't know why we didn't think of it earlier ourselves.

So — here follows the description of several ways to skin a cat/rockmelon/whatever, or build some high power audio dummy loads.

Multi-resistor method (ETI-155a)

By parallelling resistors of an appropriate value, one can obtain an effective resistance of the wanted value and ▶



ETI-155a 4, 8 or 16 ohm dummy load (50 or 100 W) using 98 390 ohm 1 W resistors.

* *For cat lovers we'll modify that to "... skin a rockmelon", or something similar!*

wattage rating. Now, the cheapest, most common power rating for carbon film resistors is one watt (1 W). To obtain a 50 watt resistor, 50 would need to be paralleled. To obtain an effective resistance of eight ohms, each 1 W resistor would have to have a value of 400 ohms. The nearest preferred value is 390 ohms. Fifty in parallel would give an effective resistance of 7.8 ohms which is about 2½% lower than the ideal eight ohms. However, 49 in parallel gives an effective resistance of 7.959 ohms — less than ½% out. If you require the tolerance of your load to be within 1% or better, then you'll have to use 1%, 1 W resistors. If you only require a tolerance of +/−5%, then the common 5%, 1 W variety will do the job. Either way, you're better off using 49 resistors so that the effective resistance of the load comes closer to the ideal eight ohms.

The dummy load described here consists of two eight ohm loads, which enables the testing of both channels of a stereo amplifier.

The idea itself is not at all new or original, having been used by radio amateurs for years to obtain resistive dummy loads for terminating radio transmitters while they are on test. The advantages of a dummy load for any kind of power source are:

- the power source (in this case an AF power amplifier) is presented with an ideal resistive load of the correct value,
- the chances of damaging expensive loudspeakers during experimental phases of construction are eliminated, and
- completely silent "full power" testing is made possible even for extended periods of time; which is great for public relations and your ears.

Essentially each dummy load consists of 49 high stability 1% metal film resistors connected in parallel to give a terminal resistance of 8 ohms. The author used cheap, readily available Beyschlag type MBE 0414 1 W series. Since the tolerance rating of the resistors is 1%, the upper tolerance limit for the combination is 8.04 ohms and the lower limit is 7.88 ohms. The number of resistors to be bought was a compromise between the desire for a result of exactly 8 ohms and the need to keep the cost to a minimum. Obviously, larger numbers of resistors could be used (say 70 x 560 ohms in parallel) and the reader can easily vary the circuit to suit the pocket and availability of the resistors. The resistors used in this project can be obtained from Crusader Electronic Components at 81 Princes Highway, St. Peters NSW, for about 6¢ each. This price is for quantities of 100 up, but since the dual circuit uses 98 resistors there is no difficulty here.

Separate terminal posts are provided for each load so that two separate 50 W sources can be terminated in 8 ohms each or the two halves may be connected in series to give a single 16 ohm 50 W load; and last but not least parallel connection of the two halves will result in a 4 ohm 100 W load. Because metal film resistors are used there are no inductive effects to worry about such as could occur if wirewound units were employed. The stray capacitances present are so low as to be insignificant.

Construction is simple, if somewhat tedious. Lots of soldering is involved! The author used two ordinary household tin cans; one can has a lid (e.g: a coffee tin) the other is a smaller one of the throw-away type (baked beans etc!). The top and bottom of the smaller can were used as soldering planes for terminating the ends of the resistors while the larger can was used to house the project with the lid carrying the terminal posts. Since the coffee tin is virtually leak proof you could fill it with some kind of insulating fluid such as transformer oil and thereby increase the dissipation capability of the dummy loads.

Tin-plated steel is very easy to solder but the sharp edges are dangerous to careless fingers. Blank copper clad printed circuit board could be used instead but does not withstand heat as well as the plain metal sheet.

The arrangement of tin cans may not seem very glamorous but it is highly effective and very cheap — the whole cost of the project comprises about $7 for the resistors and about $2 for the terminal posts. The tin can housing can be spray-painted and the terminal posts labelled and marked to suit individual needs.

Before starting choose a medium sized coffee tin with a resealable lid for the case and select a tin can of smaller diameter which will fit easily into the coffee tin. About eight or nine centimetres in diameter should be fine for the smaller tin can. Using a can opener remove the top and bottom of the smaller can and discard the contents (maybe you should eat the contents — but that's really outside the scope of ETI!). Also, discard the remaining cylindrical portion of the can! Mark up one of the tin-plated discs so obtained with a grid of ten by ten lines as shown in Figure 1 to give 100 intersections.

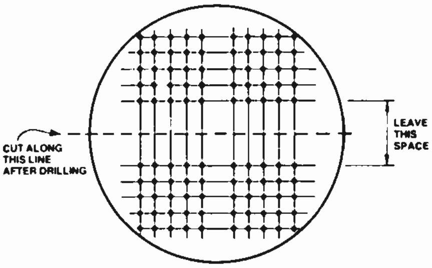


Figure 1. **Drilling and cutting details for the tin-plated discs obtained from a small can.**

Allow a space of about 10 mm along one diameter as shown. This will allow the discs to be cut in half later. Clamp both discs together onto a drill bench or a block of wood, ensuring that they are exactly superimposed. Drill a hole on each intersection of the previously marked lines. Make the holes slightly larger than twice the diameter of the resistor leads; this will assist assembly later on. Take care that your hands are kept clear during drilling since if the drill bit grabs, the two tin discs will whirl around very much like a meat slicer, and almost as sharp! Only 98 holes are needed so don't get carried away.

When the holes are drilled, cut the two discs along the middle space left along one diameter so that you end up with four half discs each with 49 holes. Tin the area around each hole with solder and proceed with assembly.

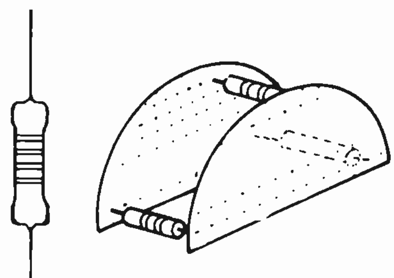


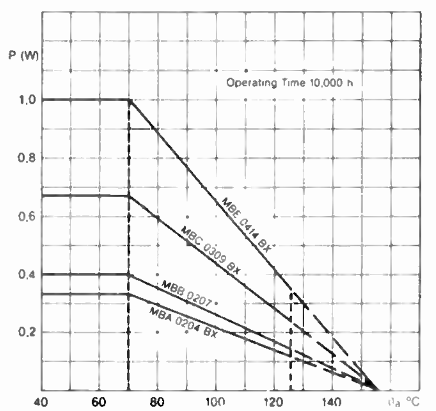
Figure 2. **Cut the resistor leads as shown at left and then solder three resistors to two half-discs as shown to make a rigid assembly.**

Trim all the resistor leads as shown in Figure 2 so that one lead is longer than the other on each component. Take two matching half-discs and using three resistors assemble a rigid structure as shown in Figure 2. Insert the resistors, one row at a time, in between the two tin plates with the leads poking through the holes. If you insert the longer lead of each resistor into its hole first, the other end should be short enough to allow manoeuvring into the hole in the second plate. After one row of resistors is in place solder all the leads of that row on both plates, then proceed with the next row.

Repeat the assembly for the second half of the unit then trim all excess leads flush with the surface of the tin plate. Using a stiff brush (e.g: an old toothbrush) scrub the soldered surface with methylated spirits to remove deposits of flux.

Connect an ohmmeter between the plates of each load — the reading, believe it or not, should be pretty close to 8 ohms. Inspect all solder joints and re-solder if the reading is not correct. Install the four terminals in the lid of the coffee tin using one red and one black terminal for each half of the unit. Lay the two assembled resistor pads side by side as shown in Figure 3. Using fairly stiff copper wire connect the upper plates to one terminal each. Use the same colour terminal for both plates as this will be important later if the loads are to be connected in series or parallel. Using the same sort of wire, but insulated, connect the lower sides of the resistor assemblies to the other two terminals. You should finish up with an assembly which will be supported under the lid of the coffee tin and which is so positioned as to allow it to be inserted into the container and for the lid to be sealed.

To prevent the two halves of the load from shorting together, install an insulating spacer between them using a scrap piece of copper-clad board or matrix board. If using the pcb material, ensure that enough copper is removed to insulate the two halves from each other. If using the matrix board, you will have to drill a couple of additional holes and use small screws to attach the spacer to ▶



The upper curve in this graph shows the typical dissipation characteristics of the Beyschlag resistors used in the ETI-155a dummy load. Power dissipation is derated at operating temperatures above 70°C.

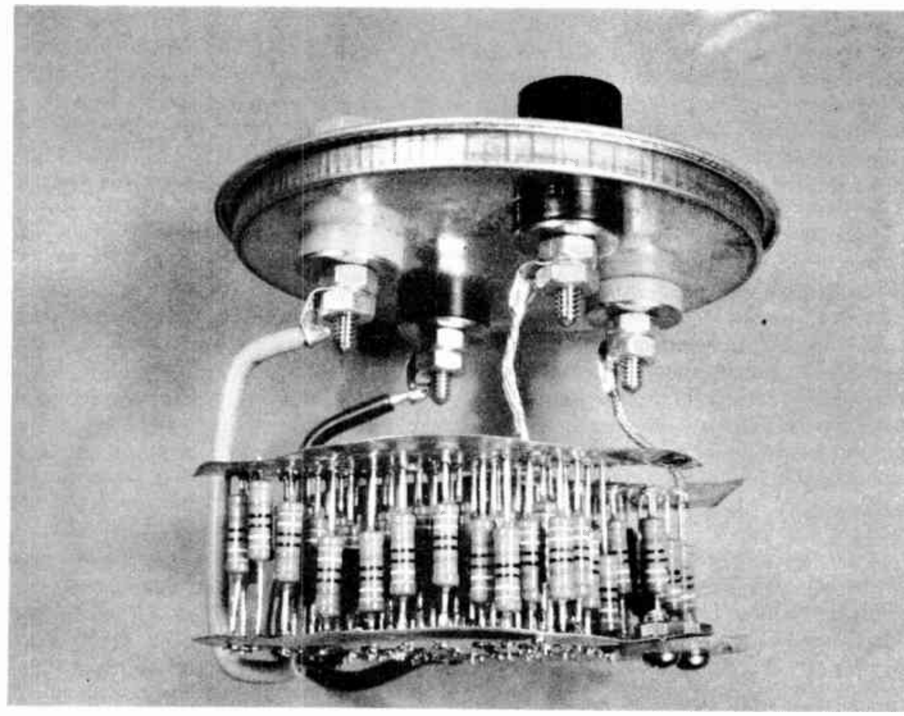


Figure 3. **The two half-disc pairs are assembled side-by-side and heavy gauge wire soldered between the discs and the terminals. An insulating spacer of matrix or pc board holds the two assemblies apart.**

the resistor assemblies.

Before inserting the assembled unit into the coffee container, mark the lid to indicate which terminals are connected by the resistive pads.

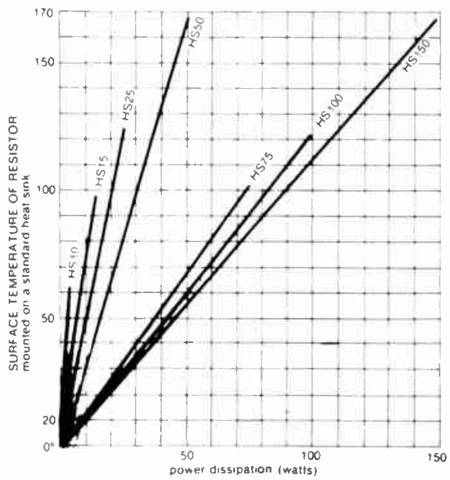
To test the unit, connect each load across a known working amplifier or if this is not convenient, use a car battery (not more than 12 V) as the driving source. If using an amplifier, connect an ac voltmeter across the load under test. If you can use a sinewave generator to drive the amplifier, all the better. Adjust the amplifier volume control to give about 10 to 15 volts across the loads. Check by feeling the resistors with your hand that they are in fact warming up. Increase the output of the amplifier until the voltage across the loads is about 20 volts. This should result in the resistors getting quite hot after a couple of minutes.

If using a car battery, connect the two loads in parallel and connect the battery across them. Check the current drawn; it should be approximately 3 A with a 12 volt battery.

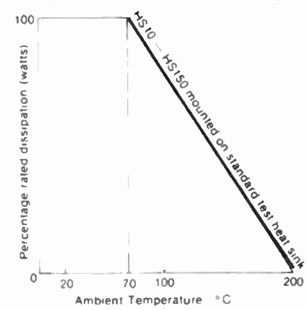
When testing is satisfactorily completed, install the whole assembly into the coffee container and press down the lid. If you plan to use the loads continuously, fill the container with insulating oil before assembling.

Metal-clad resistor method (ETI-155b)

This has to be just about the world's quickest project! Two 50 W, 16 ohm Arcol resistors connected in parallel were used, as a single 8 ohm, 10 W resistor is more expensive. The Arcol resistors have two diametrically opposed mounting tags drilled to take 6 BA bolts. We mounted them on a short (71 mm) length of heatsink obtained from Autotron Australia, of P.O. Box 202, Glen Waverley 3150 Victoria. We understand a number of component suppliers keep stocks of this product.



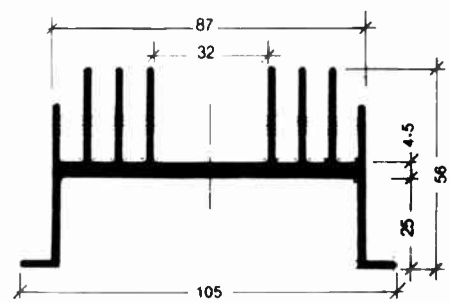
Temperature-dissipation characteristics of the Arcol metal-clad resistors. The curve marked 'HS50' applies to the types specified for the ETI-155b dummy load. (Temperatures shown are surface temperatures at reduced dissipation).



Power derating graph for the Arcol resistors.

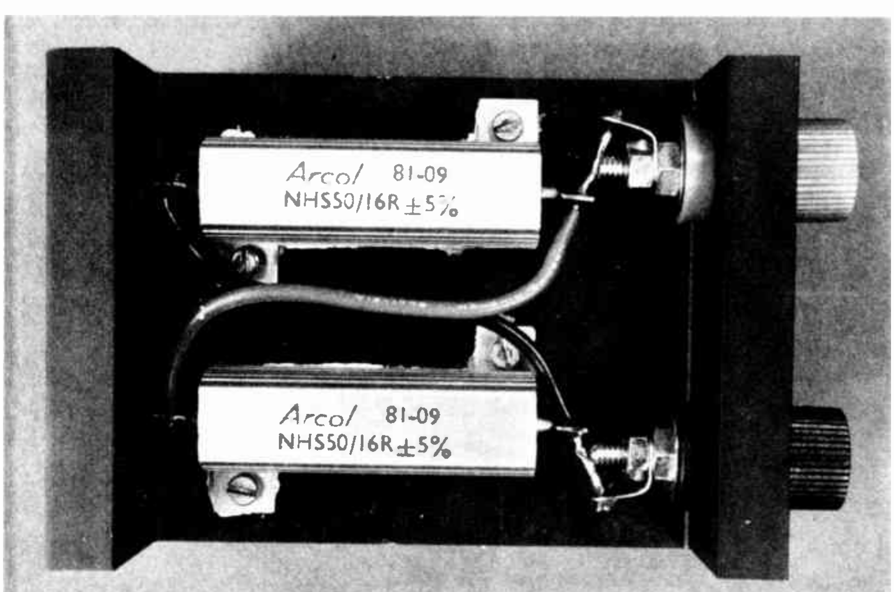
We chose it because its shape is very convenient for this application but almost any suitable heatsink on which the Arcol resistors can be comfortably mounted will suit.

The two resistors are mounted in the 'well' beneath the fins, positioned such that the securing bolt holes do not foul any of the fins. The photograph makes this clear. Two large terminal posts are mounted on one side to provide convenient connections and the resistors are wired in parallel in the manner shown in the photograph.



Cross-sectional profile of the Autotron type XA heatsink used for the ETI-155b dummy load. This style of heatsink is obtainable in a variety of lengths.

With the heatsink used, at a dissipation of 100 watts, the heatsink temperature rapidly rises and will reach 150°C after some minutes! Fan cooling keeps it within bounds, but if you expect to use the dummy load for lengthy periods then a larger section of the Autotron heatsink or whatever you wish to use is recommended. To keep the resistors at 70°C or below, (their maximum temperature at full dissipation before derating) we suggest either a single 500 mm length (standard size, natural finish) or two 200 mm lengths (standard size, black anodised). ●



The ETI-155b assembled — the world's quickest project!

PARTS LIST — ETI 155

ETI-155a
98 x 390R, 1 W, 1% or 5% carbon resistors.
4 x large binding posts, two black, two red.
Tin cans to suit — see text; high current wire (see text and pics).

ETI-155b
2 x Arcol 16R, 50 W, 5% non-inductive resistors, type NHS50.
2 x large binding posts, one black, one red.
Heatsink (see text); high current wire (see text and pics).

Price estimate

ETI-155a	**$7 - $9**
ETI-155b	**$18 - $22**

Note that these are **estimated** prices only and **not** recommended prices. A variety of factors may affect the price — cost price movements, whether you use 1% or 5% resistors, type of heatsink employed, etc, etc.

Five-mode logic pulser probe

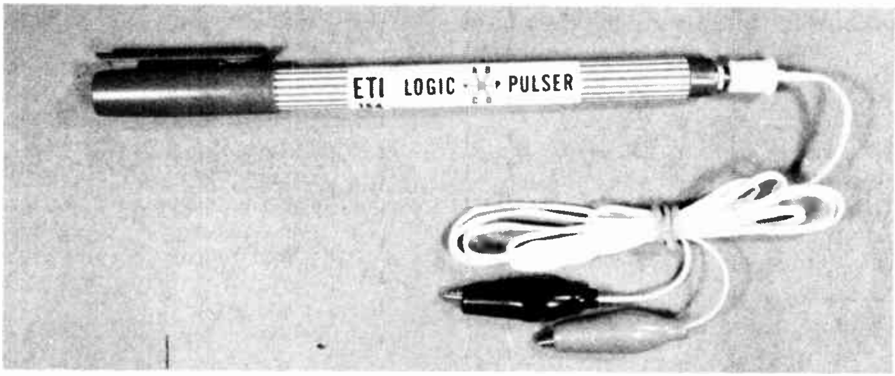
Undoubtedly, one of the most useful and convenient test instruments for designing and trouble-shooting digital circuitry is the logic probe. However, regardless of its sophistication it can only observe the circuit under test. The solution to this problem is a logic pulser used in conjunction with the logic probe.

Philip J. Jones

A LOGIC PULSER is an instrument which injects pulses into a digital circuit. These pulses are of opposite state to the point being injected and are of very short duration to avoid damage to the logic element whose output is being forced to the opposite state. Ideally, both single pulses and pulse trains of various frequencies should be available.

The logic pulser has many uses. Say, for example, a four-stage binary counter is suspected of being faulty. A pulse to the reset pin will reset it; single pulses are then fed to the clock and the four outputs are observed with the logic probe. Any counting fault will become evident as the various counts are cycled through. If a seven-stage counter is under test, the pulses are most conveniently injected in the form of a pulse train of the required frequency. Further examples will suggest themselves during use.

The pulser described here operates from a wide range of supply voltages and is compatible with both CMOS and TTL ICs. It has five modes: a single pulse mode and four pulse trains of frequencies 1, 10, 100 and 1000 Hz. The frequencies are largely dependent on the supply voltage, but in practice a precise value is not required. Single pulse injection and mode selection are achieved through the use of a touch switch. Briefly touching the switch injects a single pulse, whilst touching the switch for more than one second advances the pulser to the next mode. The current mode is shown on an LED display.

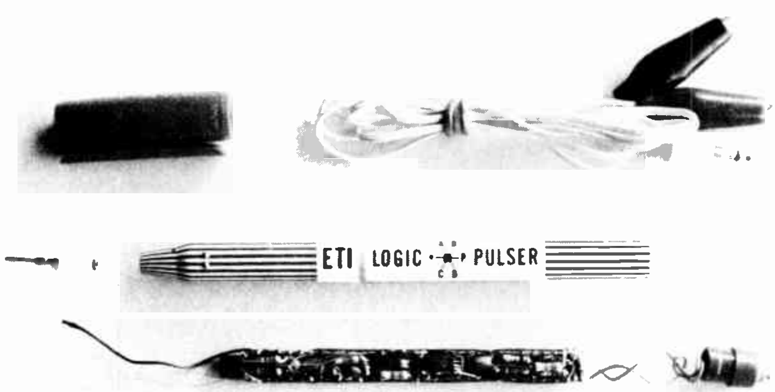


The completed probe — smart and business-like!

Pulse width is 4 μs, which represents a compromise between the much shorter width acceptable for normal IC inputs and the longer width required for, say, an interrupt to a microprocessor. The pulser obtains its power from the power supply of the circuit under test, which is assumed to be sufficiently regulated and filtered.

Construction

Construction of the pulser is largely left to the reader due to the varying nature ▶



The completed probe — but disassembled! No pc board is used, the components are wired directly together.

SPECIFICATIONS ETI-154

- CMOS or TTL compatible
- Supply voltage: 5 to 15 volts (18 V max.)
- Output impedance: approx. 10M
- Pulse width: 4 μs
- Five modes:
  - — single pulses
  - — four pulse trains of approx. frequencies 1, 10, 100 and 1000 Hz
- Current mode displayed on seven-segment LED display
- Pulse injection and mode selection by single touch switch

of pulser housings, etc, although a detailed description of the prototype construction is given for those who wish to make a normal pen-sized pulser. Many of the details given will be applicable to most forms of construction.

The pulser housing used was a Pilot "Ball Liner" pen obtainable from stationery stores, which has a length of 120 mm and an internal diameter of 8.5 mm. Whatever housing is chosen it is essential that it be made of plastic or a similar non-conducting material.

Direct point-to-point wiring has been employed in favour of a printed circuit board due to the prohibitive amount of space a board requires. To give the components the necessary support, a unique construction technique has been used. It involves the use of the ICs themselves to form the base for construction!

Firstly, the narrow part of the IC pins are cut off and the remaining stems are pushed up tight against the IC package. Then the corners of the top face of the IC are rounded. This is most easily done with an electric sander or grinder.

PARTS LIST — ETI-154

Resistors .... all ¼W, 5%

R1	390k
R2	2k2
R3	1M
R4, R7	10M
R5	6M8
R6	680R
R8	1M2
R9	100k
R10	10k

Semiconductors

IC1	4081
IC2	40106
IC3	4017
IC4	4016
Q1, Q3	BC548
Q2	BC558
D1	1N914 or similar
LED.D	Small, common-cathode 7-segment display

Capacitors

C1, C2	150n/16V tantalum
C3	220n/16V tantalum
C4	10p ceramic
C5, C6	2n2 ceramic

Miscellaneous

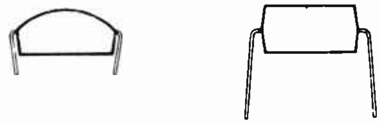
Twin lead with black and red alligator clips or E-Z hooks; 2.5 mm plug and socket (optional); pulser casing, tip, and two pins.

Price estimate

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

$9 - $11

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.



To fit inside the small pen barrel, each IC has the top ground down to a round shape and the pins cut back, as shown.

Finally, the IC packages are glued end-to-end with epoxy resin or other suitable glue. This procedure is really quite straightforward and is illustrated in the diagrams on page 60.

Now, a note on the vulnerability of the CMOS ICs involved. CMOS technology has come a long way since it was first introduced and as a result the chance of an IC being damaged by the above procedure is very small. Nevertheless, as a safeguard against later disappointment, it is advisable to check the ICs at this stage.

The next step is to mount the components and wire up the circuit. As far as the components themselves are concerned, they are best purchased over the counter so that the smallest of each can be selected from the supplier's stocks. It is surprising how much the size can vary of, say, tantalum capacitors of the same value from the same manufacturer. The hookup wire should be the single strand, plastic-coated type and have a total thickness of about 0.5 mm.

The component leads should be bent and cut before soldering with a minimum of solder. It is important to hold, rather than press, the components in position while soldering, as joints soldered under stress may come apart. With care, all the components including the LED display can be mounted on top of the IC base except for the output transistors and the zener diode, which are best mounted at either end. The transistors may be filed down to make fitting easier.

At this stage, the unit should be tested. Upon applying power, segment 'd' should light up, and briefly touching the two touch wires should result in a pulse at the output. Advancing to the pulse train modes should result in the corresponding LED segments lighting and the corresponding pulse trains appearing at the output. Finally, after the 1 kHz pulse mode, the pulser should return to the single pulse mode. If some, or all, of these functions fail to work correctly, read the circuit description and track the fault down with a multimeter or logic probe. The most likely faults are incorrect wiring and dry joints.

With the pulser now functioning correctly, construction of the housing can proceed. This involves providing a window for the LED display and fitting the contacts for the touch switch. The display window can be provided as follows: drill an oversized hole with diameter, say, 4-5 mm. Insert a soft, transparent plastic disc (the plastic used in Kodak slide boxes is ideal) of sufficient diameter to ensure a tight fit. Due to the curvature of the housing, the disc will have protruding edges which can be trimmed with a razor blade. Finally, a paper label with the correct sized window cut in it can be fixed over the disc with Contact or a similar transparent, adhesive plastic covering. The circuit should be fitted in place before the plastic disc is positioned. The purpose of the oversized hole masked by the correct-sized paper window is to reduce the precision required when positioning the circuit and LED display.

The contacts for the touch switch are made from two pins. Cut each pin about 3 mm below the head. Then solder fine

HOW IT WORKS — ETI-154

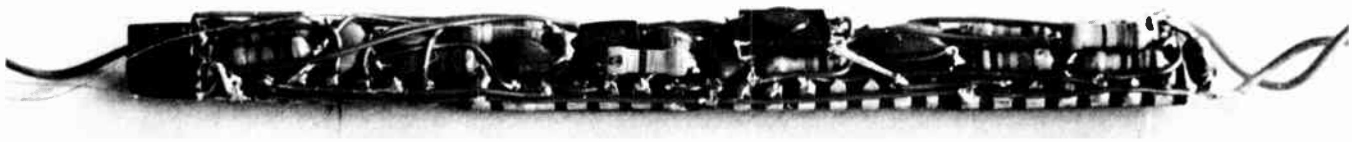
In the single pulse mode, touching the touch switch contacts makes the output of IC2a go low, with R1 and C1 eliminating switch bounce. The output of IC1b then goes low, producing a short, positive pulse at the output of IC2b. The pulse width is determined by R2 and C5 and is approximately 4 μS. This pulse is then fed to the two AND gates, IC1c and IC1d, one of which is enabled and thus switches on the appropriate output transistor. The AND gate enabled is determined by the state of the point being injected. If it is high, the output of IC1a is high, which enables gate IC1d through R3. Thus, TR3 turns on and injects the required negative pulse. The complementary situation occurs if the point being injected is low. The RC combination, R3 and C4, prevents the pulser from responding to its own pulses. Base resistors are not required for the output transistors due to the very short pulse width.

In the single pulse mode of operation, the zero output of the 4017 is high, which closes switch IC4d, thereby disabling the Schmitt oscillator. However, touching the switch for more than one second charges C2 sufficiently to cause the output of IC2e to go high, which advances the 4017 counter. Switch IC4d opens and IC2f begins to oscillate at 1 Hz. The square wave at the output is fed to the remaining input of IC1b and hence a 1 Hz pulse train is injected.

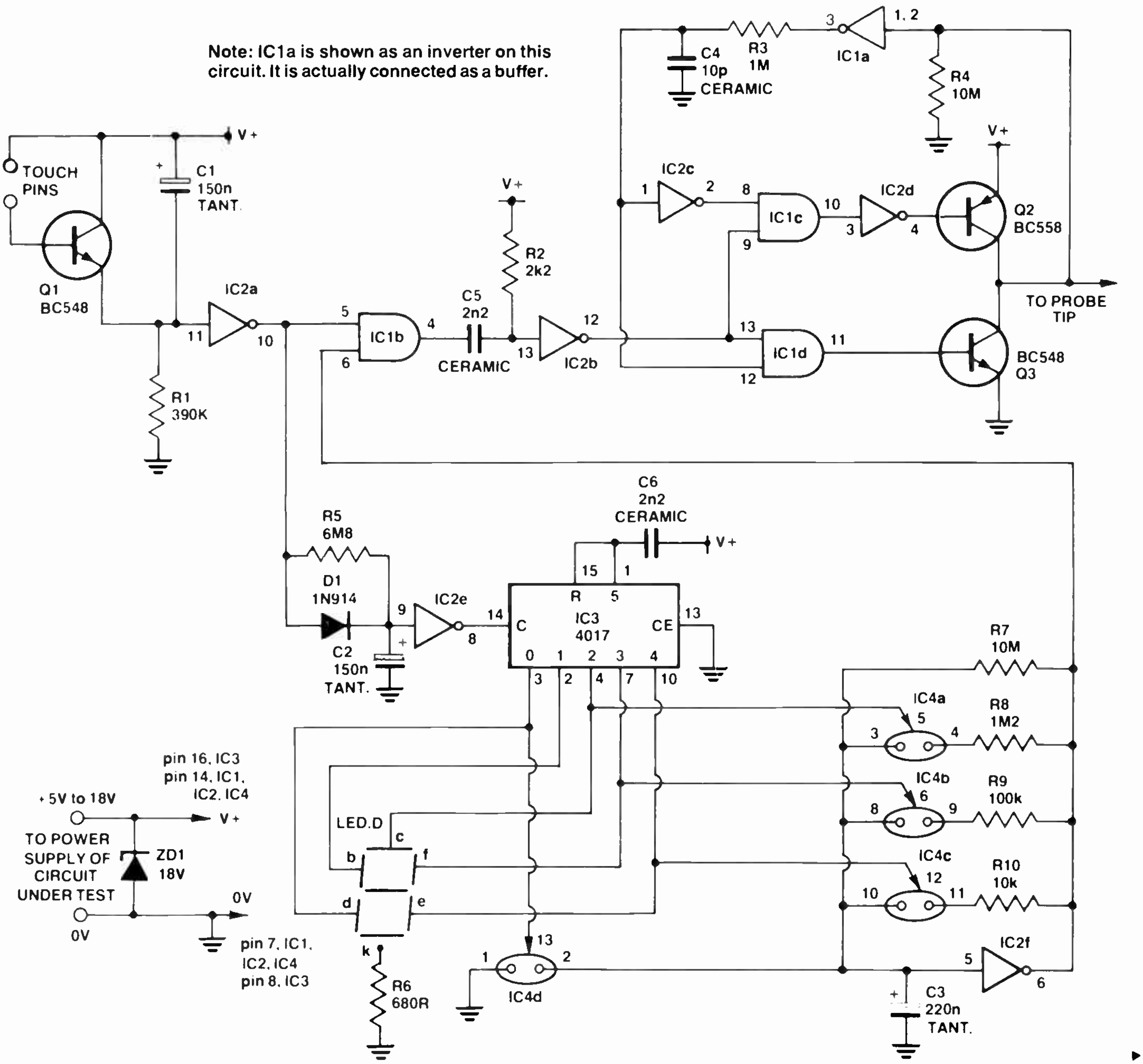
Further advancing the counter increases the pulse frequency by switching in resistors R8 to R10. The counter outputs are also used to drive a seven-segment LED display, which indicates the current mode. The '5' output (pin 1) from the counter is connected to the reset input, hence returning the pulser to the single pulse mode. Capacitor C6 ensures that the pulser will come on in the single pulse mode when the power is applied.

Zener diode, D1, provides overvoltage protection and reverse polarity protection should the power be incorrectly applied.

logic pulser probe



Close-up of the completed unit. Connections to the probe tip and the touch contact pins are to the left, power supply connections to the right. All the components are wired directly in place and small gauge insulated hookup wire used for interconnections. The ICs are glued end-to-end to form a solid 'base'. This form of construction is only necessary if you wish to construct the unit and house it in a pen barrel as the author has done. Otherwise, matrix board could well be used to support the components.



enamelled or silk-covered wire to the bottom of the cut pins, ensuring that the resultant joint is not appreciably larger in diameter than the pin itself.

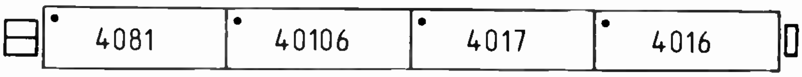
Drill two holes of appropriate diameter and spacing in the housing near the tip. Feed the wires from the pins through the holes and out the tip end and push the pins in position. Lightly touching the pinheads with a clean iron tip will set them in position.

The pulser tip used in the prototype was a gold-plated pin from a computer plug. It certainly looks the part, but a metal darning needle or similar object could equally well be used. The original plastic tip from the pen can be drilled to fit the tip chosen and the whole lot glued at the appropriate stage.

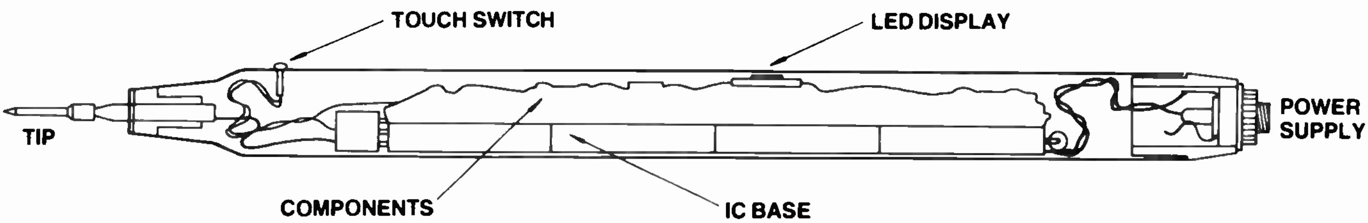
The circuit can now be positioned. The two wires from the touch switch circuitry should be of the type used for the pinheads and both these wires and the pulser tip wire should have lengths longer than the pulser housing. These three wires can be fed through the housing and the circuit then pushed into position with the LED display below the oversized hole. The five wires now protruding from the tip end can be cut to 20 mm length and the four touch wires paired, soldered, insulated, and pushed back into the housing. The remaining wire is soldered to the pulser tip, which is then glued in place. The LED display window is completed as previously described.

The two power supply leads are terminated with a 2.5 mm socket.This enables leads of various lengths with various clips to be substituted; however, the use of the plug and socket is optional.

The logic pulser is now complete, and will find many uses, in both designing and trouble-shooting digital circuitry. ●



Positioning of the ICs, bottom view. The dot indicates pin 1 on each.



Location of the components inside the pen barrel.

Project 157

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.

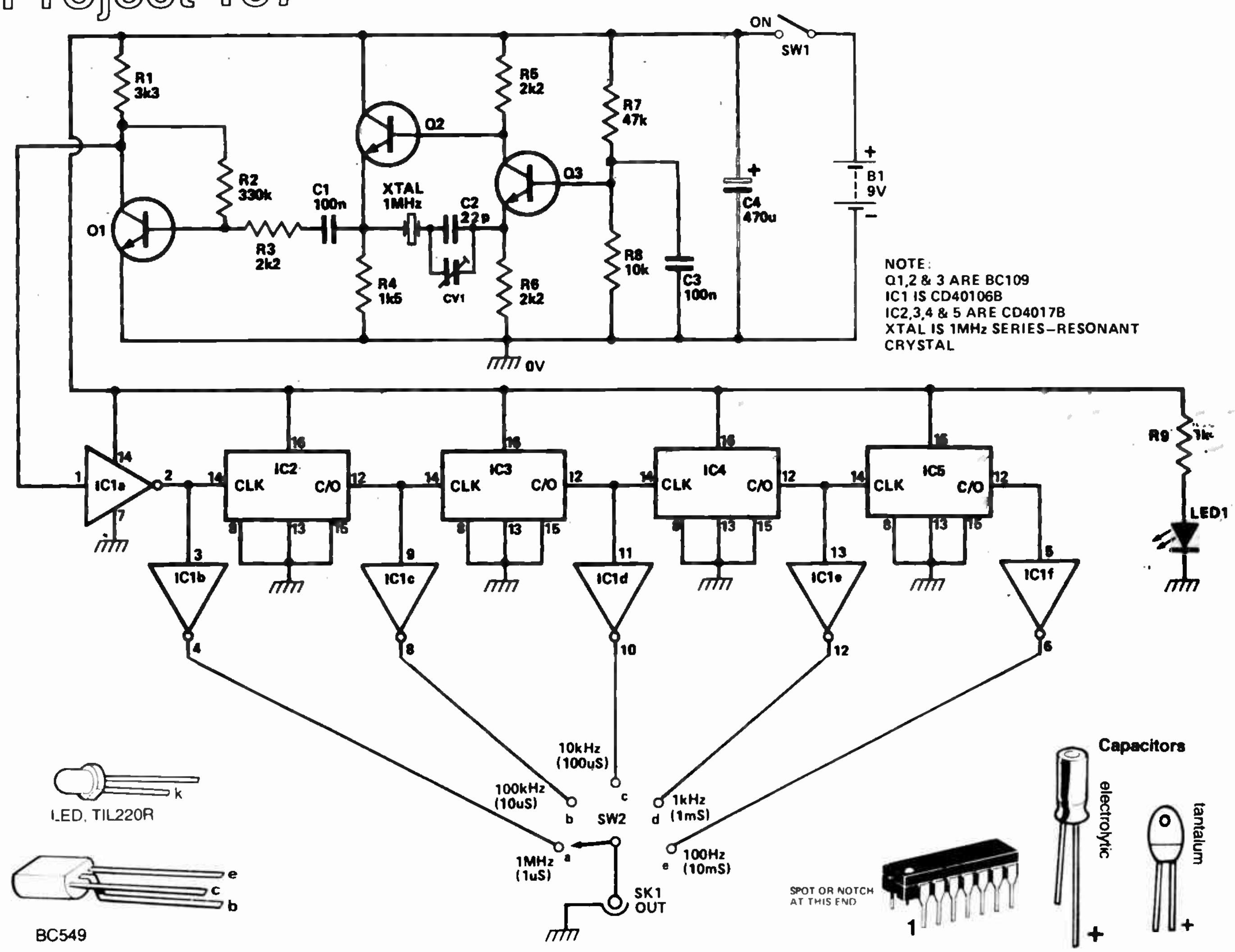
This marker generator can also be used to calibrate the timebase oscillators of frequency counters and period timers simply by plugging the marker output into the counter's input and setting the timebase frequency to obtain the correct display!

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.

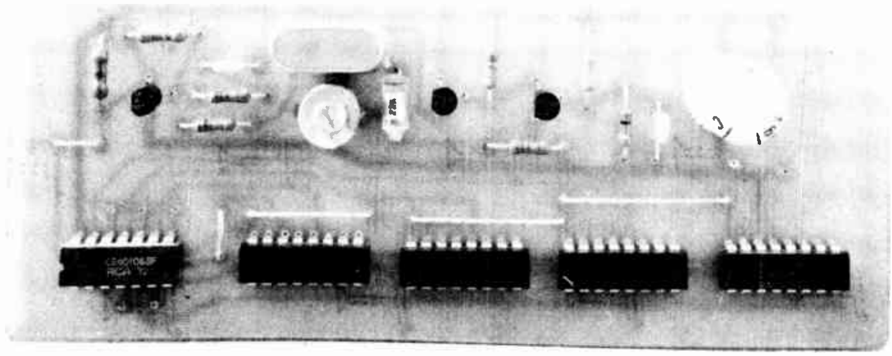
The crystal oscillator comprises Q2, Q3, R4 to R8 and C3. The circuit is an aperiodic Butler oscillator. Q2 and Q3 form an amplifier with the output linked to the input via the crystal. Positive feedback only occurs at the series resonant frequency of the crystal where the phase shift of the crystal 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 52, 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

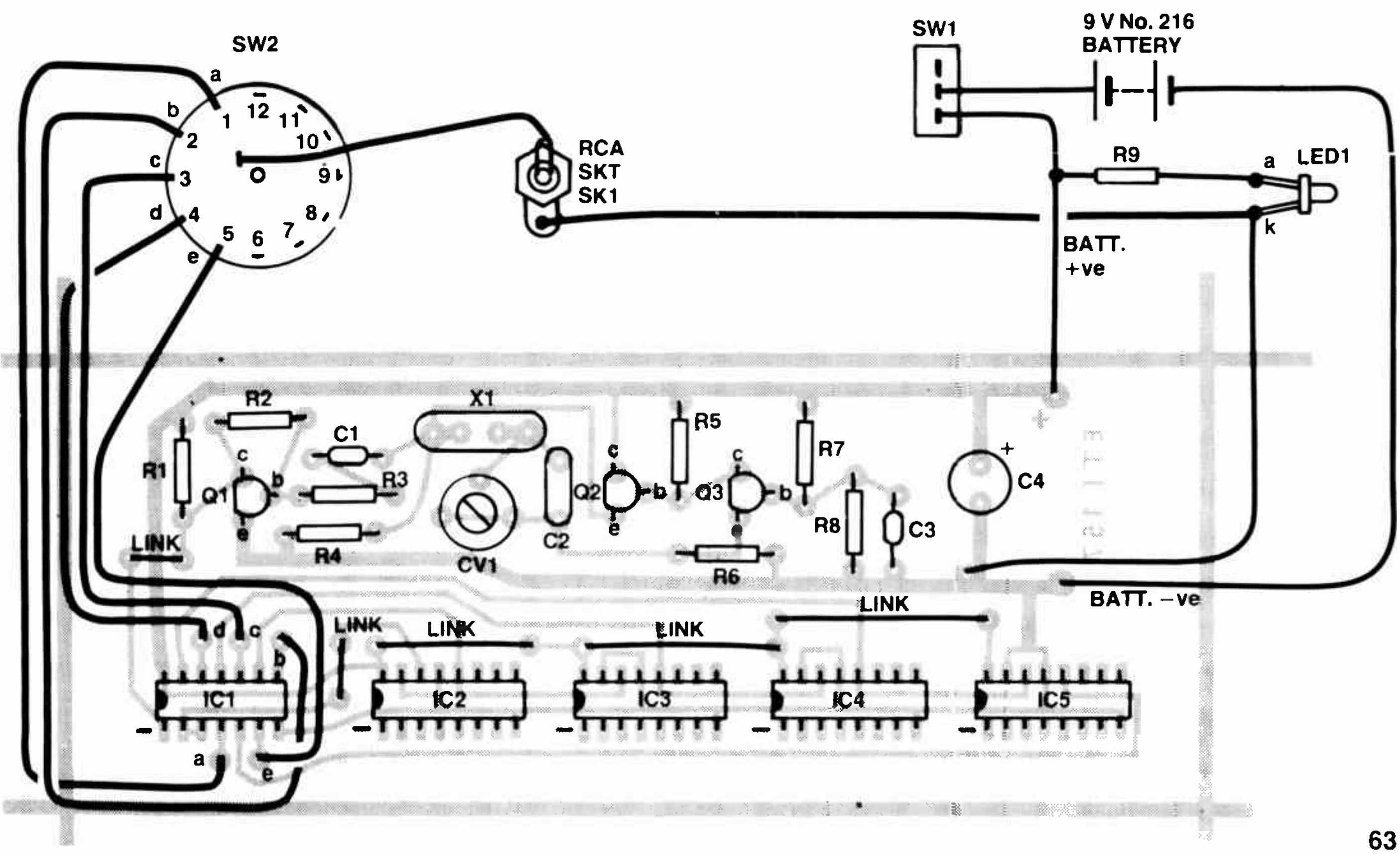
Miscellaneous

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! ●

Test meter measures resistance from 100 ohms down to 0.005 ohms

At some time or another, every practical electronics hobbyist will need to measure a low-value resistance that the ordinary multimeter can't cope with. This project, which has applications in many situations, solves this problem.

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

THERE COMES a time in the life of every person involved in electronics in a practical way when the need to measure a resistance outside the range of common multimeters arises. What do you do? Some squint at the scale of their analogue multimeter and guess that the needle, close as it is to the end of the scale, is somewhere in 'the ballpark'. Others stare at the LCD display of their digital multimeter and despair as it reads "00.2 ... woops, 00.3 ... um, 00.2" etc. At this stage you can resort to a power supply to drive some current through the resistance to be measured and use your multimeter to measure the voltage drop across it. If you can read 1 V on your multimeter with sensible accuracy you'll need to drive two amps through a half ohm resistance. And that's not a good idea for a transformer winding rated at 200 mA, for example.

This project solves the difficulties generally experienced when you try to measure low value resistances. It has applications in many situations. When paralleling power transistors or three-terminal voltage regulators, for example, 'ballast' resistors are required so that each device in the circuit shares the load current equitably. These ballast resistors generally have values much less than one ohm, sometimes less than one-tenth of an ohm (0.1 ohm or 0R1). You can make a rough estimate of the length of copper wire of a particular gauge necessary to make a resistance of the desired value, simply from the published ohms/metre data on the wire gauge, but several pieces of wire cut to the same length from the same reel will not be the same resistance, and the actual resistance may be 20% or more different from the value required, owing to variations in the composition of the wire, diameter, etc. With our Low Ohms Meter, you can cut them to the value required and be assured of the result.

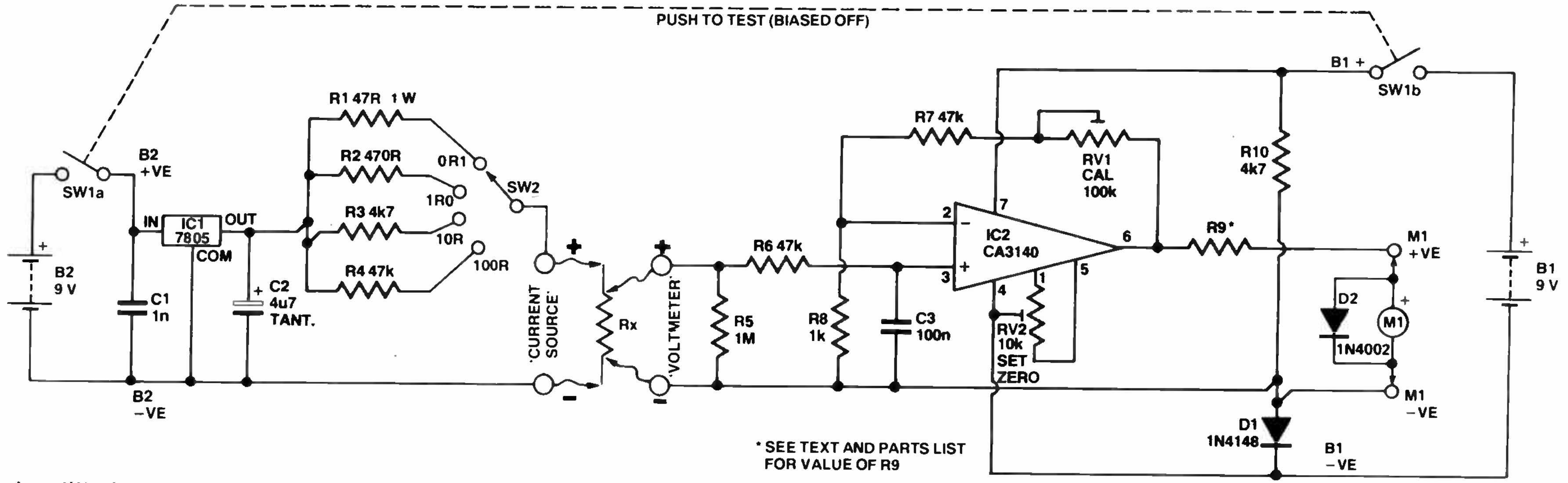
Other applications are: measuring the resistance of transformer windings, measuring the resistance of cable joints, measuring the resistance of tracks on printed circuit boards, etc.

Design

The instrument consists of a multi-range current source and a dc millivoltmeter. The measuring method is known as a 'four-terminal' technique and it has the advantage of eliminating the effect of the leads connecting the instrument to the resistance to be measured. The current source provides a predetermined constant current that is 'driven' through the resistance to be measured. The voltage drop across the unknown resistance is then measured with a high input impedance dc millivoltmeter. The meter reading is directly proportional to the resistance being measured. This gives a linear scale, which is an advantage. The maximum current supplied by the current source is about 100 mA (only on the 0R1 range), which is quite safe in the majority of circumstances encountered.

SPECIFICATIONS — ETI 158

Ranges (full-scale):	100R, 10R, 1R0, 0R1
Resolution:	0.05 of full-scale reading (0.005 ohms on 0R1 range)
Accuracy:	2.5% of full-scale reading or better (depends on meter used)
Maximum test current:	100 mA (approx.) (0R1 range)
Minimum test current:	100 uA (approx.) (100R range)



The dc millivoltmeter has a full-scale sensitivity of 10 mV. The current source provides a current on each range such that 10 mV is developed across an unknown resistance of the maximum value in each range. This four-terminal technique is widely used in precision measurement applications.

How does the instrument ignore the effect of the resistance of the connecting leads? Well, let us examine the worst case — say we are attempting to measure a resistance of around one-tenth ohm. The range switch (SW2) will be switched to '0R1'. This selects R1 to limit the maximum current to be supplied from the voltage regulator IC1, which provides 5 V. Now, if each lead from current source terminals to R_x has a resistance of half an ohm, a total resistance of one ohm will be connected in series with R_x. If R_x is one-tenth of an ohm (0.1 ohm or 0R1), then the total resistance placed across the current source terminals will be 1.1 ohms. As this is in series with R1, the current now flowing through R1, the leads and R_x will be given by:

HOW IT WORKS — ETI 158

The unit contains two separate circuits — a constant current source and a dc millivoltmeter. The constant current source drives a suitable current through the unknown resistance (R_x). The current can be selected by means of a switch (SW2, the 'range' switch). The consequent voltage drop across the unknown resistance can then be measured with the dc millivoltmeter. As the resistance of R_x is directly proportional to the voltage drop across it, and the current driven through it is known to be a constant, the meter scale may be calibrated directly in ohms (or fractions of an ohm).

The constant current source is quite simple and comprises B2 (9 V), IC1, R1 to R4, SW2 and associated components to the left of R_x in the circuit diagram. IC1 is a 7805 three-terminal, 5 V positive regulator. Capacitors C1 and C2 provide high frequency stability. Resistors R1 to R4, selected by SW2, set the current that flows in the unknown resistance, R_x. When the '0R1' range is selected, the current (limited by R1) will be around 100 mA. When the '1R0' range is selected, R2 will limit the current to around 10 mA ... and so on, through the ranges. Now, on each range, the value of the unknown resistance, R_x, will be very much lower than the value of the current limiting resistor (R1, R2 ... etc), by a ratio of around 500 to 1. The voltage drop across R_x will also be much, much lower than the output of IC1. Consequently, the test current from the current source is virtually independent of both lead resistance and the unknown resistance. On the '0R1' range, a total lead resistance of one ohm between the 'current source' terminals and the resistance being measured will only introduce an error of 2%. On the '100R' range, the same lead resistance will introduce an error of only 0.002%. The accuracy of the instrument is principally determined by the tolerances of R1 to R4 and the meter accuracy.

The dc millivoltmeter is based on a CA3140 FET input op-amp. This IC has the advantage that it will respond accurately to dc inputs right down to 0 V. The voltmeter terminals are connected to the unknown resistance so that the meter circuit can indicate the voltage drop across the unknown resistance produced by the current source. The voltmeter circuit has a very high input impedance so that the current flowing into the voltmeter input resistance is very much less than the current flowing through R_x. The voltmeter input impedance is principally determined by R5, a 1M resistor. IC2 amplifies the voltage drop across R_x, its output driving a meter. The gain of IC2 is proportional to the ratio of RV1 plus R7 to R8 and is set to about 100, so that a voltage drop of 10 mV across R_x will produce an output between pin 6 of IC2 and the 'M1 −VE' terminal of 1 V. Thus, whatever full-scale deflection value meter is used, 1 mA or 100 uA, R9 is selected so that the meter actually reads 1 V full-scale deflection. In fact, M1 and R9 may be dispensed with and you could use a multimeter set to the 1 V scale. Diode D2, mounted across the meter terminals, prevents damage to the meter if the unit is incorrectly ranged so as to produce an output from IC2 of greater than 1 V. Being a silicon diode it will conduct when the voltage across the meter terminals rises to about 0.6 V.

So that any dc offset in IC2 can be compensated for, a zero set adjustment is provided. In order to set this accurately, the output of IC2 needs to be driven slightly negative and a small negative potential is developed across a forward-biased diode, D1. Current through R10 biases this diode on.

To accurately set the full-scale reading of the dc millivoltmeter, the gain of IC2 is adjusted by RV1 with a known accurate resistance placed in circuit.

Capacitor C3 bypasses hum and noise at the input of IC2, picked up by the leads from the 'voltmeter' terminals connecting to R_x.

As B2 has to supply up to 100 mA of current, a large-capacity battery is suggested. The dc millivoltmeter circuit only draws a few milliamps and thus a standard 9 V transistor radio battery is all that is required.

$$\frac{5}{47 + 1 + 0.1} = \frac{5}{48.1}$$
$$= 104\ \text{mA}$$

Now, if the lead resistance were zero, the current flowing through R_x will be given by:

$$\frac{5}{47 + 0.1} = 106\ \text{mA}$$

Thus a lead resistance of one ohm between the current source terminals and the resistance being measured will introduce a percentage error of:

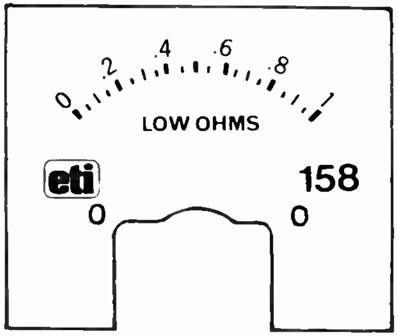
$$\left(\frac{106}{104} \times 100\right) - 100 = 1.9\%$$

Looking at it another way, the ratio of the current-limiting resistor selected by the range switch (R1, R2 ... etc) to the resistance of the connecting leads between the current source terminals and R_x is very high, and thus it is the current-limiting resistor which principally determines the current driven through R_x.

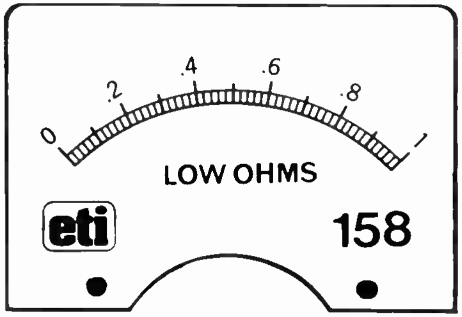
The dc millivoltmeter connects across the resistance being measured. It has an input impedance principally determined by R5, as IC2 is a CA3140 FET input op-amp with an input impedance specified as 1.5 Teraohms (10^{12} ohms!) In the worst case, when using the 100R current source range and measuring a 100 ohm resistor, the dc millivoltmeter input impedance will be 10 000 times larger than R_x and its effect will thus be insignificant. As the dc millivoltmeter is connected directly across the unknown resistance, and not across the current source terminals, the voltage drop across the leads from the current source terminals to the unknown resistance is ignored.

In practice, the accuracy of the instrument will be determined by the accuracy of the meter movement used. Most common, low-cost meter movements are 'Class 2.5' types with an accuracy of 2.5% of full-scale reading.

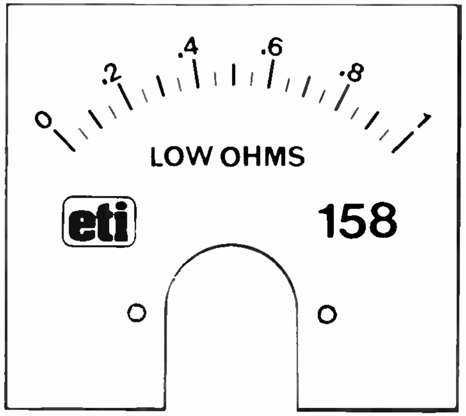
A variety of meters may be used. The common 1 mA movements are inexpensive and there are several models around. Alternatively, 500 uA or even ▶



Scale for the Minipa MU-45.

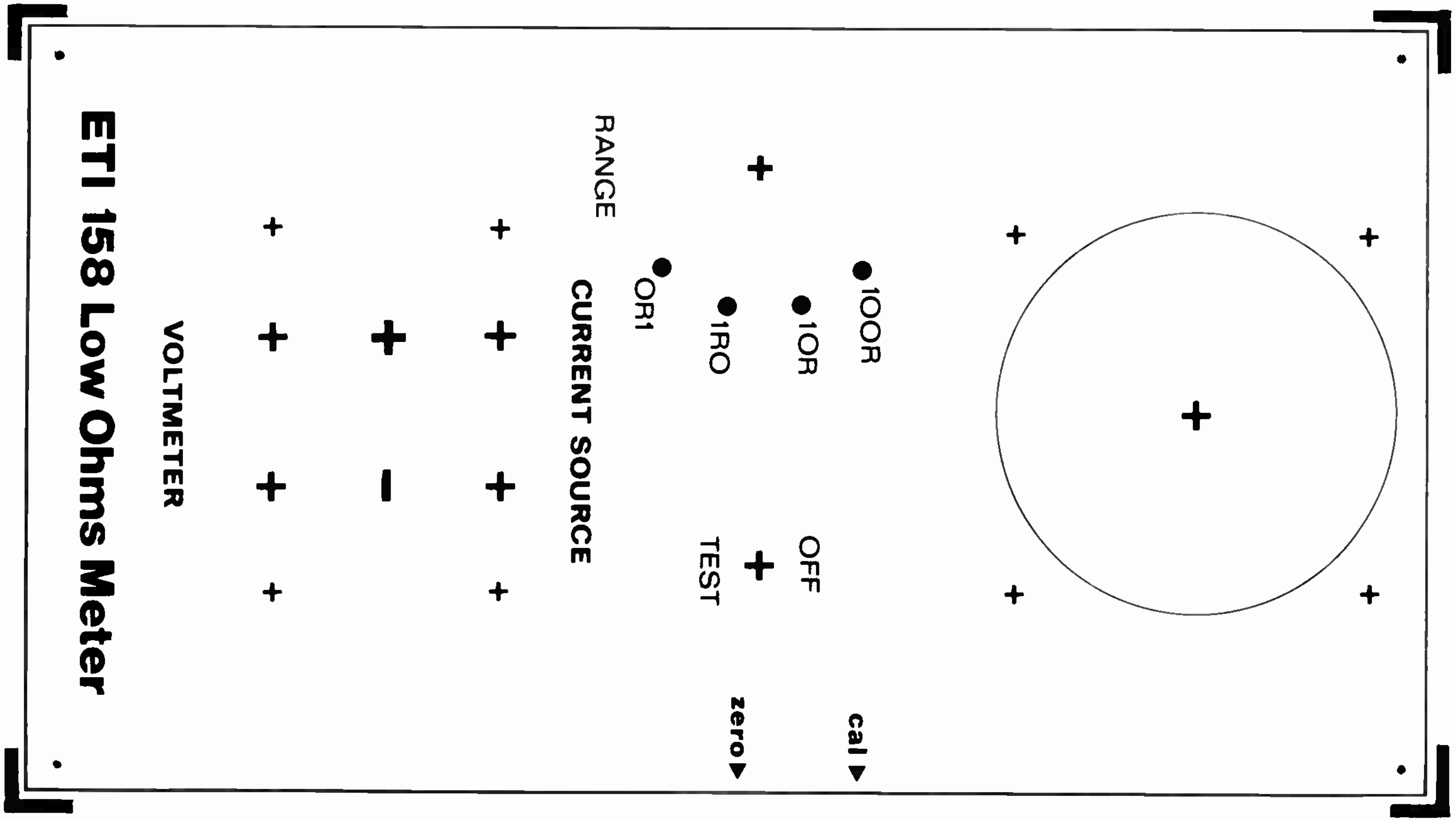


Scale for the SEW ST-65



Scale for the University TD66

Full size artwork for the front panel.



100 uA movements may be used. However, you'll find that different makes in the same sensitivity have different impedances. We used a University TD-66. These have a 100 ohm impedance in the 1 mA movement and a 2k impedance in the 100 uA movement. The Minipa meters in the MU-45 size have a 120 ohm impedance for the 1 mA movement, 1400 ohms for the 50 uA movement. The value of R9 needs to be chosen to suit the sensitivity of the meter movement used. The CAL adjustment takes care of the different meter impedances as the gain of IC2 is set to suit.

For a 1 mA movement with an impedance between 100 and about 300 ohms, R9 should be 820R 1% or 2%. For a 50 or 100 uA movement with an impedance of between 1k and about 3k, R9 should be 8k2 1% or 2%.

Construction

The electronics are contained on a small 50 x 100 mm printed circuit board and the major components are mounted on the front panel of a conveniently sized jiffy box. While we have chosen to mount the electronics on a printed circuit board, layout is not critical and they may be mounted on matrix board, Veroboard, Uniboard or whatever.

If you elect to build your unit in the same fashion as we did our prototype, then the best place to start is with the mechanical work. We dressed up our front panel with a Scotchcal overlay, the design of which is reproduced on page 67. You can use this to mark out the drill hole positions on the jiffy box front panel. Note that the holes for the meter are marked out for a University model TD-66 meter movement. You will have to mark out holes to suit the meter you have if you intend using another type. Centre punch the holes to be drilled and then drill them carefully. Sizes will vary depending on the particular components used so we haven't given any hole dimensions. Note that for the voltmeter and current source terminals we used spring-loaded speaker terminals which are conveniently colour-coded black (−ve) and red (+ve). We drilled holes behind the terminals where the solder connection to each protrudes through the panel — no need to cut slots.

Cutting the meter hole can be a hassle if you don't have a hole cutter. There are several ways to do it. One is to mark a circle on the panel just larger than the diameter of the hole required. Then, using a 3 mm or 4 mm diameter drill bit, cut a series of holes around this ring — each hole overlapping the last. The centre piece may then be pushed out and the edge of the hole cleaned up with a fine-cut half-moon file. Tedious, but it works. Another method again requires marking a hole just larger than that required and then drilling a large hole inside the circle, inserting a 'nibbling' tool and then cutting around the marked circle.

Having drilled the front panel, do a trial 'fit' of all the components that mount on it just to see that nothing needs to be adjusted or holes reamed out, etc.

If all is well, you can take the parts off the panel and then carefully stick the Scotchcal label to the panel and trim the edges. Next mount all the major components in place and orientate SW1 and SW2 so that their operation corresponds to the panel markings.

The pc board assembly may be tackled next. This is quite straightforward and the components may be assembled in any convenient order. Take care though with the orientation of IC1, IC2 and C2. Don't confuse R3 and R10. Note that R3 is a 1% or 2% metal film type whereas R10 is an ordinary 5% carbon type. Likewise, don't confuse R6 with either R4 or R7, as the former is an ordinary 5% carbon type and the latter two are metal film 1% or 2% types. Note that the two trimpots mount with their adjusting screws facing off the end of the pc board. Having completed the pc board, check it and then you can tackle the wiring from the board to the major components on the front panel.

Take care with the wiring to the voltmeter and current source terminals that you get the +ve and −ve connections the right way round. Note that diode D2 mounts on the meter terminals. Also make sure that you wire the meter the right way round. As a variety of switches are available to suit SW2 we have only shown a diagramatic wiring arrangement for this, as the pins may differ between different switch types. The enclosed type, such as those from C&K, have the pole marked 'A' and the switch position marked '1,2,3,4' and they should be wired to conform to the designations on the wiring diagram. The connections to the open type of rotary switch are readily figured out by examination.

Rear view of a C&K four-position switch showing the connections for SW2.

The only other item, or items, to watch concern the battery clip leads — make sure you connect them with the correct polarity.

Having got it all together, check your wiring and you're ready for a test flight. Plug in B1, and with nothing connected to the terminals, operate SW1 ('TEST'). Adjust the 'ZERO SET' trimpot to zero the meter.

Now, obtain a 100 ohm resistor — in fact, it is a good idea to buy a 100R 1% or 2% resistor for calibration use when you buy the rest of the components.

Plug in B2 and connect your resistor to the current source terminals. Take two leads with alligator clips on one end and connect the voltmeter terminals to the resistor — watch the polarity. Set the range switch to 100R and operate SW1. Now, adjust RV1 ('CAL') so that the meter reads full-scale deflection.

Now you're ready to roll, if all is well.

To permit adjustment of the CAL and ZERO trimpots with the project assembled in the case, we drilled two holes in the side of the case to permit access to the trimpot adjustors with a screwdriver. We located the hole positions by temporarily mounting the board in the case and marking the case on the outside where we judged the holes should be. Drill oversize holes and you can't go far wrong!

Assemble the pc board in the case, put the batteries in place and screw on the front panel. Repeat the zero procedure — but first adjust the meter movement mechanical zero, located at the bottom of the meter face. Then calibrate the unit on the 100R range using your 100R calibration resistor. Now you're calibrated and ready for work!

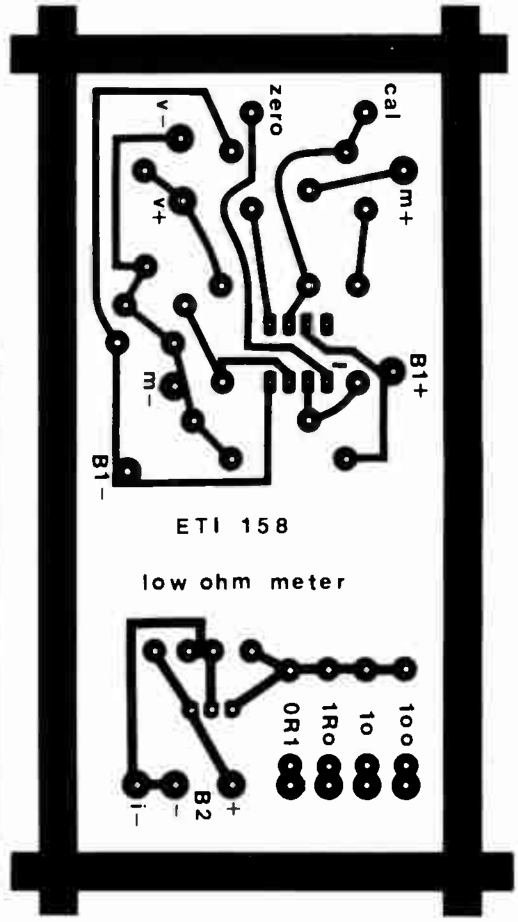
Using it

The 'TEST' switch, SW1, is a spring-return type, so that the measurement current supplied by the current source is only applied for the length of time it takes to make the measurement. This helps to prolong battery life in case you leave the unit turned on and ensures that in applications where the 100 mA maximum test current may cause component heating that it is only applied for a limited period.

In use, always connect the current

source to the unknown resistance with heavy leads that are as short as practicable. The actual connections may well have the greatest resistance, so when using the 0R1 range make sure you arrange good, solid connections to ensure the best accuracy. The voltmeter should be connected with flying leads with clips on the end — always attach the clips across the actual resistance being measured, not across the current source terminals or somewhere on the connecting leads.

To read off resistance, multiply the scale reading on the meter by the setting of the range switch. For example, if the meter reads 0.7 and the range switch is set to 1R0, the value of the resistance being measured is 0.7 ohms, or 0R7. ●



PARTS LIST ETI-158

Resistors

- R1 .... 47R/1 W, 1% or 2%
- R2 .... 470R/½W, 1% or 2%
- R3 .... 4k7/½W, 1% or 2%
- R4, R7 .... 47k/½W, 1% or 2%
- R5 .... 1M/½W, 5%
- R6 .... 47k/½W, 5%
- R8 .... 1k/½W, 1% or 2%
- R9 .... 820R, ½W, 1% or 2% (see text)
- R10 .... 4k7/½W, 5%
- RV1 .... 100k cermet multiturn horizontal trimpot
- RV2 .... 10k cermet multiturn horizontal trimpot

Capacitors

- C1 .... 1n ceramic
- C2 .... 4u7/16 V tant.
- C3 .... 100n greencap

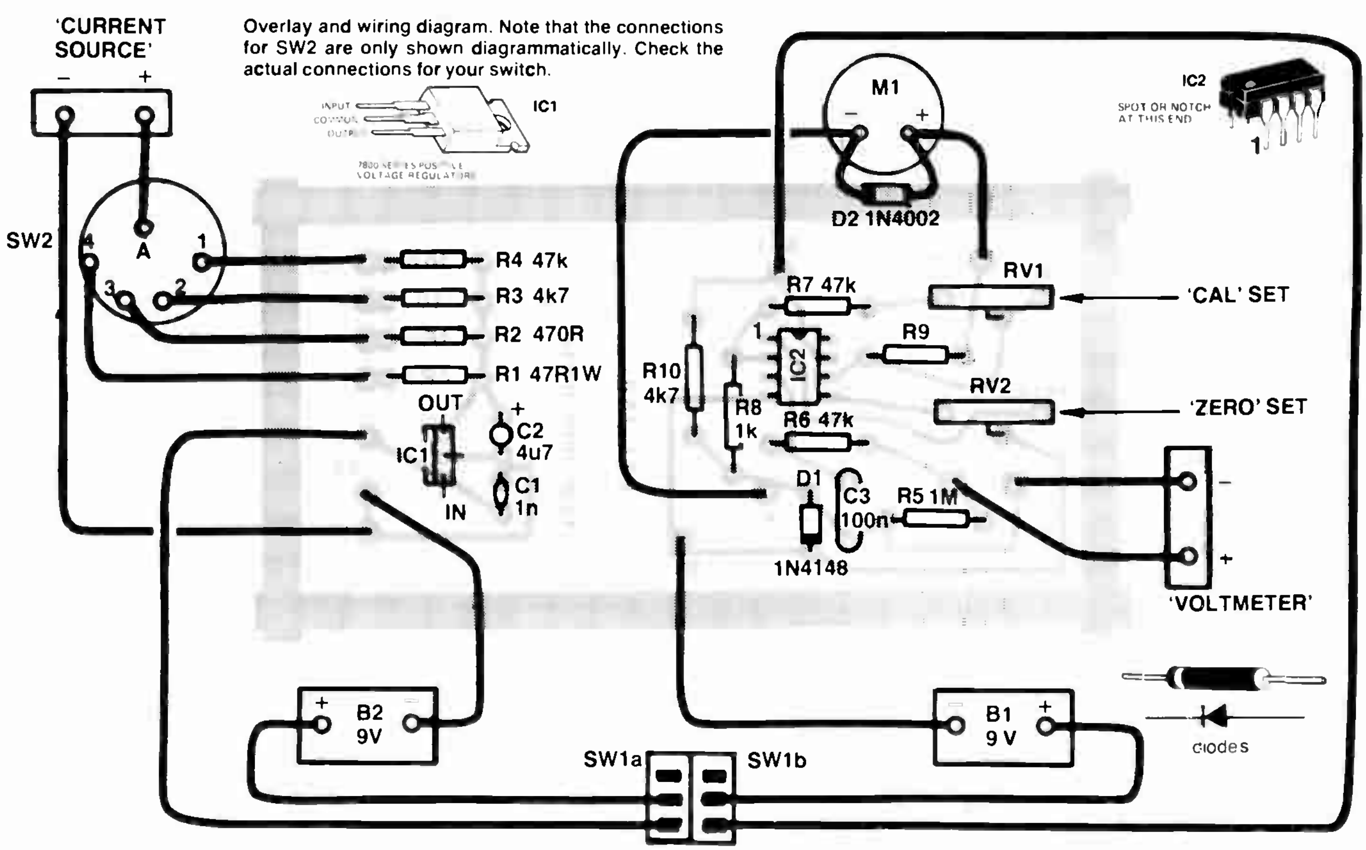
Semiconductors

- IC1 .... 7805, LM340/T5 etc, 5 V reg.
- IC2 .... CA3140
- D1 .... 1N914, 1N4148 etc.
- D2 .... 1N4001, EM401, 1N4002 or sim.

Miscellaneous

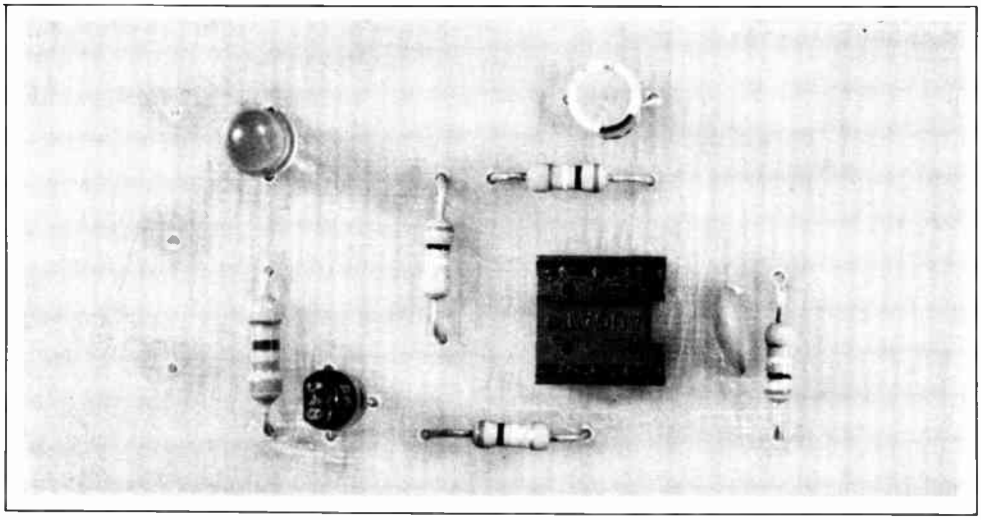
- SW1 .... DPST spring-return toggle switch
- SW2 .... single-pole, four-position rotary switch
- B1 .... No.216 9 V battery
- B2 .... No.276P 9 V battery
- M1 .... TD66 meter 0-1 mA, 100 ohms internal resistance (see text)

ETI-158 pc board; zippy box No. H0102 196 x 113 x 60 mm or similar; Scotchcal front panel and meter scale; knobs; spring terminals; battery clips, etc.



Overlay and wiring diagram. Note that the connections for SW2 are only shown diagrammatically. Check the actual connections for your switch.

Op-amp Tester



Make sure your amps are operational with this handy little device. Suits all commonly used types of IC op-amp.

Designed by Phil Wait

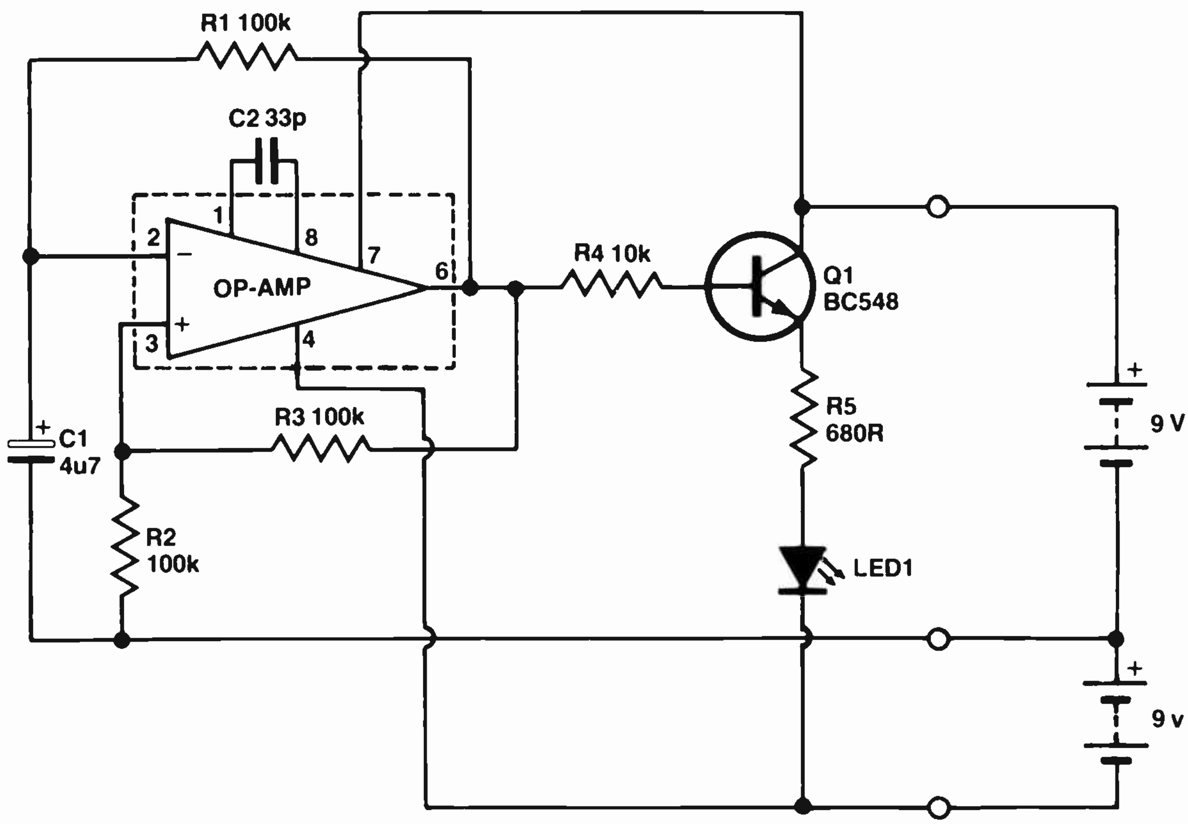
INTEGRATED circuit technology is not absolutely perfect, so chips do occasionally fail. As well as these natural invalids, a great many more ICs are rendered inactive by clumsy soldering, accidental reverse voltage or (with CMOS devices) electrostatic discharge.

If your integrated circuit op-amp has prematurely given up the ghost on you, then the circuit you're using it in won't work, of course. Chances are, when this happens, you'll go all around the circuit looking for bad solder joints, breaks in tracks and so forth. At some point in this procedure it may occur to you to suspect the op-amp, but how can you check up on it? You could put together a little circuit especially to test it, but this is a tedious procedure, to say the least.

How much better if you could just plug your op-amp into a ready-made tester and find out instantly if it's OK or not?

That's exactly what this project will do for you. When a working op-amp is inserted in its socket, our Op-amp Tester turns into a square wave oscillator whose output switches a transistor to pulse current through a light emitting diode about fifty times a minute. This makes the LED flash slowly on and off. If a dud op-amp is plugged into the socket, the LED does not flash.

The Op-amp Tester works with all the commonly used integrated circuit op-amps, whichever kind of package they come in. Only a few very rare types have different pin connections and cannot be tested with this device.



The pcb pattern is on page 76.

Construction

We've designed a printed circuit board for this project because we think that a neat and compact design is best for a unit that's going to be used a lot. However, if you want to use some other method of construction, there's no reason why you shouldn't.

Mount the 8-pin IC socket first. Make sure you mount it with the indent at the right hand side, as shown in our layout diagram. It's important to get this the right way round, because the indent shows you which way to plug in the op-amps you are testing. Like all the components on the printed circuit board, the socket goes on the plain side of the board, with its pins pushed through the holes and soldered to the tracks beneath.

Next mount the resistors and capacitors on the board. The electrolytic capacitor, C1, must be inserted the right way round or it won't work and may even burn up when the batteries are connected. Check with the small diagram to make sure that its positive lead (marked +) goes at the same end as on our layout diagram.

The transistor, Q1, and the light emitting diode, LED1, are the only other components that go on the board, and they must both be inserted the right way round. So check with our small diagrams to see that Q1 has its emitter (marked e), base (marked b) and collector (marked c) in the positions shown on our layout diagram, and that LED1 has its cathode (marked k) at the correct end.

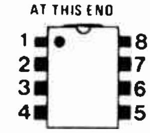
Finally connect the leads from the two battery clips at the points indicated, clip in two batteries and the unit is ready for use.

Using the Tester

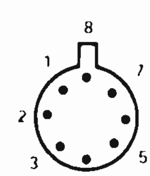
If the op-amp is in a Dual-In-Line package (see illustration below), plug it into the IC socket so that the notch or dot is at the same end as the indent in the socket. If the op-amp is good, the LED will flash, otherwise it will not.

If the op-amp is in a T05 package (see illustration below), there is a tag above one of the pins. This is pin 8. Clockwise around the package (looking down at its top) are pins 7, 6, 5, 4, 3, 2, and 1, in order. The holes in the IC socket can also be numbered clockwise, starting at the indent, from 8 down to 1, as our illustration shows. Bend the leads of the op-amp so that pin 8 fits into hole number 8 on the socket, pin 7 into hole 7 and so forth. Again, if the op-amp is good, the LED will flash, otherwise not.

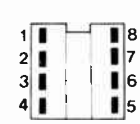
The batteries can be left connected when the Tester is not in use, because it only draws current when an op-amp is in the socket. ■



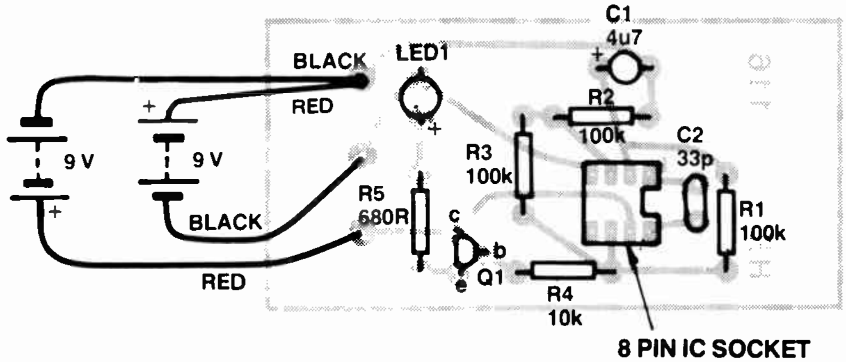
8 PIN DUAL IN LINE PACKAGE
VIEWED FROM ABOVE

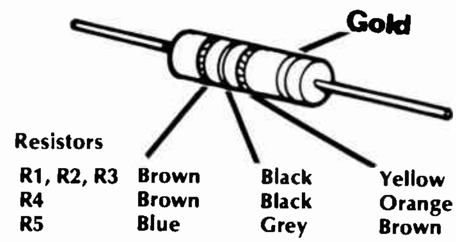


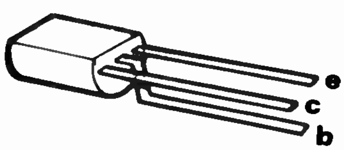
8 PIN T05 PACKAGE VIEWED FROM ABOVE



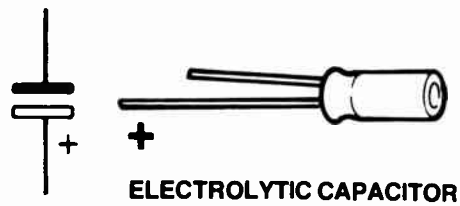
8 PIN SOCKET VIEWED FROM ABOVE



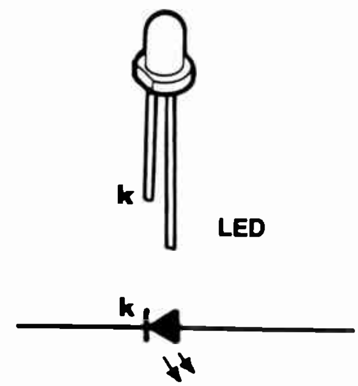




BC548 TRANSISTOR



ELECTROLYTIC CAPACITOR



LED

HOW IT WORKS

When a working op-amp is inserted in the 8-pin IC socket, it completes the circuit of a square wave oscillator, whose output switches a transistor on and off, alternately allowing current through a LED and blocking it off again, so that the LED flashes about once per second.

When the op-amp is first inserted, capacitor C1 is discharged and the voltage on the inverting input of the op-amp (pin 2) is lower than the voltage on its non-inverting input (pin 3). This makes the output of the op-amp (at pin 6) swing up to the positive supply voltage (nominally, +9 volts). Current therefore flows through R3 and R2 and the voltage drop across R3 caused by this current holds pin 3 at about half the positive supply voltage (that is, about +4.5 volts). Current also starts to flow through R1 and C1, charging up C1 and developing a voltage across it that opposes the flow of current.

After a while the voltage across C1 rises above +4.5 volts. Pin 2, the inverting input of the op-amp, is then at a higher voltage than pin 3, the non-inverting input. The output of the op-amp (at pin 6) therefore swings to the negative supply voltage (nominally −9 volts). Current now flows in the opposite direction through R2 and R3 and the voltage drop across R2 holds pin 3 of the op-amp at half the negative supply voltage (nominally −4.5 volts). Current also flows through C1 and R1, so that C1 begins to discharge and then charge in the opposite direction. After a while the voltage across C1 has dropped so low that pin 2 of the op-amp, the inverting input, is at a lower voltage than pin 3, the non-inverting input. The output (pin 6) therefore swings up again to the positive supply voltage and the whole cycle repeats itself. The voltage at pin 6 therefore alternates between about +9 volts and about −9 volts.

This alternating voltage is applied to the base of transistor Q1, so that current between Q1's collector and emitter and through LED1 is alternately cut off and switched hard on, making the LED pulse. Resistor R5 limits the current through LED1, preventing it from burning out.

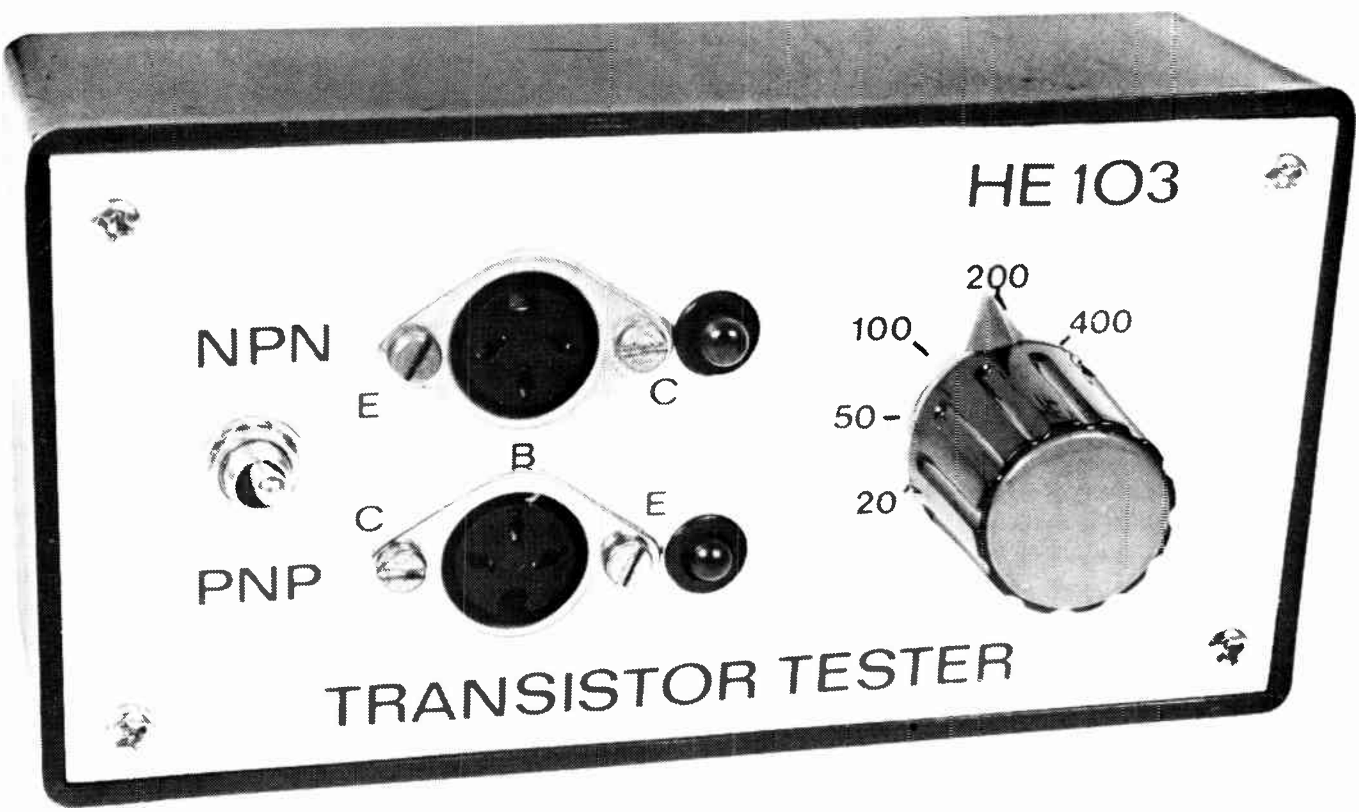
PARTS LIST

RESISTORS	All ½W, 5%
R1, R2, R3	100k
R4	10k
R5	680R
CAPACITORS	
C1	4u7, 25V electrolytic
C2	33p ceramic
SEMICONDUCTORS	
LED1	any LED
Q1	BC548 or similar

MISCELLANEOUS
HE 116 pc board, 8 pin IC socket, two 9 volt transistor radio batteries and clips.

Transistor Tester

This ingeniously simple piece of test gear not only tells you if your transistors are working properly, it even shows you how much gain they have.



UNLESS YOU'RE quite rich and live next door to a component shop, you probably find yourself using the same transistors more than once in different circuits. By the time you've soldered and unsoldered them a few times, you may be a bit dubious about whether they're still working or not. It's nice to be optimistic, of course, but saying "She'll be right" and putting them in anyway could cause you a lot of frustration later if she's *not* right!

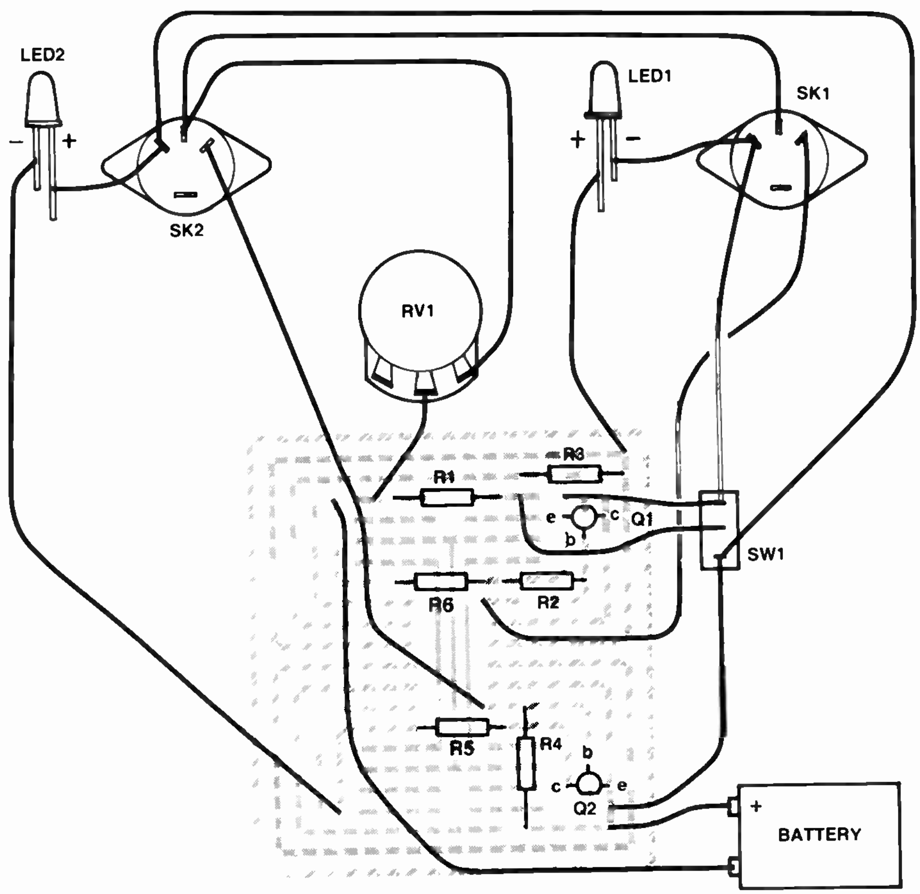
Maybe, too, you have some transistors that you've salvaged from junk boxes. If so, you'd probably like to know if they are still usable and how much gain (amplification) they have.

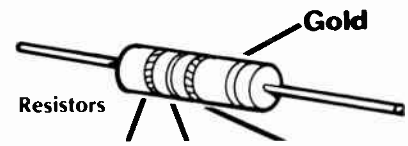
No worries! Our transistor tester will give you the answer in a moment. All you do is flick the switch to NPN or PNP, set the pointer to maximum and insert the transistor leads in the appropriate socket. Then you rotate the pointer and if your transistor is OK a LED will light at some point before you reach zero. The position of the pointer when the LED first lights tells you the approximate gain.

If you're not sure whether your transistor is NPN or PNP, just make a guess and if you get no result, try the other socket. You won't harm the transistor or the tester.

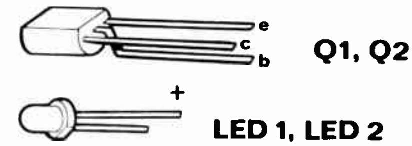
Construction

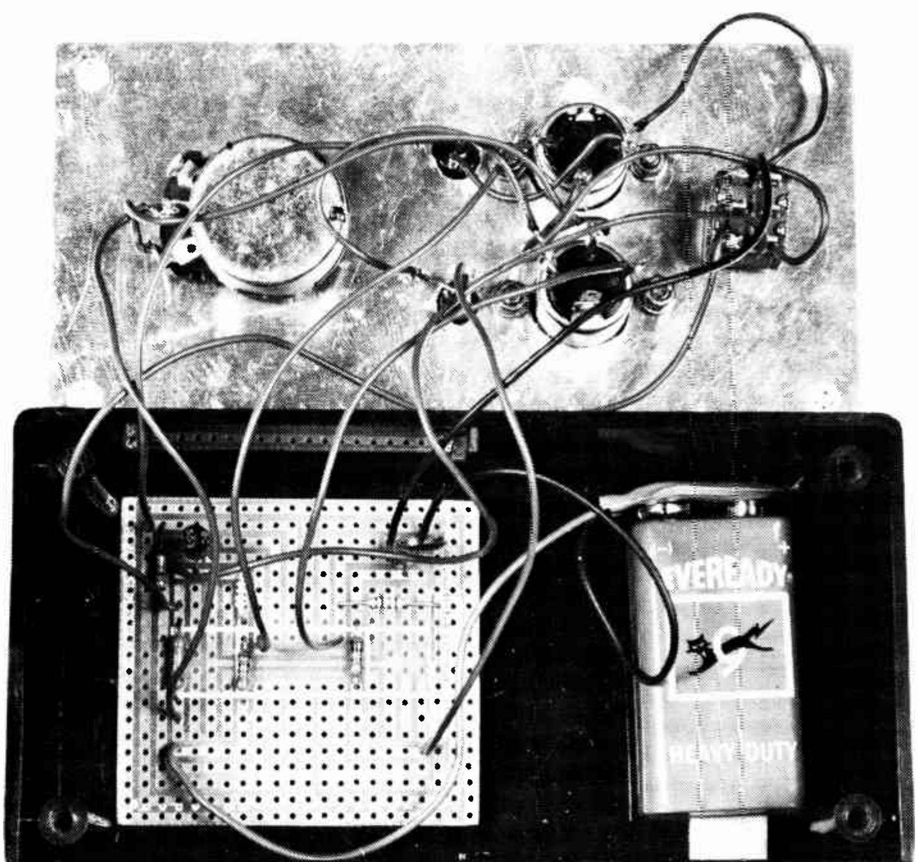
Like many great ideas, this one is very simple. There is only a handful of components and construction is not critical. We built our prototype on Uniboard,





R1	Brown	Grey	Orange
R2, R4	Brown	Green	Brown
R3, R5	Brown	Black	Red
R6	Brown	Black	Brown





Inside the case. The Uniboard and the battery are attached with sticky pads.

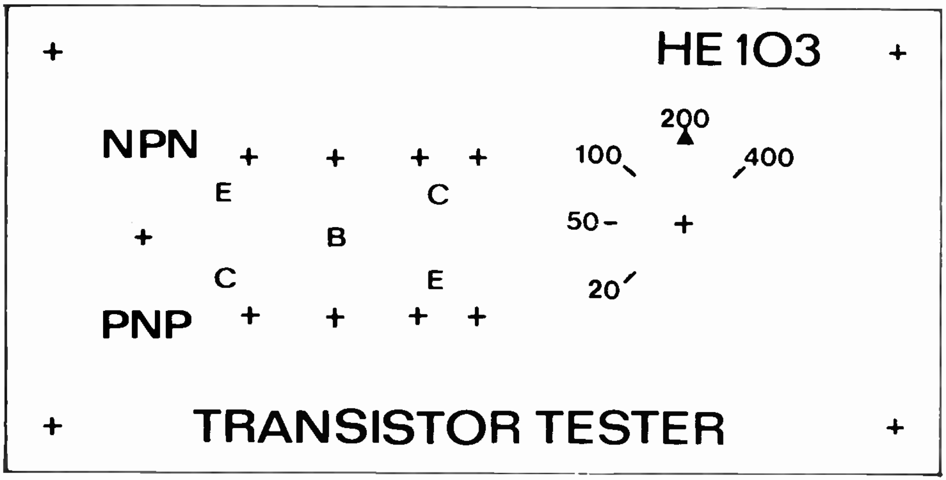
but there's no reason why you shouldn't make yours on matrix board if you prefer.

Uniboard is a relatively new construction aid, which you may not have heard of before. It's a thin square board made out of insulating material and it has an array of holes punched through it. On the reverse of the board is a pattern of conducting metal strips and there's a printed pattern (in yellow and blue) on the front showing where the strips are on the back. Once you've worked out the circuit configuration, you mount the components on the front, inserting the leads through the holes and soldering them to the strips on the reverse. The leads are then cut off short, giving the back of the board a tidy appearance. For simple projects like this, where it's not really worth designing a special printed circuit board, the Uniboard method is neat and compact.

Mount the resistors on the board first, referring to the layout diagram on this page for their positions, then the two transistors Q1 and Q2. Check with the small component lead diagrams to make sure you are soldering them in the right way round.

The rest of the components are mounted in or on the box. We used a plastic 'jiffy' box, but if you don't want to there's really no reason to use a box at all. The unit will work just as well with all components glued onto plywood or even embedded in plasticene! Nevertheless, a box makes for a better-looking unit which is easy to stash away when you're not using it.

Many kit suppliers provide the box with the holes ready-drilled, but some do not. If you have to drill your own holes, use our front panel artwork (on page 75) as a template. Once the holes



PARTS LIST

RESISTORS	(all ¼W, 5%)
R1	18k (1)
R2, 4	150R (2)
R3, 5	1k (2)
R6	100R (1)
POTENTIOMETERS	
RV1	2M2 linear (1)
SEMICONDUCTORS	
Q1	BC559, BC179 or similar (1)
Q2	BC549, BC109 or similar (1)
LED1, 2	Red LED, TIL 220R or similar (2)
MISCELLANEOUS	
SW1	SPST miniature toggle switch (1)
SK1, 2	3-pin DIN sockets (2)

One square of Uniboard, pointer knob, plastic box (130 mm x 65 mm x 40 mm), 9 volt transistor radio battery, battery clip, hookup wire, nuts and bolts, collars for LEDs.

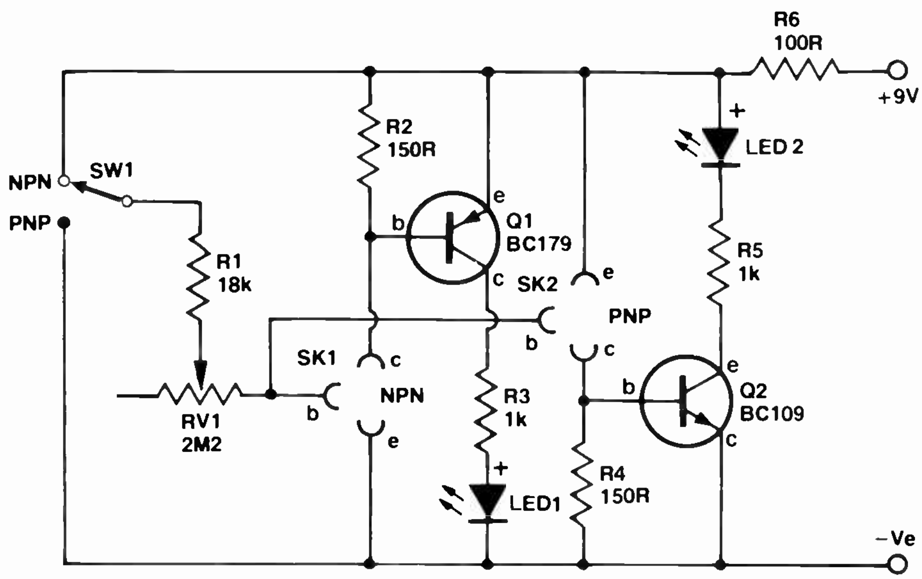
are drilled, stick on the front panel label.

Now mount the potentiometer (RV1), the two LEDs, the switch and the two sockets (SK1 and SK2) in the lid of the box. Begin wiring these components to the board, as shown in the diagram. Check with the small component lead diagrams that you are connecting the LEDs the right way round. You will need to use collars to make sure that they stay in place.

Finally attach a battery to the battery clip and stick it to the bottom of the box using double-sided sticky tape or some other tacky substance. No on/off switch is needed because the unit doesn't draw any current unless a transistor is actually being tested in one of the sockets.

Many transistors will plug directly into the DIN sockets. Of course you need to put the base lead in the hole marked B, the collector lead in the C hole and the emitter lead in the E hole. If you don't know which lead is which, try all the possibilities — there are only six different ways of putting three leads into three holes so it won't take long — you won't damage the transistor or the tester.

For transistors that won't plug in directly you will need to attach wires to the transistor pins and poke these wires in the sockets. People with fewer than six hands will find it a great help to wire up a 3-way DIN plug with three different-coloured leads and attach a crocodile clip to each lead. ■



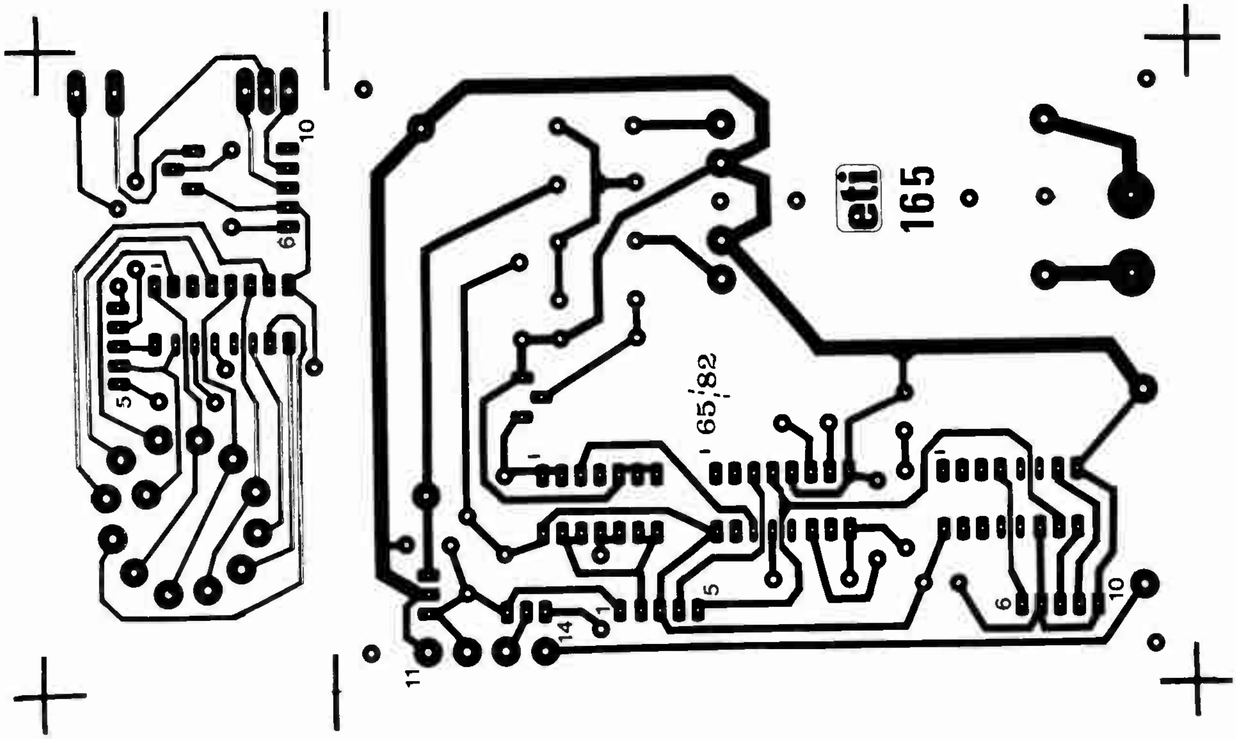
HOW IT WORKS

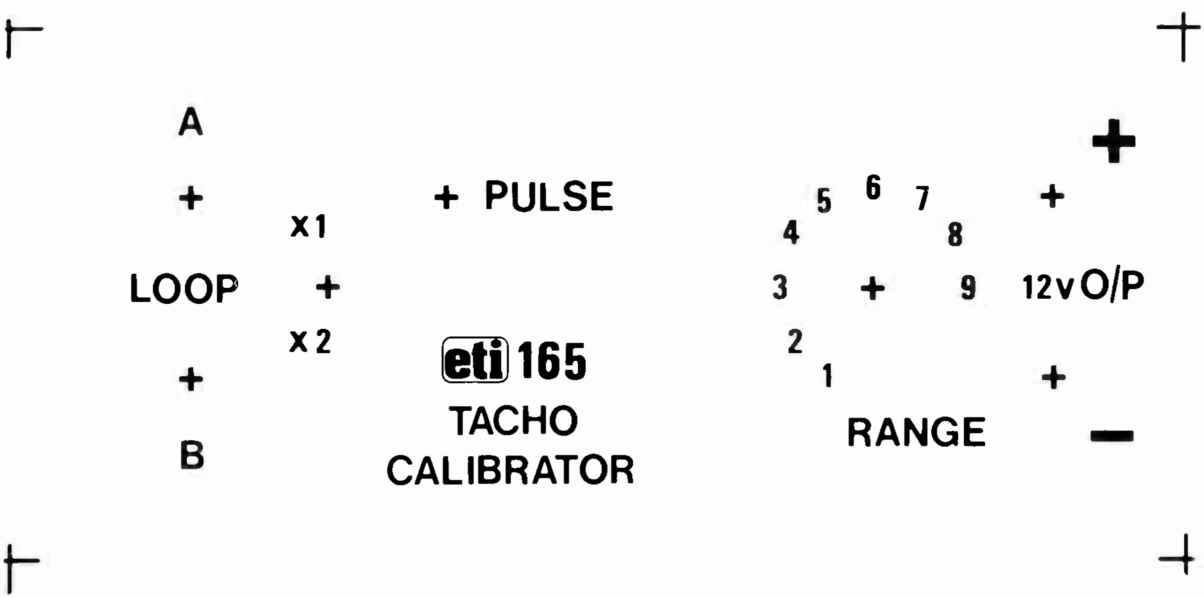
With the switch in the NPN position and an NPN transistor inserted for testing in the NPN socket, current flows from the positive rail through R1 and RV1 and through the base-emitter junction of the transistor under test. If this transistor is good, a larger current will flow from the positive rail through R2 and through the collector and emitter of the transistor. This current causes a voltage drop across R2 and, if this voltage is more than 0.6 volts, Q1 is switched on and current flows through R3 and LED 1, making it light up.

A current of 4 milliamps must flow in the collector-emitter circuit of the device under test before the voltage dropped across R2 reaches 0.6 volts and the LED lights. The magnitude of this current depends on the current flowing in the base-emitter circuit and on the current gain of the transistor under test (collector-emitter current = base-emitter current x current gain). If RV1 is set to its maximum value of resistance, then not enough current will flow to turn on Q1.

As the resistance of RV1 is decreased, the collector-emitter current will increase until it reaches 4 milliamps, at which point Q1 turns on and LED 1 lights. The base-emitter current at this point is equal to the voltage drop between the positive rail and the base, divided by the total resistance of R1 and RV1. Hence the current gain can be calculated. In practice, to save calculation, the scale on the front panel is calibrated to indicate current gain directly.

For PNP transistors the operation of the circuit is very similar. With the switch in the PNP position and a PNP transistor in the PNP socket, current flows from the positive rail through the base-emitter junction of the transistor under test and through RV1 and R1 to the negative rail. If the transistor is good, then at some setting of RV1, the current flowing through its emitter and collector will be sufficient to drop 0.6 volts across R4, turning on Q2 and lighting LED2.


eti 165


A
+
+ PULSE
x1
LOOP
+
x2
+
B
eti 165
TACHO
CALIBRATOR
5 6 7
4 8
3 + 9
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1
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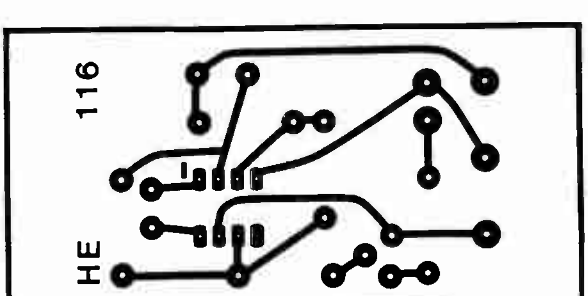
+
12v O/P
+
RANGE
–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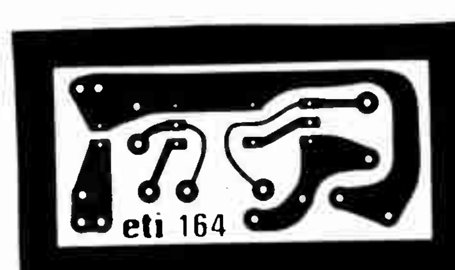

eti 164

Zener diode tester plugs into your multimeter

Geoff Nicholls

This handy little adjunct for your multimeter allows you to read out the actual zener voltage of any zener diode up to 60 volts and will also test LEDs!

EVER DUG INTO a tray of components looking for a zener diode only to find that the markings have worn off? Even a brand new zener is usually marked with a code number giving little indication of the thing you want to know — the actual zener voltage rating. This simple tester will save you thumbing through the data books looking for a 1N4XXX, and allows easy identification of those unmarked diodes.

Most multimeters have a diode check position, but few can test LEDs, let alone zeners. This handy little adjunct for your multimeter allows you to test zeners up to about 60 volts, and can drive enough current through a LED to light it (and give you a reading of its forward voltage drop).

The tester simply plugs into your multimeter (a digital meter is ideal) and gives a direct reading of zener voltage. The circuit uses an inverter to provide a current-limited output of up to 70 volts dc from a nine volt battery. Table 1 shows the output characteristics of the prototype.

The leads on diodes are designated *anode* and *cathode*, the latter being marked by a band. When connected to the tester with the cathode to the black or negative terminal, the multimeter will indicate the diode forward voltage. For a silicon diode this will be about 650 mV while a germanium diode will read around 300 mV. Zener diodes are normally operated in reverse bias and are therefore tested with the cathode (banded end) connected to the red or positive terminal so that the zener voltage is displayed on the meter.

Zener characteristics

The zener voltage rating of a diode is only a nominal figure and should be considered with other parameters when designing circuitry. The first thing to realise is that the zener voltage is rounded to the *nearest preferred value*. Secondly, the voltage rating is dependent on the current passing through the diode. The diode manufacturers usually quote zener voltages at a current of 5 mA for voltages up to 30 volts and at 2 mA above this.

Low voltage zeners will not develop their nominal voltage until the current reaches a few milliamperes. As the diode current is increased the voltage drop will also increase, representing a dynamic resistance which varies from tens of ohms for zeners between six and ten volts, to hundreds of ohms outside these limits.

Lastly, the zener exhibits a temperature sensitivity that varies with zener voltage as shown in Figure 2. A detailed explanation of the temperature characteristic may be found in any solid state physics textbook, the essential features being a negative temperature coefficient associated with true zener breakdown below six volts and a positive temperature coefficient associated with avalanche breakdown above six volts.

It is possible to combine zener diodes with opposing temperature coefficients in order to obtain a near temperature-independent reference, or to use a normal diode (with a negative coefficient) and a zener with the same result.

For further information on practical zener usage, refer to *ETI Circuit Techniques, Vol 1*, pages 136 to 141.

Push-to-read. The tester is housed in a 'zippy' box with banana plugs protruding from the rear spaced to suit the multimeter input sockets spacing.

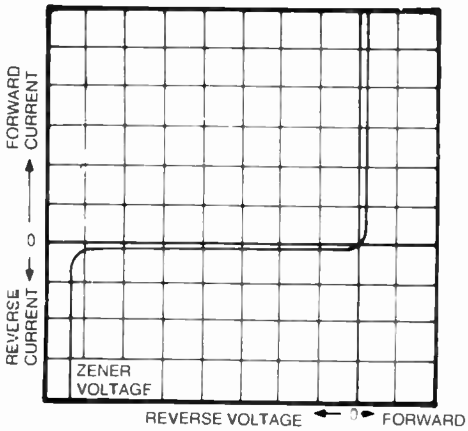


Figure 1. The fundamental characteristics of a zener diode. Little reverse current flows until a certain voltage — the zener voltage — is reached. This voltage is almost constant.

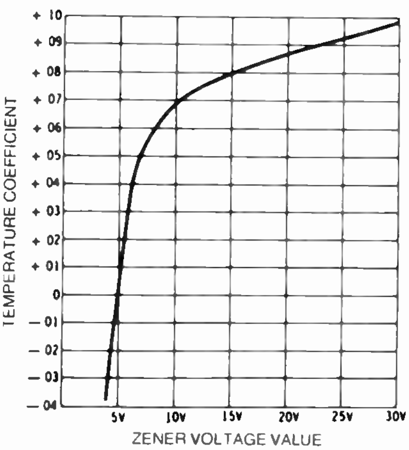


Figure 2. Temperature characteristics of zener diodes — depends on the zener voltage value.

Construction

I built the zener tester into a plastic zippy box with metal lid measuring about 30 x 50 x 80 mm. This is the smallest common low cost box that will accommodate the electronics and battery.

The pushbutton switch is mounted centrally in the lid about 10 mm from one end with the two banana plugs in the box underneath the switch. The spring terminals mount on the other end of the box, as shown in the photographs. You may wish to vary construction to suit the components on hand, but check ▶

TRANSFORMER NOTES

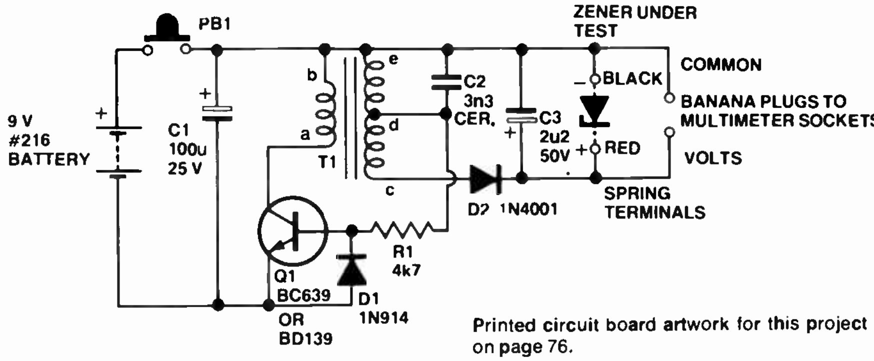
The transformer used in this zener tester is a 'transistor audio transformer'. Two separate types were tested, with virtually equivalent results.

The Dick Smith M-0216, described in the catalogue as being 'primary 1k ohm CT/secondary 8 ohm' was the one used in designing the circuit (CT means 'centre tapped'). Although described as having a ferrite core, the several we purchased had iron cores.

Many component suppliers stock this transformer, or an equivalent type. For example, Altronics call it an 'output transformer', catalogue number M 0216; Electronic Agencies have a '1k CT/8 ohm' mini transformer listed as cat. no. ME4012.

Just for safety's sake, in case the 1k CT/8 ohm transformers may not be available at some time or another, we tried a 500 ohm CT/8 ohm type from Altronics, cat. no. M 0226. Many other suppliers stock a transformer like this, too. As results were virtually equivalent, we can safely say transformers of this type may be used for T1 also. Connections were found to be the same as the M-0216.

Note that it may be physically larger, necessitating mounting R1 on the copper side of the board.



Printed circuit board artwork for this project is on page 76.

HOW IT WORKS — ETI-164

The operation of apparently simple inverter circuits is usually exceedingly complex, so the following is a simplified explanation!

After PB1 is closed, current flows through terminals 'e' and 'd' of the transformer (and C2) to the base of Q1 via R1. Q1 starts to conduct and causes current flow through transformer terminals 'b' and 'a' (the primary winding) which causes the magnetic field to build up in the transformer. This field increases the base current to Q1 because of the phasing of the windings.

The magnetic field increases until the transformer core saturates, when the transistor base current reverses, turning the transistor off.

Diode D1 protects the base-emitter junction against excessive reverse bias voltage.

The energy in the transformer's magnetic field is dissipated via several mechanisms, one being to charge C3 via D2.

The whole cycle repeats at a rate of a few kilohertz.

Capacitor C1 provides a low impedance source to ac signals and improves operation with a battery supply.

that the bits all fit together before chopping up your box.

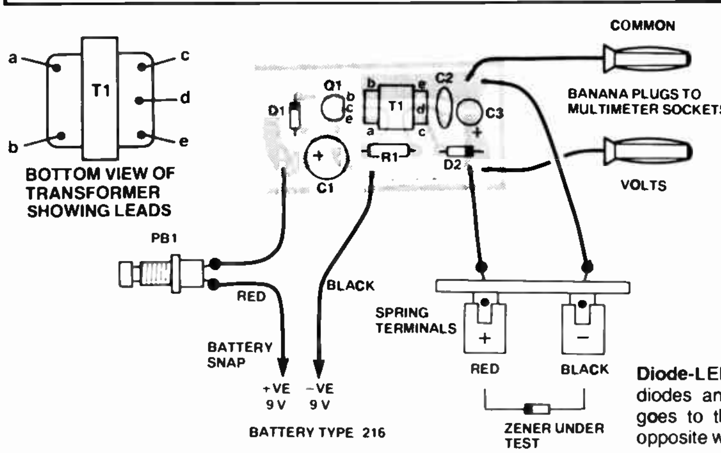
The banana plugs are mounted at a spacing of 0.75", or about 19 mm, which allows the tester to plug straight into a standard multimeter with 'GR' inputs.

To mount the plugs, first remove the plastic handles and cut them down to 20 mm so they can be fitted inside the box. Solder about 100 mm of insulated wire to each plug and feed the end through the holes in the box. Grab each plug with pliers and push them through the holes from the bottom. Now slip the handles over the wires and tighten up the plugs.

If all that seems too much, you may want to simply bring a couple of wires out to the multimeter with the banana plugs soldered to the ends.

The spring terminals I used had mounting holes about 45 mm apart which allowed screws to tap into the plastic pillars in the corners of the box. You may also mount the terminals on the long side of the box. In any case, a couple of holes will be necessary under the spring terminals to allow the solder lugs to pass through.

The pc board is straightforward to assemble, watch the orientation of the electrolytic capacitors, the two diodes (note: D1 is the smaller) and the transistor. There are several types of transformer available and some may require R1 to be mounted on the copper side of the board in order to fit properly. The pc board may slot into a groove inside the box, or simply lay alongside the battery as in our prototype. ●



Diode-LED test. When testing diodes and LEDs, the **anode** goes to the **red** terminal, the opposite way to zeners.

TABLE 1 Performance of prototype.

OUTPUT VOLTAGE volts	OUTPUT CURRENT mA	BATTERY DRAIN mA
0	5	140
5	8	160
15	9	190
24	9	190
48	5	160
60	1.5	130
72	0	120

PARTS LIST — ETI-164

Resistor .... ¼W, 5%
R1 .... 4k7

Capacitors
C1 .... 100u/25 V (or 16 V) RB electro.
C2 .... 3n3 ceramic
C3 .... 2u2/50 V RB electro. (see text).

Semiconductors
D1 .... 1N914
D2 .... EM401, 1N4001, EM402, 1N4002, etc.
Q1 .... BC639 or BD139

Miscellaneous
PB1 .... momentary action pushbutton
T1 .... transistor audio transformer, '1k CT to 8 ohm', D.S.E. M-0216 or similar (see text).

ETI-164 pc board; UB5 zippy box (28 x 54 x 83 mm); spring terminals; wire etc.

Price estimate $8 — $9

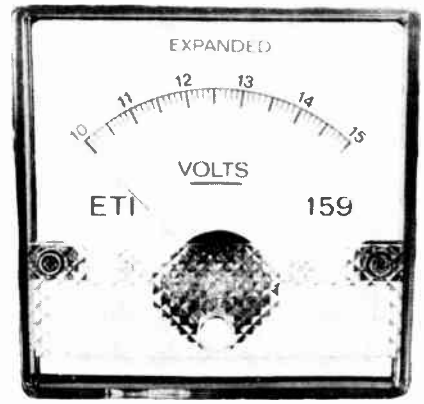
Inside story. Internal view of the zener tester. Note the cut-down banana plug handles at the top of the box.

Expanded scale voltmeter covering the 10 - 15 V range

A simple, low-cost instrument that can be built into power supplies or used as a portable or fixed 'battery condition' monitoring meter.

Simon Campbell

Roger Harrison



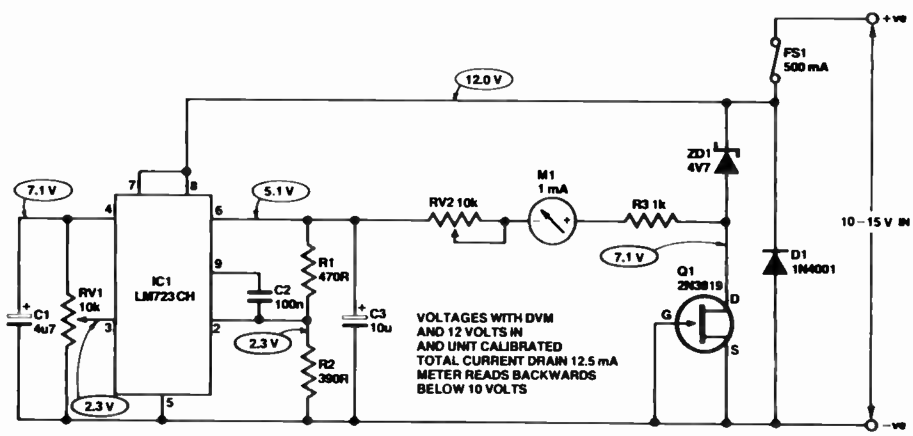
COMMON STORAGE BATTERIES to power nominal 12 Vdc electrical systems have a terminal voltage that ranges from a little over 10 volts when discharged to around 15 volts when fully charged, the operating voltage being somewhere in the range 11.5 V to 13.8 V. Lead-acid batteries, for example, may have a terminal voltage under rated discharge that commences at around 14.2 V and drops to about 11.8 V. A 12 V (nominal) nickel-cadmium battery may typically have a terminal voltage under rated discharge that starts at 13 volts, dropping to 11 volts when discharged.

Equipment designed to operate from a nominal 12 Vdc supply may only deliver its specified performance at a supply voltage of 13.8 V — mobile CB and amateur transceivers being a case in point. Other dc operated equipment may perform properly at 12.5 V but 'complain' when the supply reaches 14.5 V.

To monitor the state of charge/discharge of a battery, a battery-operated system or the output of power supplies, chargers, etc, a voltmeter which can be easily read to 100 mV over the range of interest, i.e: 10 to 15 volts, is an invaluable asset. This project does just that.

Some readers may note that our Expanded Scale LED Voltmeter (Project 326, ETI Sept 1980) does much the same job. However, the function of each is somewhat different. The ETI 326 has 10 LEDs indicating each half volt between 10.5 V and 15 V and is intended to be read 'at a glance', giving a general indication of battery condition or whatever. Its main application is in vehicles or other areas where operation is only checked periodically.

This instrument, being of the true analogue type, is intended for more exacting measurement and is better characterised as a test instrument.



The circuit

We originally came across this circuit in an article by Danny Apted (then VK7ZDA) published in 'QRM', the newsletter of the Northern Branch of the Wireless Institute of Australia, Tasmanian Division.

An LM723 variable voltage regulator IC is employed to set an accurate 'offset' voltage of 5 V, and the meter (M1) plus the trimpot RV2 and R3 make up a 5 V meter, with the trimpot allowing calibration. The negative terminal of the meter is connected to the output of the

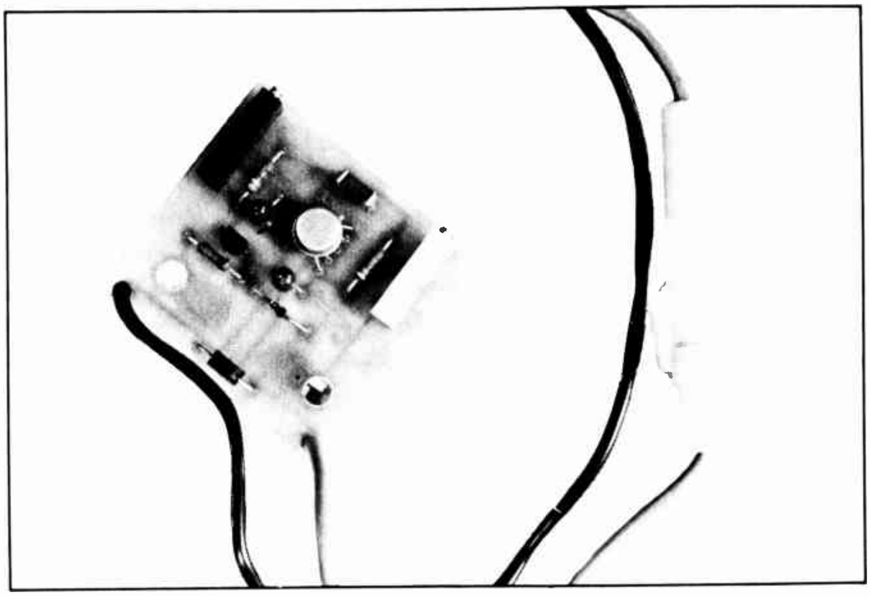
HOW IT WORKS — ETI 159

The meter, M1, is a 1 mA meter with series resistance — made up of R3 and RV2 — so that it becomes a 0-5 V voltmeter. The negative end of the meter is maintained at 5 V above the circuit negative line by the output of IC1, a 723 adjustable regulator. The positive end of the meter is connected to the circuit positive line via ZD1, a 4V7 zener diode. Thus, no 'forward' current will flow in the meter until the voltage between the circuit negative line and the circuit positive line is greater than 5 + 4.7 = 9.7 volts.

Bias current for the zener is provided by a FET, Q1, connected as a constant current source so that the zener current is accurately maintained over the range of circuit input voltage. This ensures the zener voltage remains essentially constant so that meter reading accuracy is maintained.

The trimpot RV1 sets the output voltage of the 723. This determines the lower scale voltage. Trimpot RV2 sets the meter scale range. More resistance increases the scale range, less resistance decreases it.

Diode D1 protects the circuit against damage from reverse connection.



723 so that it is always held at 5 V 'above' the circuit negative line. The positive end of the meter goes to a zener which will not conduct until more than 5 V appears between the circuit +ve and −ve lines. Thus the meter will not have forward current flowing through it until the voltage between the circuit +ve and −ve rails is greater than 10 V, and will read full scale when it reaches 15 V (after RV2 is set correctly).

The meter scale limits may be adjusted by setting the output of the 723 higher or lower (adjusted by RV1) and setting RV2 so that the meter has an increased or decreased full-scale deflection range.

A variety of meter makes and sizes may be used.

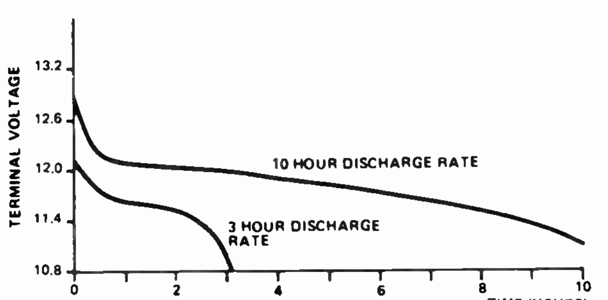


Figure 1. **Typical discharge characteristics of a 12 V (nominal) lead-acid battery.**

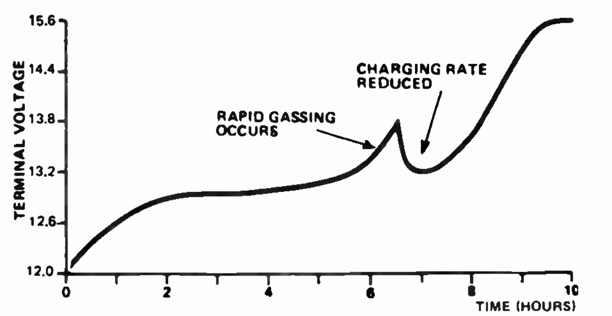


Figure 2. **Charging characteristics of a 12 V (nom.) lead-acid battery. The 'kink' in the curve near 6 hrs is explained in the text.**

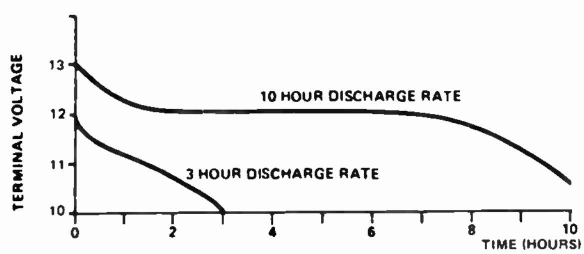


Figure 3. **Typical discharge characteristics of a 12 V (nom.) nickel-cadmium battery (usually consisting of 10 cells in series).**

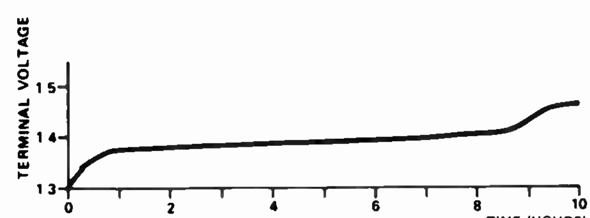


Figure 4. **Typical charging characteristics of a 12 V NiCad battery (10 cells) charged with a constant current at one-tenth rated capacity (0.1C).**

Battery condition and terminal voltage

The 12V battery, in its many forms, is a pretty well universal source of mobile or portable electric power. There are lead-acid wet cell types, lead-acid gel electrolyte (sealed) types, sealed and vented nickel cadmium types, and so on. They are to be found in cars, trucks, tractors, portable lighting plants, receivers, transceivers, aircraft, electric fences and microwave relay stations — to name but a few areas.

No matter what the application, the occasion arises when you need to reliably determine the battery's condition — its state of charge, or discharge. With wet cell lead-acid types, the specific gravity of the electrolyte is one reliable indicator. However, it gets a bit confusing as the recommended electrolyte can have a different S.G. depending on the intended use. For example, a low duty lead-acid battery intended for lighting applications may have a recommended electrolyte S.G. of 1.210, while a heavy-duty truck or tractor battery may have a recommended electrolyte S.G. of 1.275. Car batteries generally have a recommended S.G. of 1.260.

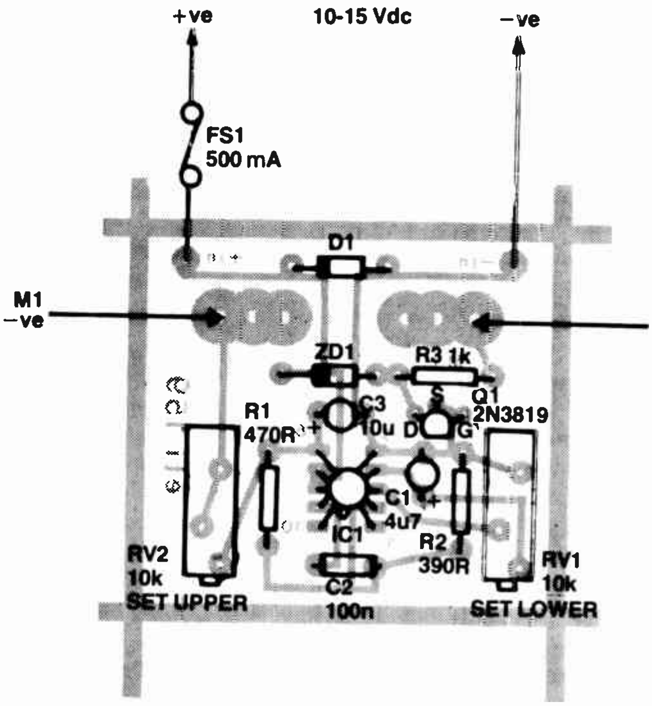
That's all very well for common wet cell batteries, but measuring the electrolyte S.G. of sealed lead-acid or nickel-cadmium batteries is out of the question.

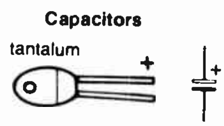
With NiCads, the electrolyte doesn't change during charge or discharge.

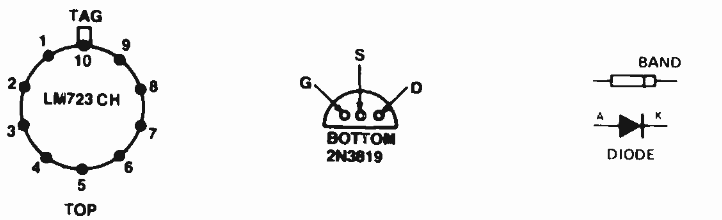
Fortunately, the terminal voltage is a good indicator of the state of charge or discharge. In general, the terminal voltage of a battery will be at a defined minimum when discharged (generally between 10 and 11 volts), and rise to a defined maximum when fully charged (generally around 15 volts). Under load, the terminal voltage will vary between these limits, depending on the battery's condition.

Hence a voltmeter having a scale 'spread' to read between these two extremes is a very good and useful indicator of battery condition. It's a lot less messy and more convenient than wielding a hydrometer to measure specific gravity of the electrolyte!

The charge and discharge characteristics of typical lead-acid and sealed NiCad batteries are given in the accompanying figures.







PARTS LIST — ETI 159

Resistors .... all ½W, 2% metal film
- R1 .... 470R
- R2 .... 390R
- R3 .... 1k
- RV1, RV2 .... 10k cermet multiturn horizontal trimpot

Capacitors
- C1 .... 4u7/10 V tant.
- C2 .... 100n greencap or ceramic
- C3 .... 10u/10 V tant.

Semiconductors
- IC1 .... LM723CH
- ZD1 .... 4V7, 400 mW or 1 W zener
- Q1 .... 2N3819
- D1 .... 1N4002 or similar

Miscellaneous
- M1 .... 1 mA meter (see text)
- FS1 .... 500 mA fuse and in-line fuse holder

ETI-159 pc board; meter scale to suit meter; colour-coded (red & black) 'figure-8' cable, etc.

Price estimate

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

$20—$23

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.

The pc board and meter scale artwork are on page 113.

Construction

Mechanical construction of this project has been arranged so that the pc board can be accommodated on the rear of any of the commonly available moving coil meter movements. We chose a meter with a 55 mm wide scale (overall panel width, 82mm). A meter movement with a large scale is an advantage as it is considerably easier, and more accurate, to read than meters with a smaller scale. It also pays to buy a 'Class 2' meter (2% fsd accuracy) for best accuracy.

Having chosen your meter, drill out the pc board to suit the meter terminal spacing first. The components may then be assembled to the board in any particular order that suits you. Watch the orientation of the 723, ZD1, the FET and particularly D1. The latter is an 'idiot diode'. That is, if you have a lapse of concentration or forethought and connect your project backwards across a battery, the fuse will blow and not the project. Fuses are generally found to be cheaper than this project!

Seat all the components right down on the pc board as the board may be positioned on the rear of the meter with the components facing the meter. The size of C2 may give you a little trouble. Greencaps are generally too large and therefore unsuitable. We used a 'Monobloc' type capacitor — as commonly used on computer pc boards as bypasses. Alternatively, a 100n tantalum capacitor (+ve to pin 2 of IC1) may be used. The actual value or type of capacitor is not all that critical.

We have used multiturn trimpots for RV1 and RV2 as they make the setting up a whole lot easier.

Note that the fuse (to protect the project) is inserted in an in-line holder in the external connecting leads. For these leads we used 'automotive' figure-8 cable, colour-coded red (for +ve) and black (for −ve).

Calibration

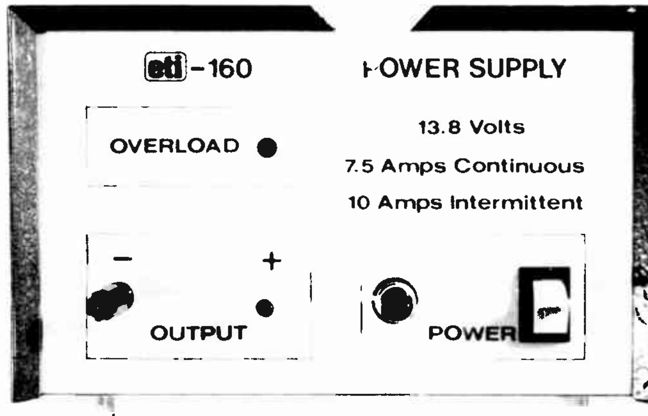
For this you will need a variable power supply covering 10 to 15 volts and a digital multimeter (borrow one for the occasion).

First set the 10 V point. Connect the digital multimeter across the power supply output and adjust the power supply to obtain 10.00 volts. Set the mechanical zero on the meter movement to zero the meter's pointer. Connect the unit to the power supply output and adjust RV1 to zero the meter needle.

Next, set the power supply to obtain 15.00 V. Now adjust RV2 so that the meter needle sits on 15 V (full scale). Check the meter reading with the power supply output set at various voltages across the range. We were able to obtain readings across the full scale within ± half a scale reading (±50 mV). With a Class 2 meter the worst error may be about ± one scale division.

When set up, our unit drew 12.5 mA maximum current drain, which is probably typical, but current drain may be around 20 mA or so maximum. Note that, when the input voltage is below 10 V, the meter needle will move in the reverse direction. ●

13.8 V regulated high current supply



Here's a supply that's just the thing for operating transceivers, RF power amplifiers, etc, or anything that requires a 13.8 Vdc (nominal) supply and pulls more amps than the general run of 'CB' type power supplies can deliver.

Roger Harrison
Geoff Nicholls

MANY AMATEURS operate a mobile VHF or UHF transceiver at home as well as in the vehicle — it's convenient and economical. Until a year or so ago, most of these transceivers ran about 10 W output, drawing up to 2 A from the 12 Vdc (nominal) supply. Then transceivers delivering 25-30 W and incorporating multimode operation appeared on the market. These draw about 6-7 A from the 12 Vdc supply, and owners of 10 W output transceivers often add an 'afterburner' to boost the transmitter output. The ETI-710 (April '76) and ETI-716 (Jan. '78) 2 m booster amplifier projects provided around 40-45 W output on 2 m from a drive of 10 W, drawing around 7 A from a 12.5 V supply. A number of commercial amplifiers giving similar performance is available, too.

For novices, HF band transceivers, such as the Yaesu FT-7, are popular, but operate from a 12.5 Vdc supply. The FT-7 draws about 3.3 A on transmit, and similar transceivers from other manufacturers are much the same. Trouble is, the common 'CB'-type power supplies are generally rated to deliver only 2 A continuous, and while some will deliver up to 4 A intermittent, a 3 A load is too much for them.

Marine VHF FM band transceivers require a dc supply and, as they run 25 W, CB-type supplies are unsuitable if mains operation is contemplated for a base installation.

This power supply is intended to suit all the sorts of applications mentioned above — and any others you can think of where dc-operated equipment draws more than 3-4 A.

As most dc operated equipment is specified to operate from a 13.8 V supply, that's the output voltage we have settled on. The current rating we have quoted is based on several factors. Firstly, while the transformer specified has a secondary rating of 18 V/6 A, it is capable of delivering much more before the secondary output voltage loads down seriously. In addition, transformer temperature rise needs to be taken into account. Hence we determined a current rating by experiment, taking these factors into account, and it turns out to be 7.5 A. However, as much as 10 A can be drawn from the supply intermittently. At this point the regulator circuit cannot maintain output voltage, as the input-to-output differential begins getting a little too low. Short circuit current limit was set at this point too, for convenience.

No current meter was provided as this project was not intended as a test bench supply. The only indicators are a bezel lamp to indicate the supply is on and an 'overload' LED to warn that the supply has gone into current limit should you attempt to draw too much current or have a short circuit on the output.

Design notes

A capacitor-input bridge rectifier provides about 25 V input to the regulator circuit. This consists of a 12 V three-terminal regulator with output current being boosted by a pair of MJ15004 PNP bipolar power transistors connected in parallel. Current limiting is provided by a Darlington pair, Q1 and Q2, which senses the emitter current through the power transistors. When the current exceeds an amount determined by R2 (about 10 A), Q2 and Q1 turn on, Q1 robbing Q3 and Q4 of base current drive and preventing further increase in output current. When Q2 turns on, LED1 will turn on, providing indication of the overload condition.

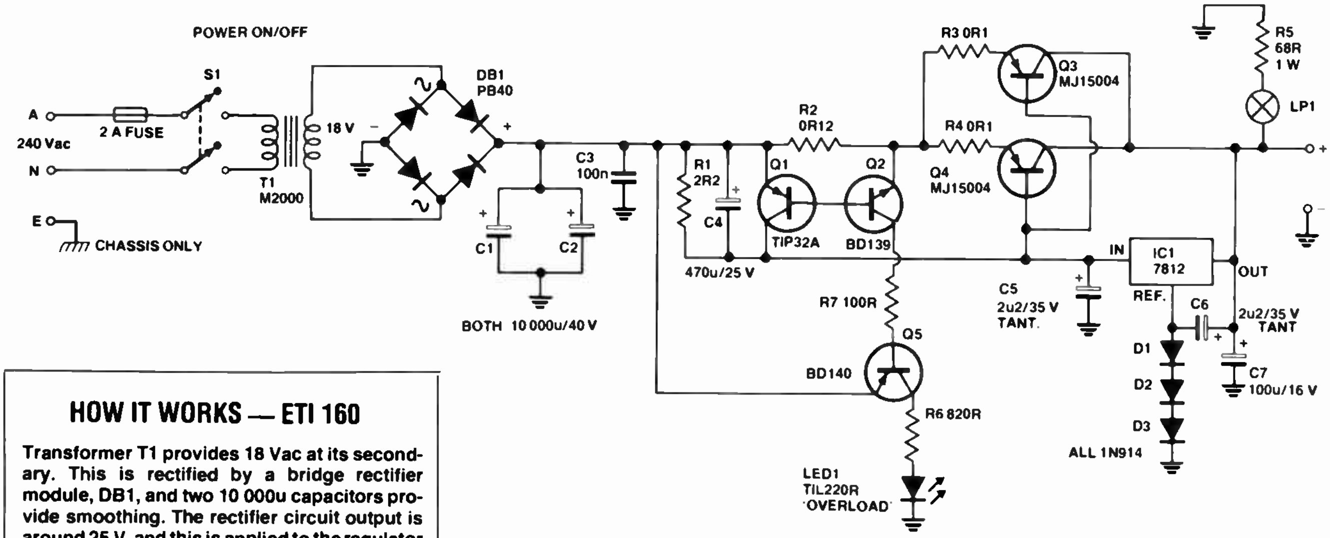
The output voltage is determined by the three-terminal regulator, IC1. Its reference terminal is 'jacked up' by 1.8 V by the drop across the diode string D1 to D3, resulting in an output voltage of 13.8 V.

Construction

We housed the power supply in a large K&W case, model C1064, measuring 155 x 155 x 255 mm overall. This has a U-shaped aluminium chassis with an etched front panel and four plastic feet that mount on the bottom. The case lid is steel, with ventilation slots punched in it and edges which wrap around the front and rear panels. It is secured by eight screws, four on each side panel. We made up a plastic Scotchcal stick-on label for the front panel.

Layout is generally non-critical, so components were placed in convenient positions. The heatsink carrying the major regulator components was mounted in a vertical position in the centre of the rear panel. The transformer was mounted on the bottom of the chassis, slightly to the right of centre, and the rectifier components were mounted to the rear panel. The over-current protection components were mounted on a small piece of matrix board on the bottom of the chassis, just to the left of centre and immediately behind the output terminals.

Unless you are purchasing this project as a kit with prepared metalwork, construction starts with the mechanical work. The heatsink should be tackled



HOW IT WORKS — ETI 160

Transformer T1 provides 18 Vac at its secondary. This is rectified by a bridge rectifier module, DB1, and two 10 000u capacitors provide smoothing. The rectifier circuit output is around 25 V, and this is applied to the regulator circuit, which consists of Q1 to Q4, IC1 and associated components. Q5 drives the overload indicator LED.

IC1 is a positive 12 V three-terminal regulator, such as a 7812 or similar. A parallel pair of PNP power transistors, Q3 and Q4, are arranged to boost the output current. A portion of the input current to IC1 flows through the base-emitter junctions of Q3 and Q4. Their collectors are connected to the output and, as they are operated here as current amplifiers, the load current supplied is much greater than the three-terminal regulator can provide. Resistors R3 and R4 ensure collector-emitter currents through Q3 and Q4 are shared equally. About 300 mA of the load current is contributed by IC1.

The reference pin of IC1 ('REF.') is raised by about 1.8 volts by the three series-connected diodes, D1, D2 and D3. They are forward biased by the bias current that flows from IC1's reference pin. Thus the output voltage is nominally 12 + 1.8 = 13.8 volts.

Over-current protection is provided in the following way: when the load current passing through Q3 and Q4 exceeds about 10 amps, the voltage across R2 will be about 1.2 volts. This will forward bias the base junctions of Q1 and Q2, which will turn on. When Q1 turns on, its collector-emitter junction effectively shunts the bases of Q3-Q4, robbing them of drive current and thus limiting their collector current. When Q2 turns on, its collector current forward biases the base-emitter junction of Q5, turning it on. The collector current of Q5 flows through LED1, which lights, indicating the overload condition.

For thermal protection, IC1 is mounted on the heatsink along with Q3 and Q4. Three-terminal regulators incorporate a 'thermal shutdown' mode where, upon reaching an internal junction temperature of 150°C, circuitry on the chip shuts off the output.

Capacitor C3 is a high frequency bypass for the regulator circuit input. Capacitor C4 prevents instability of the overload protection circuit. Capacitor C5 ensures stability of IC1, while C6 improves transient response. C7 provides a low impedance ac shunt for the regulator circuit output. Lamp LP1 provides indication that the supply is on.

Note that the chassis is not connected to the regulator circuit common rail, and the whole circuit 'floats', permitting negative or positive grounded equipment to be connected without fear of possible shorts between the equipment and the power supply.

SPECIFICATIONS
ETI-160 POWER SUPPLY

Output voltage	13.8 Vdc
Output current	
continuous	7.5 A
intermittent	10 A
Regulation	
0-7.5 A	50 mV
10 A	1.3 V

first. Mark out and drill the heatsink according to the accompanying drilling diagram. When drilling the TO3 pattern for the MJ15004 transistors, drill the lower bolt clearance holes first and then use the transistor insulating washer as a template to mark out the positions of the emitter and base pins and the other bolt hole. The emitter and base holes can be drilled to whatever clearance suits you — say 3 mm or 5 mm.

Don't forget the mounting holes on the heatsink flanges.

Using the drilled heatsink as a template, place it on the rear panel of the case as centrally as possible, flanges down and with the fins vertical. Now mark the positions of the four mounting holes and drill them to 3 mm. Draw two lines on the case rear, diagonally between the mounting holes just drilled. Where they cross, drill a 9 mm or 10 mm hole and insert a rubber grommet in it (that's a ⅜" grommet — they don't seem to have gone metric yet).

The transformer mounting holes should be drilled next. Place the transformer in the bottom of the case, orientated as shown in our internal picture, about 10 mm or so from the rear panel and about 15 mm to the right of the approximate centre line (when viewed from the front). The grommet you just inserted marks the approximate centre line. Mark and drill the transformer mounting holes to 6 BA clearance (3 mm is fine). Next mark and drill the mains cable entry hole, the fuseholder hole and holes for the mains cable clamp and terminal block. We mounted the fuseholder above the mains cable entry hole. The terminal block and cable clamp were located in a convenient position adjacent to the transformer on the bottom of the case. Drill a hole for the mains earth lug-mounting screw near the rear corner foot-mounting hole. When the mains cable is installed, the earth lead will thus be the longest, ensuring it is the last to break should the mains cable become detached.

The front panel may be marked out and drilled now, using the artwork or Scotchcal as a template. You can lay the artwork directly on the front panel and prick through it with a scriber or other sharp-pointed instrument at the hole centres. Or, you could trace the hole centres on tracing paper and mark them in the same way.

Three more holes need to be drilled in the rear panel — two to mount the clamps that secure the filter capacitors, and one for the bridge rectifier. The two 10 000 uF filter capacitors are each secured to the rear panel with a 30 mm diameter cable clamp. They are a bit larger in diameter than the caps so we used a strip of double-sided sticky tape to build out the diameter so the clamps gripped effectively. The general mounting and wiring arrangement of the caps and rectifier is shown in the accompanying diagram. Twist the positive and negative leads of the caps together. The positive leads can be brought through the +ve terminal of the bridge rectifier, as we did, if you're careful.

The Scotchcal front panel may be mounted now. We used the plastic-type ▶

Scotchcal, but these need attaching with care to avoid bubbles and ripples. The way we have found best is to first peel the backing from one edge, align the label with the edge of the case and rub it down firmly. Then, peeling off the backing as you go, smooth the label onto the panel, taking it slowly to avoid bubbles and ripples forming. If you do get a bubble, try to smooth it towards the nearest edge to remove it.

Use a sharp knife or scalpel blade to cut the Scotchcal label away over the holes in the front panel. When this is finished, all the components that mount on the front panel can be attached: the two output terminals, overload LED, bezel lamp and mains switch.

Since there are relatively few components, we have used a point-to-point wiring technique rather than assembling most components on a pc board. The regulator components are soldered on a tagstrip mounted in the heatsink 'well' and between this and the device pins. The overload protection components mount on a small piece of matrix board, as can be seen in our internal photograph.

Mount the power transistors, Q3 and

PARTS LIST — ETI 160

Resistors .... all 5%, powers as noted

R1	2R2, 1W
R2	0R12, 10W
R3, R4	0R1, 5 W
R5	68R, 1W
R6	820R
R7	100R

Capacitors

C1, C2	10 000u/40 V Elna RB electro.
C3	100n greencap
C4	470u/16 V RB electro.
C5, C6	2u2/35 V tant.
C7	100u/16 V electro

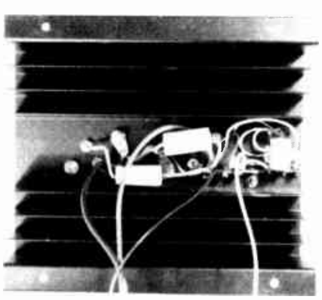
Semiconductors

D1-D3	1N914, 1N4148, etc.
DB1	PB40, 40 A bridge rectifier
IC1	7812
Q1	TIP32
Q2	BD139
Q3, Q4	MJ15004
Q5	BD140
LED1	TIL220R

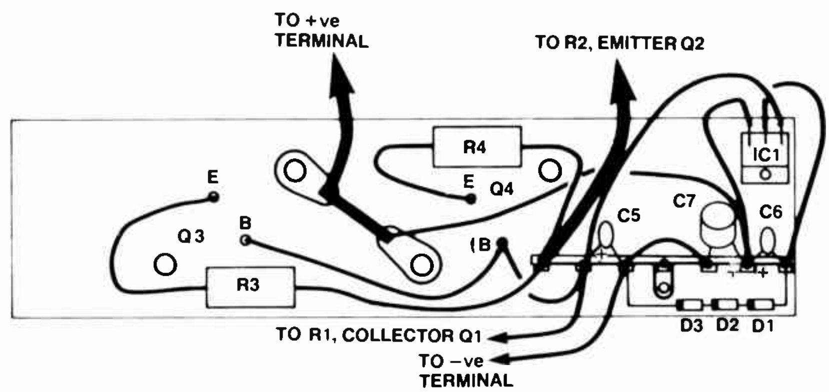
Miscellaneous

LP1 — 6 V/100 mA E.S. lamp; S1 — DPDT 240 Vac rated paddle switch; T1 — 18 V/6 A transformer, e.g: D.S.E M2000; case — K&W C1064; bezel mount for lamp LP1; LED mounting hardware; 240 Vac cable and plug; terminal block; two grommets; cable clamp; three tag strips; Scotchcal front panel; heavy duty terminals; 150 mm length of 45D6CB heatsink; transistor insulating washers, etc; 4 x 6 mm standoff pillars; nuts, bolts, wire, etc.

Price estimate
$72-$80

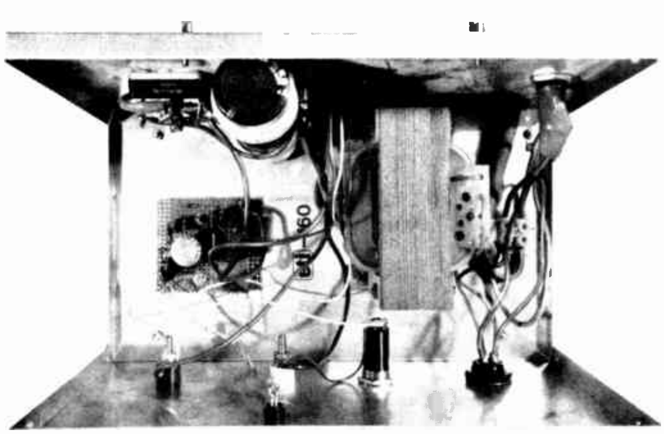


Inside the heatsink.

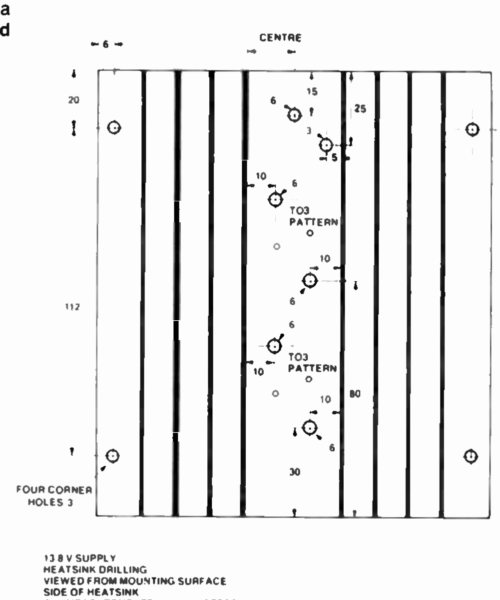


Wiring inside the heatsink.

NOTE: Front Panel artwork for this project can be obtained by sending a stamped, self-addressed A4-sized envelope to:
Project 160 Artwork
ETI Magazine
140 Joynton Ave
Waterloo NSW 2017



Inside the chassis, showing general component location.



Drilling the heatsink.

Q4, and the three-terminal regulator, IC1, on the heatsink, along with the tagstrip. You'll have to bend up the legs of IC1 back over its body. Carefully deburr all holes on the heatsink first and use mica washers and insulating bushes to mount them. Smear the mica washers with thermal compound beforehand. Use solder lugs under the nuts on the two mounting screws nearest to one another on Q3 and Q4 — as shown in the accompanying wiring diagram for the heatsink components. With a multimeter, check that the cases of Q3 and Q4 and the tag of IC1 are not shorted to the heatsink. If they are, disassemble the offending device and fix the problem before continuing.

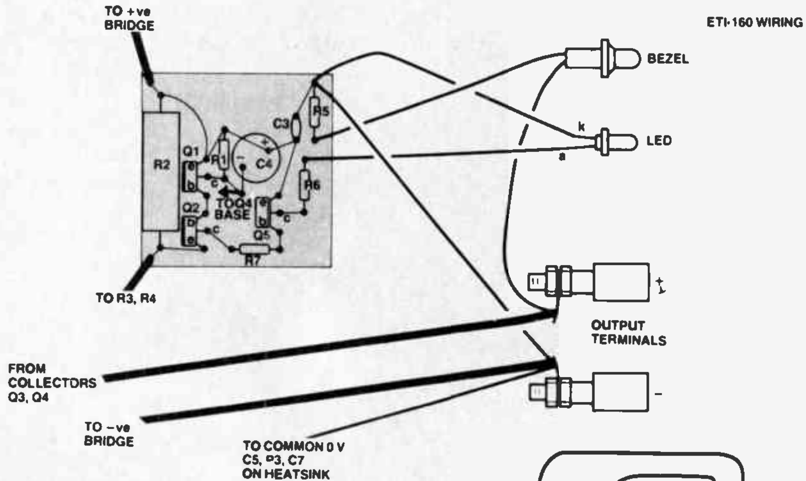
Solder the three 1N914 diodes (D1-D3) in series, with short leads between each, and solder them to the tagstrip as per the heatsink wiring diagram. Now solder C5, C6 and C7 to the tagstrip. Complete the wiring on the heatsink. Wire the collectors of Q3 and Q4 together using heavy duty hookup wire — preferably 32 x 0.2 mm. This point and the juncton of R3 and R4 should then have 250 mm lengths of heavy duty hookup wire attached, ready for wiring to the +ve output terminal and the emitter of Q2 respectively.

Two more wires run from the heatsink circuitry to inside the chassis — to the collector of Q1 and the +ve output terminal. Again, these should be 250 mm long, but only ordinary hookup wire is necessary. The heatsink assembly can now be mounted on the rear panel using 6 mm spacers.

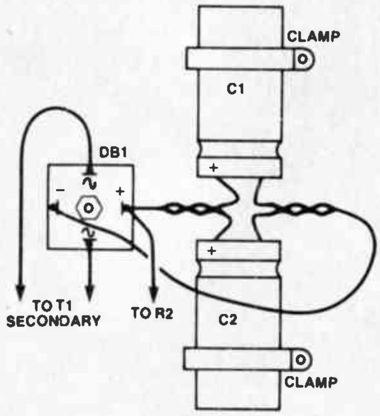
To mount the overload protection components we used a piece of matrix board about 55 mm square. General layout and component wiring is shown in the accompanying diagram. Remember to drill mounting holes in the matrix board and the bottom of the chassis. When completed, this board is mounted using 6 mm spacers.

Complete the construction by bolting in and wiring up the power transformer, the mains cable, fuse and switch, and the components mounted on the front panel. Note that it is important to use heavy duty hookup wire (at least 32 x 0.2 mm) between the filter caps' negative terminals and the −ve output terminal as well as from the rectifier's positive terminal to R2. Don't forget to bolt the four feet on the case.

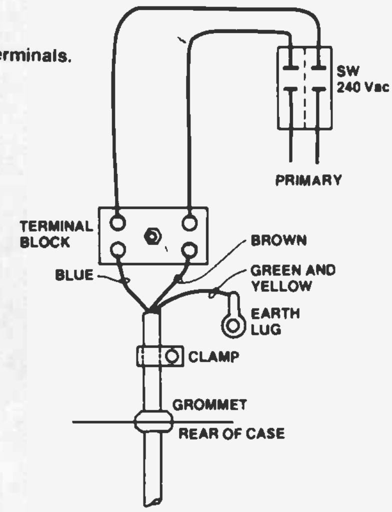
We used a 6 V/100 mA globe and a series resistor for the bezel lamp. You may have to change the value of the series resistor (R5) to accommodate globe rating. A 12 V globe could be used without a resistor, if you wish.



Wiring the overload components, bezel and output terminals.



Wiring the rectifier and filter capacitors.



Mains cable wiring. Be sure to sleeve all exposed connections for your own protection.

Testing it

Carefully check all your wiring. If you're satisfied all is well, plug in and switch on. The bezel lamp should light immediately. Check the output with a multimeter. It should read within ±100 mV (0.1 V) of 13.8 V. If not, switch off and trace the fault. If the output is around 25 V, you have a fault in the regulator wiring. If the output is greatly lower, look for faulty rectifier wiring, or even a faulty rectifier (rare). Generally, problems will be caused by a wiring error.

If the output voltage is OK, you can apply a load and see what happens. A 100 W load consisting of a single car light, or a combination to make up that power, will draw around 7.25 amps. The output voltage should drop no more than 50 mV.

If you can make up a load to draw 10 A (you'll need two multimeters for this one), check that the output does not drop lower than 12.4-12.5 volts.

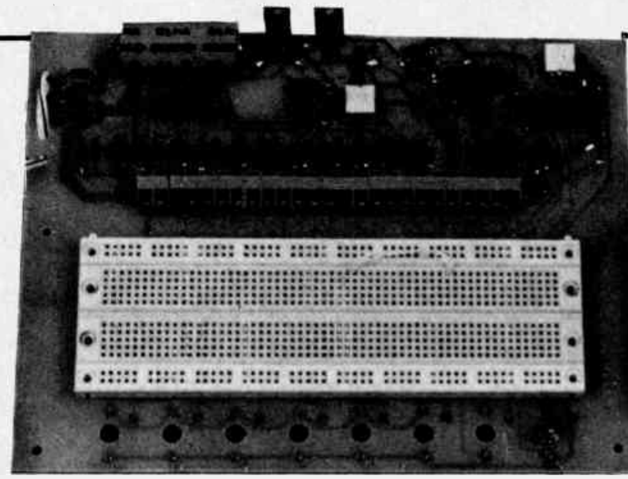
A multimeter capable of reading at least 12 A can be used to check the overload protection. Connecting the meter directly across the output terminals should result in a current of a little over 10 A (some 300-400 mA of the load current is contributed by IC1). This may vary somewhat, depending on the exact value of R2. If R2 is low, you may have to parallel another resistor across it to bring the overload current closer to 10.5 amps.

The overload LED should light when the load draws more than 10 amps.

When an overload remains on the supply for some time, the temperature of the heatsink will rise until IC1 reaches its temperature cutout point, at which stage it will turn off, turning Q3 and Q4 off, until the heatsink temperature drops. If the overload is still there when IC1 turns back on again, the process will be repeated until the overload is removed. This provides thermal protection to the unit. That's it!

We think you'll find this supply a very handy adjunct to the shack or workshop. ●

Project 145



'Prototyper' breadboard

This is just the thing for lashing up circuits, experimenting with circuit techniques and component values, trying out circuit ideas, attempting circuit modifications, etc. If you're a dyed-in-the-wool experimenter, this project will be just your cup of tea.

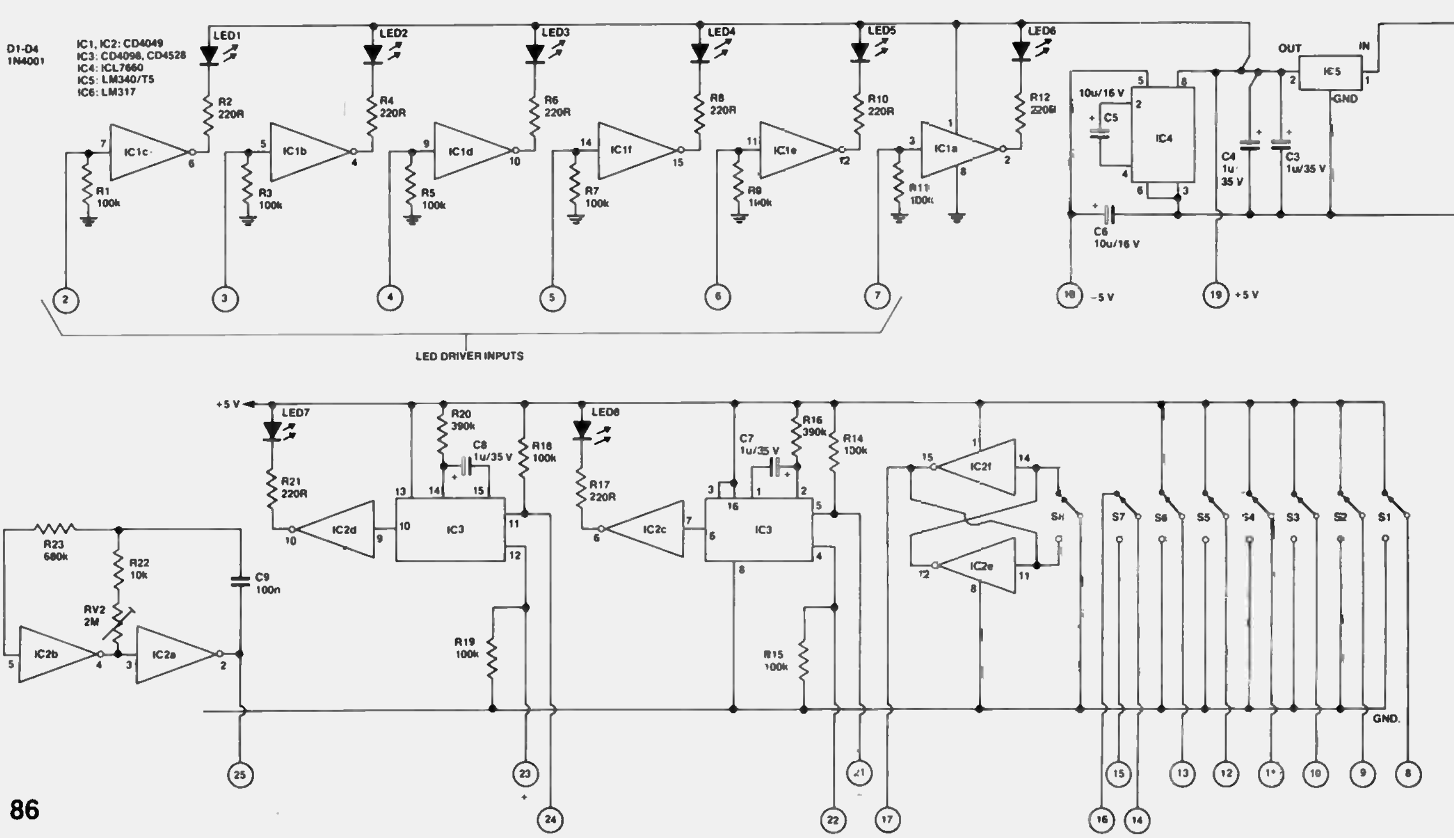
Graeme Teesdale

MANY HOBBYISTS have some form of 'patch board' or 'breadboard' used to mock-up circuits and make adjustments or modifications before laying out a printed circuit board. So many circuits only require a simple lash-up in order to 'prove' operation, but such lash-ups generally become monsters with power supplies, oscillators and whatever hanging off them all over the place. This project combines a number of useful pieces of test equipment on the one master printed circuit board. The unit is pretty well self-contained, with two fixed and one variable supply on-board, plus an oscillator, various indicators etc. Digital and analogue circuitry can be accommodated. It is powered from an ac plugpack — which keeps 240 Vac mains out of harm's way.

The overall size of the board is 200 x 155 mm, so it's quite compact. It fits readily into a briefcase . . . or even Roger Harrison's handbag! (— Eh? . . . Ed.).

The specifications table here lists the main features. The photograph at the head of the article shows the overall layout and construction. The pc board has been designed so that a 'breadboard' can be attached in the area toward the front. This consists of rows of pin sockets which accept transistors, ICs, wire and component leads, all arranged to make interconnection of components easy and logical.

Bus strips permit power supply connection. These are widely available and are known as 'breadboards', 'bimboard',



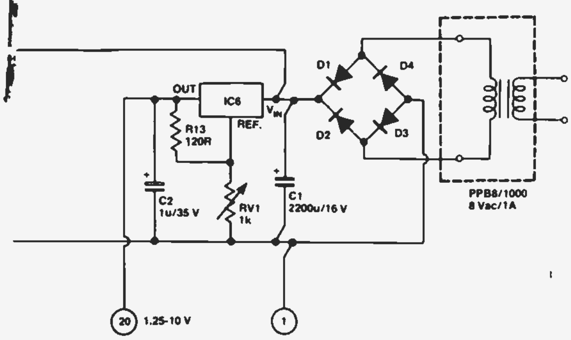
SPECIFICATIONS

Supplies	• +5 V @ 150 mA*
	• −5 V @ 18 mA
	• +1.25 — 10 V @ 100 mA*
	*more with heatsink on regulators, see text
Signal	• Variable frequency multi-vibrator — 3 Hz to 600 Hz
Sources	• Debounced, spring-return SPDT switch (for single-shot pulses)
Indicators	• 6 x buffered LEDs
	• 1 x positive-going, edge-triggered pulse indicator
	• 1 x negative-going edge-triggered pulse indicator
Switches	up to seven SPDT switches, contacts available

'breadboard socket', 'solderless breadboard', 'proto-board', etc. They are manufactured by firms such as Atek, Continental Specialities Corporation and others. You should be able to purchase one to suit this project for around \$10 — \$12. Make sure you get one that provides bus strips alongside the main breadboard for power supply connections.

Construction

The unit is constructed on a double-sided printed circuit board with components mounted generally on the uppermost side. The indicator LEDs and the switches mount onto the board and their leads are soldered onto the rear side.



The Klippon screw terminal strips mount on the topside of the board, the pin connections being soldered on the rear side. Links from the top to the bottom side provide interconnection between tracks on each side of the board.

Circuitry occupies a strip along the upper portion of the board, the row of LED indicators coming between this and the Klippon screw connector strip. The switches are arranged in a row on the lower edge of the board. The terminations on the screw connector strip are marked on the upper surface of the board, etched in copper. Each of the switches and LEDs is similarly marked. Each of the first six switches connects the switch pole to 0 V (logic low) in one position ('down'), and to +5 V (logic high) in the other position. The seventh switch has all three terminals 'free', while switch eight is a spring-return type hooked up to a debouncing circuit to provide one-shot pulses for manual clocking, triggering, etc.

It is recommended you purchase a ready-made pc board if you are not experienced at making your own pc boards. For those who wish to tackle the board themselves, remember that it is double-sided as you will need to take particular care with registration to ensure board holes line up from top to bottom.

Commence assembly by carrying out a visual inspection of the pc board, looking for any shorts between adjacent tracks and (rarely) broken tracks. Check also that holes are drilled to convenient sizes for the LED mounting hardware, switches, etc. If your board is not drilled, then tackle the drilling first as it's difficult to do once you've mounted components to the board. LED mounting holes need to be drilled out to 6 mm diameter, but as switches vary we'll have to leave their hole sizes to you. ▶

HOW IT WORKS — ETI 145

There are five sections in the Prototyper: power supplies, LED drivers, pulse indicators, square wave oscillator and switches.

POWER SUPPLIES

There are three power supplies: +5 V and −5 V fixed supplies and a positive variable supply with a range of 1.25 to 10 V.

The Prototyper has been designed to work from an 8 Vac output plugpack, thus removing any 240 Vac mains connections from the pc board. A full-wave bridge rectifier (D1 — D4) and capacitor (C1) provide a 12.5 Vdc supply to the inputs of two three-terminal regulators, IC5 and IC6. IC5 is a positive 5 V regulator (7805, LM340/T5, etc), while IC6 is an adjustable positive three-terminal regulator (LM317, etc). R13 and RV1 provide a bias for the reference terminal ('REF.') of IC6, permitting adjustment of the output voltage over the range 1.25 V to 10 V.

Output decoupling capacitors (C2 and C3) are provided for each regulator, mounted physically close to the devices, to improve transient response and reduce supply interaction between devices where several power supplies may be hooked up to one circuit. Both three-terminal regulators have internal short circuit and thermal overload protection.

The −5 V rail is derived by IC4, an Intersil ICL7660 voltage converter. The operation of this device is explained in the panel elsewhere in this article.

LED DRIVERS

The LED indicators, comprising LEDs 1 to 4, are driven by CMOS inverters from a 4049 hex inverting buffer chip. LEDs may be directly driven from the output of a CMOS inverting buffer, providing the current is limited to about 15 mA, hence 220 ohm resistors are connected in series with each LED (R2, R4, R6, R8, R10, R12). The input state of each of these buffers is determined by a 100k resistor from input to 0 V. This ensures the inputs are low, and thus the LEDs off, when the buffer inputs are open circuit.

PULSE INDICATORS

To indicate the presence of narrow digital pulses which would not light a LED long enough to be seen, two monostables are connected as 'pulse stretchers'. IC3 contains two CMOS monostable multivibrators — either a 4098 or 4528 may be used here. They can be configured to provide stable retriggerable/resettable one-shot operation. The leading edge (positive-going) and trailing edge (negative-going) inputs are brought out to the input connector strip on-board (21 and 24), each having the appropriate resistor connected to +V or 0 V so that either input is enabled (resistors R14-15 and R18-19).

Timing of the 'stretched' pulses is determined by external RC networks — R16/C7 for IC3a and R20/C8 for IC3b. With the values chosen, the period is approximately 200 ms using the 4098; a small variation occurs with the 4528. With the latter, the 'reset' input is unused and connected to +V. Its 'disabled' operation can be observed when first switching power on. LEDs 7 and 8 will come on for the delay period, after which the circuit reverts to normal operation.

The 'Q' output of each monostable drives a LED (7 and 8) via buffers from IC2 (IC2c and d).

OSCILLATOR

A variable frequency astable multivibrator provides a signal generator or clock source. Two inverting buffers from IC2 (another 4049) are connected so that positive feedback is provided via C9. R23 aids stability, and the frequency of oscillation is principally determined by C9/R22/RV2. The time to complete one charge-discharge cycle is approximately 1.4 times the RC time constant — but this can vary quite widely due to a 3:1 ratio of the transfer voltage within the device specification.

The oscillator has been made relatively independent of supply voltage variations by using a resistor (R23) in series with the input to the first inverter (IC2b). The frequency of oscillation is adjusted by varying the RC time constant. In this circuit RV2 permits varying the frequency over about a 220:1 range — giving coverage from around 3 Hz to 600 Hz. The frequency range can be reduced by increasing the value of C9.

The oscillator output is on pin 29 of the screw terminal strip.

SWITCHES

Eight switches are provided for on-board; all are single-pole, double-throw types. Six (S1 to S6) are wired so that the pole switches between +5 V (logic high) and 0 V (logic low). One has all terminals brought out (S7), and one is connected to a debounce circuit (S8).

The debounce circuit employs two inverting buffers from IC2 cross-connected in a flip-flop configuration. One output from the flip-flop is connected to pin 17 of the screw terminal strip. This switch can be used as a debounced manual clock. Drive capability of the output is equivalent to two DTL/TTL loads, i.e: Vcc = 5 V, Vdl ⩾ 0.4 V and Vdm ⩾ 3.2 mA.

Project 145

Next, insert and solder in place all the top-to-bottom wire links. These are marked with a '•' on the component overlay.

All the resistors may now be mounted on the pc board and soldered in place. Note that some have their leads soldered on both sides of the board, the lead acting as a through-hole link. The four rectifier diodes can come next, followed by the filter capacitor and bypass capacitors C1, C2, C3, C4 and C6. Take care with the polarity of these capacitors and the diodes. Again note that some have leads soldered both sides of the board.

Mount the two voltage regulator ICs, IC5 and IC6, next. It is useful to bend their leads so that the rear of the metal tabs on these ICs is in line with the edge of the pc board. Then you can attach a heatsink to them later if more current consumption is called for on the fixed +5 V rail and/or the variable supply. A 60 mm length of 25 x 25 mm aluminium angle bracket would make a fine heatsink and permit current outputs up to two or three times the currents specified.

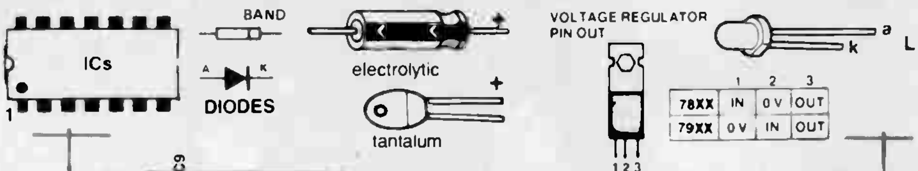
The variable supply trimpot, RV1, can be mounted now, along with the ICL7660 chip (IC4) and C5. Watch the orientation of the IC and the capacitor.

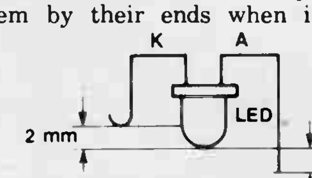
Power can now be applied for a test, if you wish. Check the supply voltages at the screw terminal strip pads. The two 5 V rails should be at 5 V ±0.1 V, and RV1 should provide an output from the variable supply that ranges between 1.25 V and 10 V. If RV1 is mounted correctly, a *clockwise* rotation will cause the variable supply output to *increase*. On no load, the voltage of the −5 V rail should be very close to 5 V (within 100 mV either way). Placing a 470 ohm resistor on its output as a load will cause the output voltage to fall to around 4.3 V, which is fine.

Mount the three remaining capacitors, taking care with the polarity of C7 and C8. The hardware for mounting the LEDs can be assembled to the board next. Prior to mounting the LEDs, each should have its lead formed as per the diagram here.

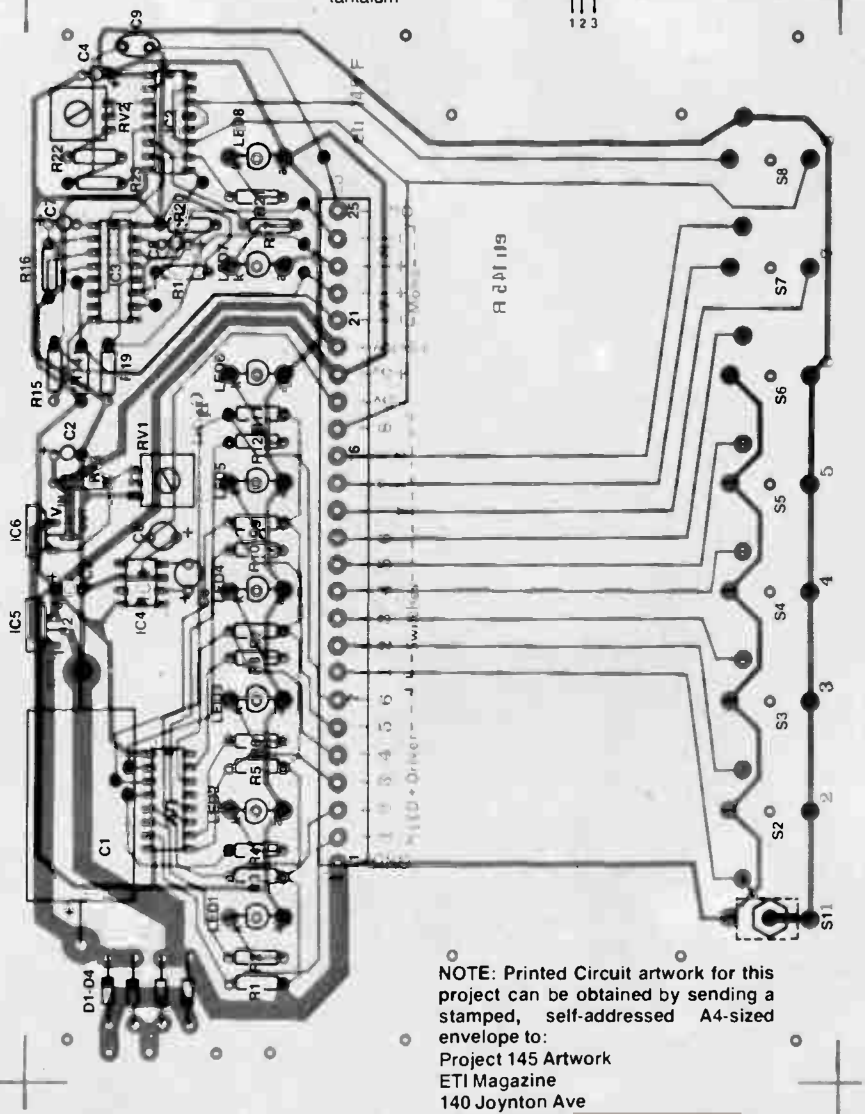
The cathode lead (K) should be bent and trimmed as shown, the anode lead being left longer and straight so that it provides a link to the +5 V rail when soldered on the top side of the board. When inserting the LEDs, make sure this lead protrudes through the top side of the board.

Now ICs 1, 2 and 3 can be mounted. Watch orientation and only handle them by their ends when inserting ▶





Bending the leads for LEDs 1 to 8.



NOTE: A '•' DENOTES PADS TO BE SOLDERED TOP AND BOTTOM SIDES OF BOARD VIA LINK OR COMPONENT LEAD.

NOTE: Printed Circuit artwork for this project can be obtained by sending a stamped, self-addressed A4-sized envelope to:
Project 145 Artwork
ETI Magazine
140 Joynton Ave
Waterloo NSW 2017

PARTS LIST — ETI 145

Resistors .... all ½ W, 5%

R1, 3, 5, 7, 9, 11, 14, 15, 18, 19	100k
R2, 4, 6, 8, 10, 12, 17, 21	220R
R13	120R
R16, R20	390k
R22	10k
RV1	1k 'Helitrim' trimpot
RV2	2M 'Helitrim' trimpot

Capacitors

C1	2200u/16 V axial electro.
C2, 3, 4, 7, 8	1u/35 V tantalum
C5, C6	10u/16 V RB electro.
C9	100n greencap

Semiconductors

D1-D4	1N4001, EM401 etc
IC1, IC2	4049
IC3	4098, 4528
IC4	ICL7660
IC5	LM340/T5
IC6	LM317
LED1-8	TIL220R or sim.

Miscellaneous

S1 - S7	up to seven SPDT toggle switches (as required)
S8	SPDT spring-return toggle switch

ETI-145 pc board; one PPB8/1000 ac plugpack; two pc board mounting strip connectors — 'Klippon' type MK 8/10 or similar; one pc board mounting strip connector — 'Klippon' type MK 8/2 or similar; one pc board mounting strip connector — 'Klippon' type MK 8/3 or similar; one length of figure-eight flex; 4 x 12 mm standoffs; 4 x rubber feet or grommets; nuts and bolts to suit; one 'breadboard' strip — such as Atek type AT-2N, Bimboard (e.g. Dick Smith Catalogue No. P-4612) or Proto-board (e.g. Dick Smith Catalogue No. P-4614).

Price estimate **$60-$70**

them, avoiding touching the pins, as they are CMOS devices. Solder their supply pins first — pins 1 and 8 on ICs 1 and 2, pins 16 and 8 on IC3.

The only remaining components to mount are the switches, the screw connector strips and the breadboard strip. Refer to the overlay for wiring the switches. Now fix the figure-eight ac input flex to the board, looping it through the two holes near the rectifier diodes. This provides a very effective, yet simple, cable clamp.

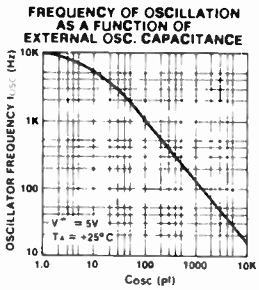
Connect the ac input cable to the PPB8/1000 plugpack and apply power. LEDs 7 and 8 should come on momentarily when you switch on. The LED driver and inputs can be tested by connecting switches 1 to 6 to the LED driver inputs 1 to 6. Putting a switch to '1' should cause the appropriate LED to come on. Switch 8 can be tested by linking it to one of the LED driver inputs. Holding SW8 on the '1' position will cause the appropriate LED to light. If anything doesn't work at this stage, make a careful wiring check, especially orientation of ICs and LEDs, and correct any faults.

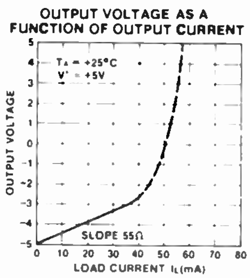
Once SW8 has been tested, it can be used to test the monostable inputs (marked 'Mono'). Link pin 17 (marked '8') to pin 21 (Mono '7', marked '-'). When SW8 is operated and released, LED7 will come on for 200 ms on the '1' to '0' transition. The reverse happens when you link SW8 to the '+' input, pin 22.

The last section to test is the square wave oscillator. Connect the 'Osc' terminal (pin 25, on the right hand end) to one of the LED driver inputs. Turn RV2 to the fully anti-clockwise position and the LED should flash at about a 3 Hz rate. To observe the maximum frequency, an oscilloscope is required, although you could couple the oscillator output to an audio amplifier (but remember the output is at quite a high level) and listen to the squeal produced. Varying the trimpot should vary the frequency.

That's it. Happy prototyping! ●

THE INTERSIL ICL7660 VOLTAGE CONVERTER





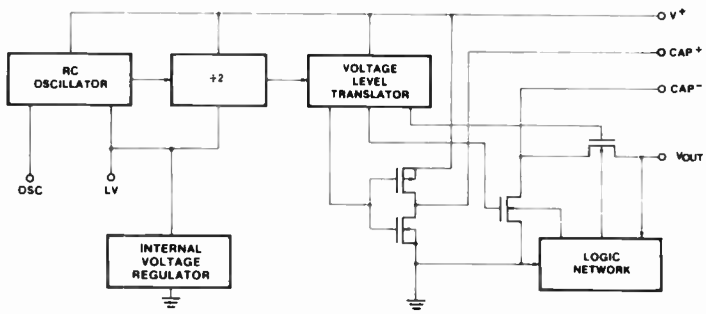


Figure 2. **Internal block diagram of the ICL7660.**

The Intersil ICL7660 is a monolithic 'MAXCMOS' power supply circuit which performs the complete supply voltage conversion from positive to negative for an input range of +1.5 V to +10.0 V, resulting in complementary output voltages of −1.5 to −10.0 V with the addition of only two non-critical external capacitors.

Contained on-chip are a series dc power supply regulator, an RC oscillator, a voltage level translator, four output power MOS switches, and a unique logic element which senses the most negative voltage in the device and ensures that the output N-channel switches are not forward biased. This assures latch-up free operation.

The oscillator, when unloaded, oscillates at a nominal frequency of 10 kHz for an input supply voltage of 5.0 volts. This frequency can be lowered by the addition of an external capacitor to the 'OSC' terminal, or the oscillator may be overdriven by an external clock.

The 'LV' terminal may be tied to ground to bypass the internal series regulator and improve low voltage (LV) operation. At medium to high voltages (+3.5 to +10.0 volts), the LV pin is left floating to prevent device latch-up.

The ICL7660 may be obtained in 8 pin DIL or TO-99 can packages, pin configurations being shown in Figure 1. The internal block diagram is shown in Figure 2.

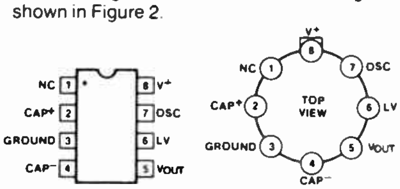


Figure 1. **Pinouts of the DIL and TO-99 packages for the ICL7660.**

FEATURES

- Simple conversion of +5 V logic supply to ±5 V supplies.
- Simple voltage multiplication ($V_{OUT} = (-)nV_{IN}$)
- 99.9% typical open circuit voltage conversion efficiency
- 98% typical power efficiency
- Wide operating voltage range 1.5 V to 10.0 V
- Easy to use — requires only two external non-critical passive components

APPLICATIONS

- On-board negative supply for up to 64 dynamic RAMs
- Localised μ-processor (8080 type) negative supplies
- Inexpensive negative supplies
- Data acquisition systems

CIRCUIT DESCRIPTION

The ICL7660 contains all the necessary circuitry to complete a voltage doubler, with the exception of two external capacitors which may be inexpensive 10u polarised electrolytic capacitors. The mode of operation of the device may be best understood by considering Figure 3, which shows an idealised voltage doubler. Capacitor C1 is charged to a voltage, V+, for the half cycle when switches S1 and S3 are closed. (Note: Switches S2 and S4 are open during this half cycle.) During the second half cycle of operation, switches S2 and S4 are closed, with S1 and S3 open, thereby shifting capacitor C1 negatively by V− volts. Charge is then transferred from C1 to C2 such that the voltage on C2 is exactly V+, assuming ideal switches and no load on C2. The ICL7660 approaches this ideal situation more closely than existing non-mechanical circuits.

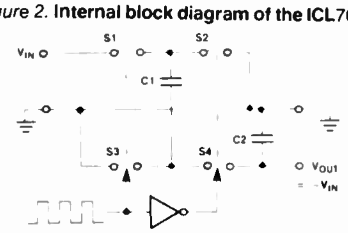


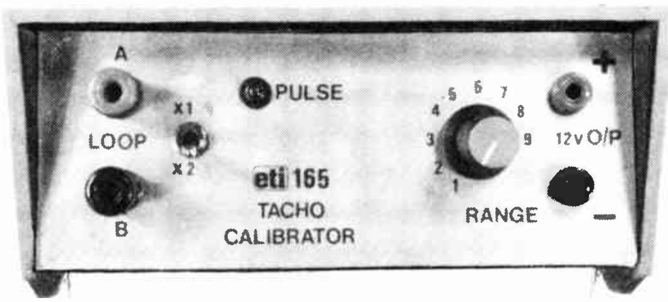
Figure 3. **Internal representation of how the ICL7660 works.**

The four switches in Figure 3 are MOS power switches; S1 is a P-channel device and S2, S3 and S4 are N-channel devices. The main difficulty with this approach is that in integrating the switches, the substrates of S3 and S4 must always remain reverse biased with respect to their sources, but not so much as to degrade their 'on' resistances. In addition, at circuit start-up and under output short circuit conditions ($V_{OUT} = V+$), the output voltage must be sensed and the substrate bias adjusted accordingly. Failure to accomplish this would result in high power losses and probable device latch-up.

This problem is eliminated in the ICL7660 by a logic network which senses the output voltage (V_{OUT}) together with the level translators, and switches the substrates of S3 and S4 to the correct level to maintain necessary reverse bias.

The voltage regulator portion of the ICL7660 is an integral part of the anti-latch-up circuitry; however, its inherent voltage drop can degrade operation at low voltages. Therefore, to improve low voltage operation the 'LV' pin should be connected to ground, disabling the regulator. For supply voltages greater than 3.5 V the LV terminal must be left open to insure latch-up-proof operation, and prevent device damage.

Tacho calibrator



A handy test instrument for the motoring enthusiast. Installing and calibrating a new tacho is a pain in the exhaust. Here's the pill for the pain.

Graeme Teesdale

THIS PROJECT was developed initially to calibrate Smiths impulse tachometers, but with the addition of a transformer and diode can be used with peak reading or pulse types. The unit has also been useful in testing transistor-assisted ignitions by simulating the pulses from the distributor breaker points.

The calibrator is locked to the mains frequency — 50 Hz. It provides a selection of 14 different pulse rates from 25 Hz to 450 Hz in 25 or 50 Hz steps. Using the conversion chart, the pulse rate can be converted into RPM for the number of cylinders in the vehicle's engine.

Construction

Two printed circuit boards are used and the whole unit is housed in a low cost ABS plastic case which is locally produced by Sigea in Melbourne (case model EC.1001). We 'dressed up' the front panel with Scotchcal.

One pc board holds the power supply and most of the circuitry, with the exception of one IC and the rotary switch, which are located on another smaller board along with a few other components. This board mounts behind the front panel of the case and connects to the main board via two lengths of ribbon cable.

Commence construction by using the larger pc board as a template to mark out mounting holes on the case bottom. Also mark out the mains cable inlet grommet hole and terminating block position. The front panel can be marked out using the Scotchcal as a template.

Drill the case, then mount and terminate the mains cable as indicated in the drawings.

Now you can start assembling the pc boards. Note the three links on the small pc board. LED1 actually mounts on this board, as does SW2. Make sure you cut the shaft of this switch to suit the knob you're using. Leave the leads of LED1 long and don't solder it in place until you have determined how long they should be by making a trial assembly once all the other components are mounted. SW1 is wired to the board after mounting to the panel.

When assembling the larger pc board, leave T1 and C1 till last. Watch orientation of the ICs, transistors, diodes and polarised capacitors, as usual. Note that the ICs are CMOS types, so observe the usual handling precautions. Don't handle the pins, pick them up with thumb and forefinger on the ends of the package; solder the power supply pins first.

When mounting T1, secure it in place with two PK screws before soldering to the pins to avoid straining the pins and possibly breaking the wires terminated to them.

When both boards have been assembled and checked, wire them together with two lengths of 5-way ribbon cable about 130 mm long each. Solder flying leads to the 240 Vac input terminals on the board (use mains cable).

Then, mount the larger pc board in the case and terminate the 240 Vac input wires to the mains terminal block.

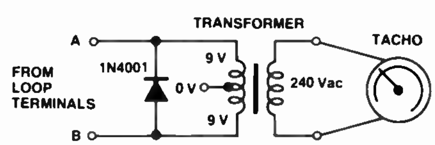
Attach the Scotchcal to the front panel of the case and mount SW1. Take care of the Scotchcal when tightening the nut. Solder three wires to its terminals and terminate them on the appropriate place on the small pc board. Then mount the small board. Take care when tightening the nut on the shaft of the rotary switch that you don't damage the Scotchcal.

After a careful final check, you're ready to switch on.

Testing it out

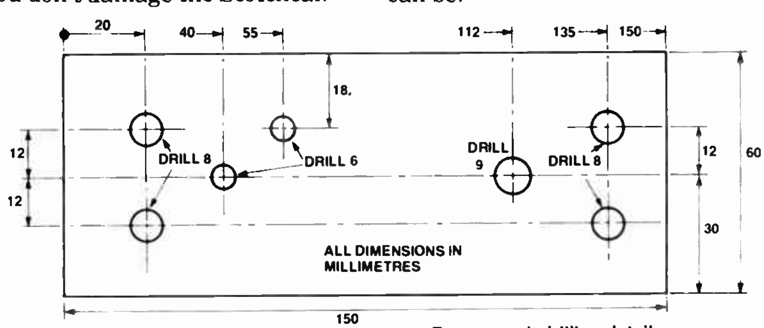
Set the range switch to position 1 and switch on. The pulse LED will flash at a rate of one second on, one second off. As you vary the range switch, the LED will flash at an increasing rate. If nothing's happening, then switch off and check your wiring, component orientation etc. See that supply voltage exists on the small pc board. Otherwise, you'll need either a logic probe or a CRO to fault-find.

If all is well, connect the primary loop of the pickup coil of a tachometer to the loop terminals. Vary the number of turns in the loop until the tachometer gives a reading. Use the accompanying table to determine the RPM, knowing the pulse rate and number of cylinders. Alternatively, if a peak reading or pulse type tacho is used, connect up the following additional circuitry:



Beware of the high voltage pulses on the secondary of the transformer in this circuit.

A little experimentation will show you how versatile this pulse generator can be. ▶



Front panel, drilling details.

PARTS LIST — ETI-165

Resistors .... all ½ W, 5% unless noted

R1	22k
R2	8k2
R3	1k5
R4	100R
R5	470k
R6	27k
R7	100k
R8	10k
R9	560R
R10	1k
R11	22R, 5 W

Capacitors

C1	1000u/25 V axial electro.
C2	10n greencap
C3	1n greencap
C4	1u/16 V tant.
C5	22u/16 V RB electro.

Semiconductors

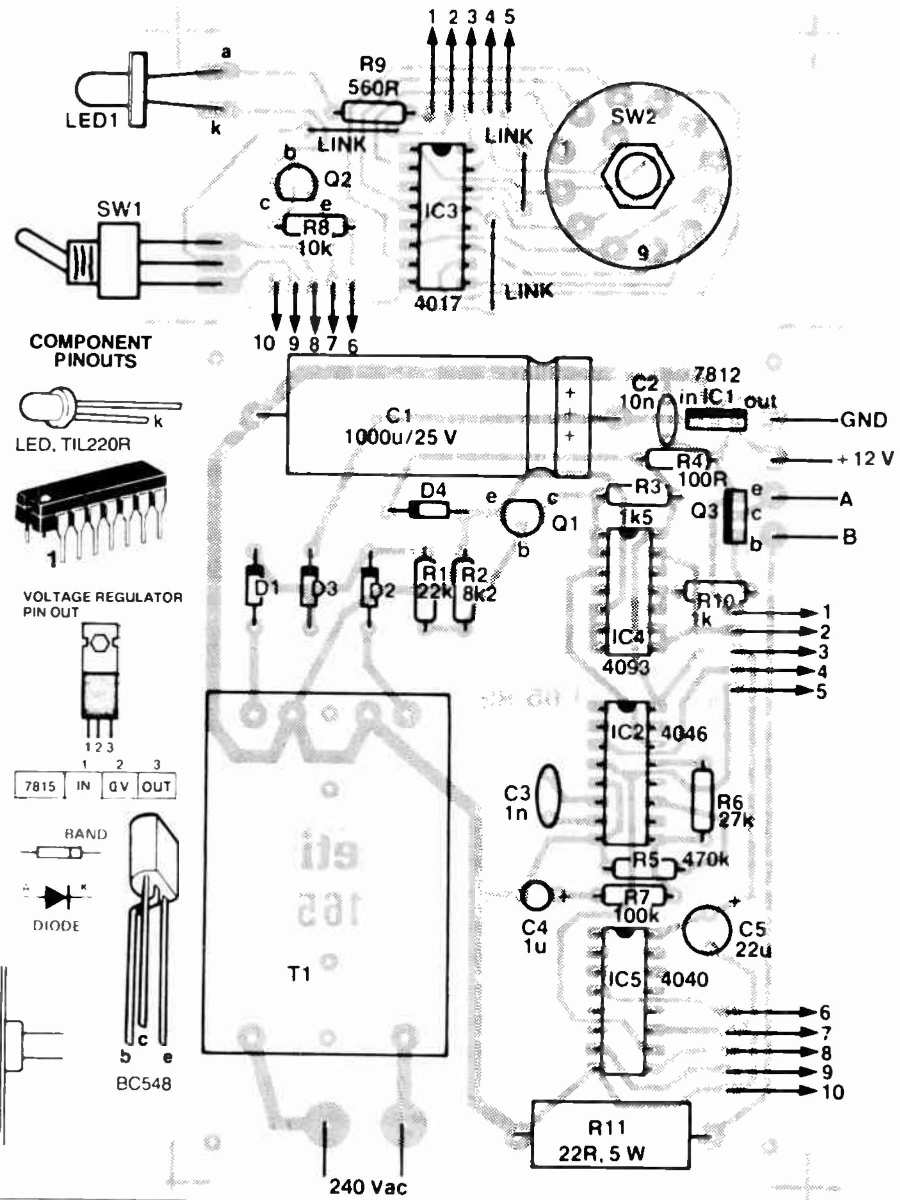
D1, 2, 3, 4	1N4001, EM401 etc.
IC1	LM340T/12, 7812
IC2	4046
IC3	4017
IC4	4093
IC5	4040
LED1	TIL220R red LED
Q1, Q2	BC548
Q3	BD266 or similar

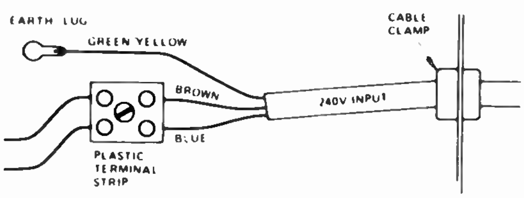
Miscellaneous

TR1	PL24/5 VA, Ferguson
SW1	SPDT switch
SW2	1-pole, 9-position rotary C&K Lorlin or similar.

ETI-165 pc board(s); two lengths of five-conductor ribbon cable (or hookup wire); case to suit; mains cord and clamp; etc.

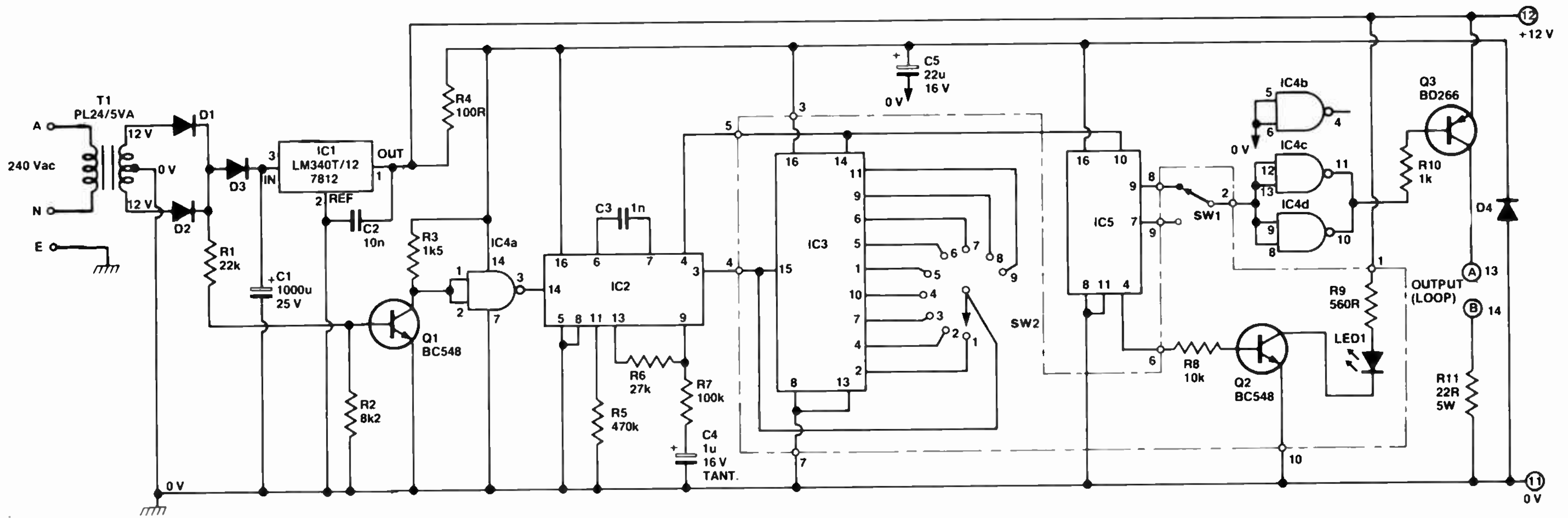
Price estimate $36-$40





MAINS INPUT WIRING

Project 165 — tacho calibrator



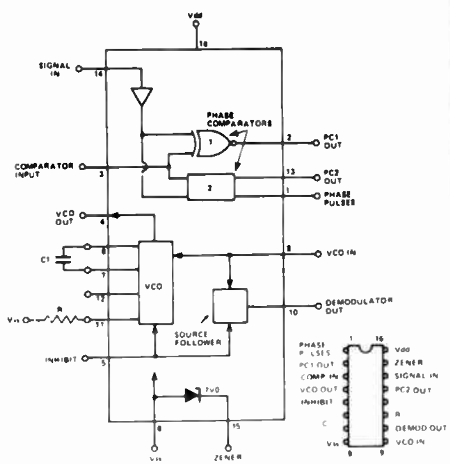
HOW IT WORKS ETI-165

Diodes D1 and D2 are a full wave rectifier, delivering half-sine pulses of 17 V peak at their cathodes. These half-sine pulses are coupled to a smoothing capacitor, C1, via D3 and also to the base of Q1 via R1. D3 serves to isolate the smoothing effect of C1. A 12 V regulated supply rail for the rest of the circuitry is provided by a 7812 three-terminal regulator.

The half-sine pulses coupled to the base of Q1 turn it on and off 100 times per second, the 100 Hz pulses on Q1's collector driving the input of IC4a, a Schmitt NAND gate connected as a buffer (4093). The output of IC4a drives the 'signal' input of IC2, a 4046 CMOS phase-locked loop (PLL). Its internal block diagram is shown in Figure 1. The VCO centre frequency of the PLL is determined by R5 and C3. An error signal from the phase comparator 2 (PC2) output (pin 13) is fed back to the VCO input (pin 9) via a second order low-pass filter consisting of R6, R7 and C4. Between the VCO output (pin 4) and the phase comparator input (pin 3) a divider having selectable outputs (IC3 — a 4017) is connected. This provides 1x to 9x the 100 Hz input frequency at the VCO output. The VCO output is further divided by two or by four by IC5 (a 4040) to provide scale multiplication of x1 (÷ 4) and x2 (÷ 2). To give an indication of the unit's operation, an output is taken from pin 4 on IC5. Q2 acts as a buffer between LED1 and the pin 4 output from IC5. The LED pulses on and off to show the unit is operating.

The selectable output from SW1 is connected to two paralleled sections of IC4 (IC4c and d) to interface to the 'loop' switch, Q3, a Darlington PNP transistor. For impulse operation, the primary loop of the tacho pickup coil is connected between the output loop terminals A and B.

The 12 V supply rail is available for powering any external equipment. R4 and D4 are included to protect the CMOS ICs against damage from negative spikes and unintentional application of an external voltage to the 12 V rail the wrong way round.



RANGE x1	RANGE x2	OUTPUT pulses/sec.	READING. rpm 4 cyl. tacho	READING. rpm 6 cyl. tacho	READING. rpm 8 cyl. tacho
1		25	750	509	375
2	1	50	1500	1000	750
3		75	2250	1500	1125
4	2	100	3000	2000	1500
5		125	3750	2500	1875
6	3	150	4500	3000	2250
7		175	5250	3500	2625
8	4	200	6000	4000	3000
9		225	6750	4500	3375
	5	250	7500	5000	3750
	6	300	9000	6000	4500
	7	350	10 500	7000	5250
	8	400	12 000	8000	6000
	9	450	13 500	9000	6750

NOTE: Printed circuit board and front panel artwork is located on page 76.

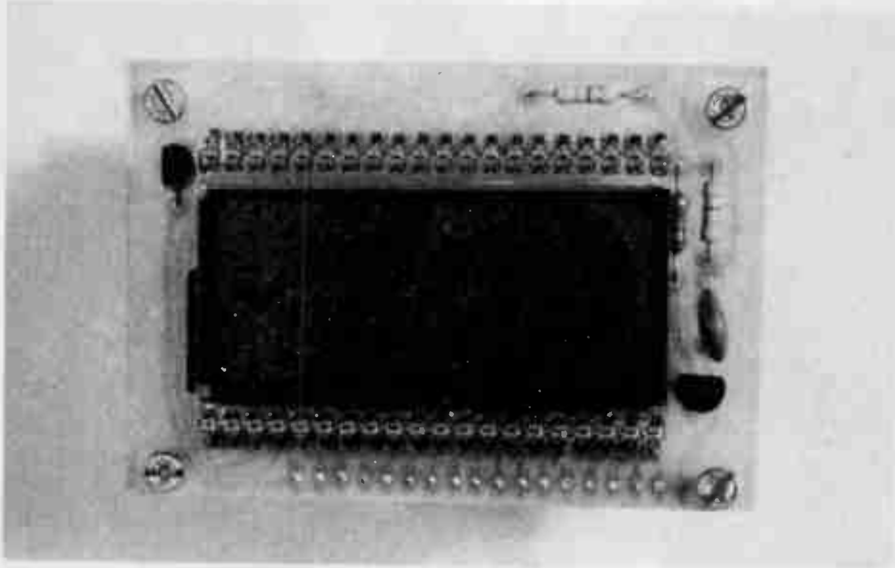
Versatile digital panel meter with liquid crystal display

David Tilbrook

This simple, versatile project can be used as the basis of many test instruments or as a stand-alone meter to measure voltage (as low as 200 mV) or current.

THERE ARE many applications that require a digital readout of dc voltage. To fulfil this requirement we published a digital voltmeter, the ETI-135 digital panel meter in October 1977. It was based around the Intersil ICL7106 digital voltmeter IC, which was at that time available in the form of an evaluation kit. Although the individual ICs are widely distributed now the evaluation kits are becoming scarce. For this reason we have decided to republish the design in a form suitable for commonly available components. The kit was supplied with small rectangular capacitors enabling them to be laid on their side to reduce height and allow the display to be mounted as closely as possible to the front panel. Unfortunately these capacitors are not commonly available. Greencaps work well in this application but their physical size requires a new pc board layout.

We overcame these problems by designing a pc board suitable to be cut in half. The display, the 7106 IC and a few other components mount on one of the pc boards, while all other components, including the battery if required, mount on the other pc board. This enables almost any sized components to be used and by mounting one of the pc boards behind the other, ensures the display occupies as little front panel space as possible. ▶



SPECIFICATIONS

Full scale readout	depends on setup. Full scale sensitivity is 199.9 mV
Resolution	100 uV
Accuracy	< 1 digit when correctly calibrated
Display	3½-digit LCD
Input Impedance	> 10^{12} ohms
Input bias current	approx. 2 pA
Polarity indication	automatic
Conversion method	dual slope
Reference	internally generated ±100 ppm
Power supply	9 V @ approx. 1 mA

Construction

The project can be constructed in two forms, either on a single pc board, or as mentioned above, by cutting the pc board in half and mounting one half behind the other. If your application requires that the pc board be cut, do so before mounting any of the components.

Start construction by deciding on the sensitivity that best suits your requirements. This decides the value of resistor R3. If a 200 mV (199.9 mV) maximum sensitivity is required R3 is omitted. For a 2 V (1.999 V) meter, the required value of R3 is 100k while for a 20 V (19.99 V) meter, use 10k.

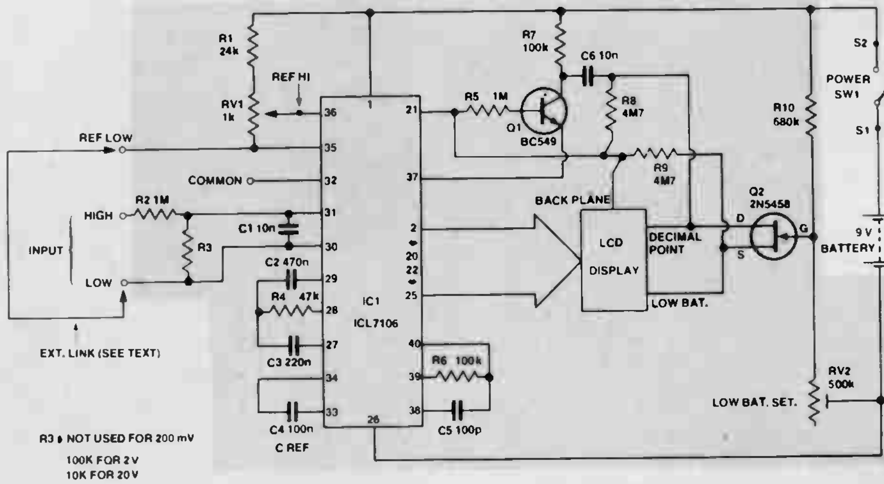
If the meter is setup for 200 mV operation it is advisable to solder an additional 1M resistor in parallel with the input, i.e: directly from the low input terminal to the high input terminal. This reduces the input impedance of the meter to 1M and reduces the sensitivity of the instrument to stray static voltages. Without this resistor the display has an input impedance of more than 10^{12} ohms. So the input capacitance can easily become charged by static, prohibiting the meter from zeroing correctly. On the other ranges, a parallel resistor is automatically present so the additional 1M resistor is not necessary.

Having decided on the value of R3, solder all resistors and capacitors onto the pc boards, with the exception of capacitor C6. Next, solder the 10-turn trimpot, RV1, and the 'low batt.' set trimpot, RV2. The latter is best mounted lying down. If the project is constructed using the single pc board approach all the capacitors should also be mounted lying down so that the display can be as close as possible to the front panel. If the twin pc board approach is used only those components mounted under the battery need be mounted lying down. The battery is mounted on a 9 V battery clip using 6 mm long spacers as shown in the accompanying photos. If the project is constructed using the single pc board approach, mount the battery clip, once again with 6 mm spacers, but on the copper side of the pc board.

The main IC and the liquid crystal display can now be mounted. The 7106 is mounted under the LCD display, so if a socket is required ensure that it is a low height type. Otherwise, solder the IC directly to the pc board making sure that the device has been inserted the right way around. Check this against the construction overlay before soldering. The LCD display should be mounted using Molex pins. This spaces the display off the pc board and ensures that the transistors and capacitors around the display are not higher than the display itself. It is probably easier to plug in the display before soldering the remaining components. There are no convenient orientation marks on the display so it is necessary to hold it at a slight angle and look for the outline of the digits. The display should be mounted with the decimal points at the bottom and the 'LOW BAT' indicator in the top left hand corner of the display.

Finally, solder the remaining transistors and capacitor C3, being careful to orientate the transistors correctly and not to scratch the front glass of the display.

If the single pc board approach has been adopted, construction is complete at this stage. If the twin pc board approach has been used however, it is necessary to solder the 18 wire links



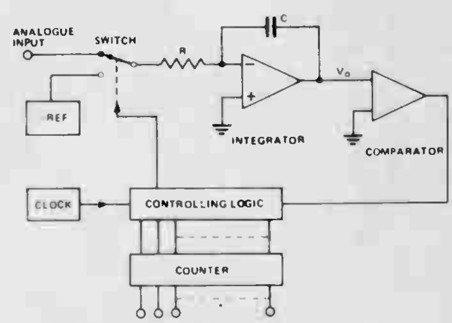
Printed circuit board artwork for this project is on page 102.

HOW IT WORKS — ETI-161

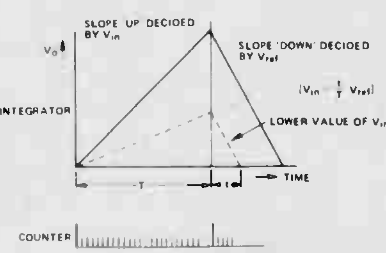
Most of the work is done by the ICL7106 IC. This uses the dual-slope integration technique to ensure good long-term accuracy and reliable operation. The analogue input is first converted to a time period which is then converted to a binary number by a digital counting system. This conversion system is illustrated in the block diagram. When the switch connects the analogue signal input to the input of the integrator, the output from the integrator ramps up at a rate determined by the input voltage. At the same time, the counter is started at zero and begins to count clock pulses. When a predetermined number of pulses has been counted the input is switched to the reference by the control logic. At this time, the integrator capacitor, C, has been charged linearly to some voltage determined by the ramp rate and therefore by the input voltage. As the switch changes to the reference, the counter is reset to zero and commences counting again. The reference is of appropriate polarity to that of the input signal and so causes the integrator to ramp down with a fixed slope. When the output reaches zero, the counter is stopped and its contents displayed on the digital readout. The count displayed is the ratio of the counts during the downward ramp to the counts during the upward ramp.

The value of the integrator capacitor and clock frequency are of little significance, provided they are stable for the duration of the conversion period.

This is a true dual polarity system so the integration direction depends on the polarity of the input voltage. Provided ac ripple on the input averages to zero over the count time it will be rejected. If 50 Hz ripple is to be rejected, for example, a 50 kHz clock rate could be used, giving an 80 ms sampling time (four cycles of 50 Hz). The clock can be adjusted by varying



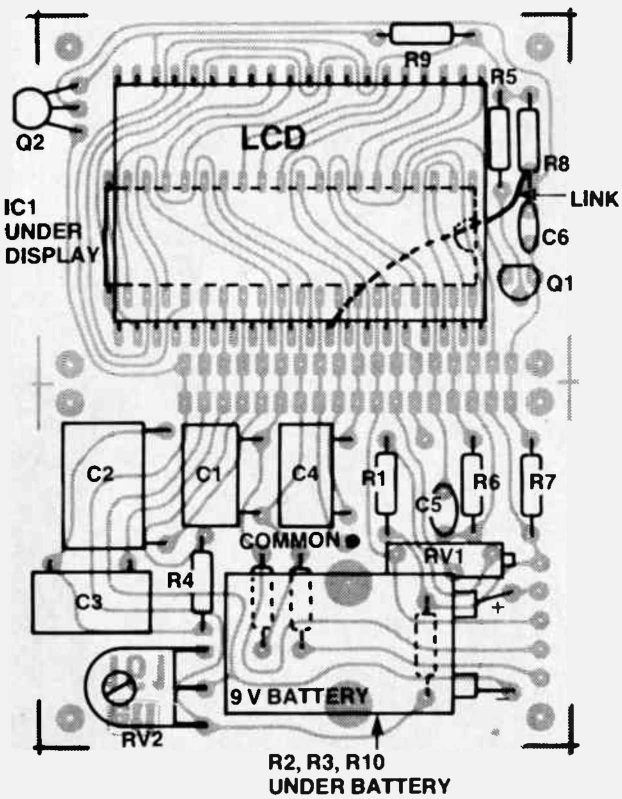
Block diagram of the dual-slope integration technique

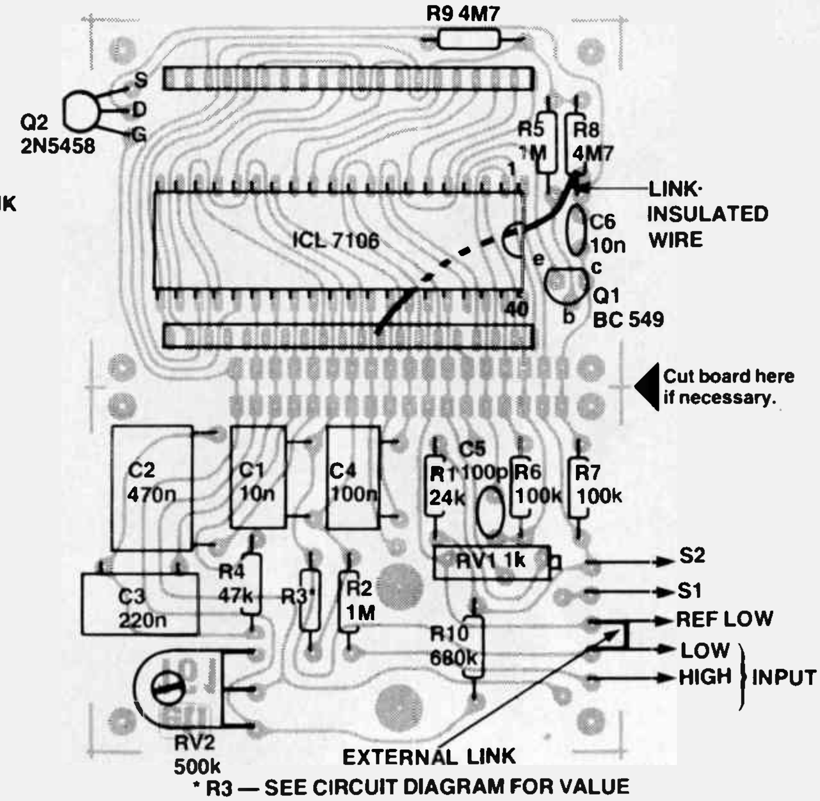


Timing diagram of the dual-slope A/D conversion technique.

the value of R6. We experienced no problem with 50 Hz ripple. Capacitor C1 in conjunction with resistor R2 function as a low pass filter with a −3 dB rolloff point well below 50 Hz.

The 2N5458 JFET (Q2) is used simply as a voltage sensor to monitor the battery voltage and drive the LOW BAT indicator if the voltage falls below that determined during set up.





COMPONENT OVERLAY SHOWING POSITION OF LCD AND BATTERY

COMPONENT OVERLAY WITHOUT LCD OR BATTERY SHOWING POSITION OF IC, R2, R3 AND R10

between the two boards. Before doing this however, solder a lead from the point on the pc board marked 'COM.' It is necessary to connect this point to one of the two input terminals. The usual method is to connect COM to the low input. Also, connect REF LOW to the low input. This configures the meter to a normal absolute reading voltmeter that will display the voltage between the low and high input terminals with normal polarity indication. The module is also capable of ratiometric measurement. For information about this application consult the data sheet included for the ICL7106.

Mount the pc boards, spacing them approximately 20 mm apart, either using spacers or simply an entire set of nuts on the four mounting bolts. Use tinned copper wire to make the links between the pc boards, soldering each one at both ends before proceeding to the next. A fine-tipped soldering iron and fine solder (22g) should be used for this project and is especially important at this stage.

Calibration

Before powering up, ensure that all components have been soldered correctly and have been inserted with the correct orientation. If all is well plug in the battery and connect the points S1 and S2 to each other. The display should immediately stabilise with all digits reading zero. Use a power supply to generate a test voltage and adjust RV1 so that the panel meter agrees with another voltmeter. Preferably use a digital voltmeter for this, although a good analogue instrument can also be used with decreased accuracy. RV2 is used to adjust the low battery indication on the display. The best way to do this is to run the unit from an adjustable power supply, checking operation against a known voltmeter while decreasing the supply voltage. Set the LOW BAT indicator to come on at a supply voltage just above where the panel meter fails to read accurately. Do not exceed 9 V on the supply leads when doing this test.

Once calibrated correctly this project is capable of very accurate measurement. The 7106 is used in many commercial digital multimeters and the high input impedance enables the module to be used in many applications.

We intend publishing several projects using the display, but even as a general purpose dc voltmeter the module has proved very useful. A 1R shunt resistor can be soldered directly across the input to convert the module into a dc current meter reading in milliamps (i.e: 199.9 mA). Use an OR1 shunt to read dc amps (i.e: 1.999 A). Add an 'absolute value' generator to enable ac voltage or current to be measured. ▶

PARTS LIST — ETI-161

Resistors .... all ¼W, 5%

R1 .... 24k
R2, R5 .... 1M
R3 .... see note
R4 .... 47k
R6, R7 .... 100k
R8, R9 .... 4M7
R10 .... 680k
RV1 .... 1k 10-turn trimpot
RV2 .... 500k horizontal trimpot

Capacitors

C1 .... 10n mylar, 50 V
C2 .... 470n mylar, 50 V
C3 .... 220n mylar, 50 V
C4 .... 100n mylar, 50 V
C5 .... 100p NPO ceramic
C6 .... 10n ceramic

Semiconductors

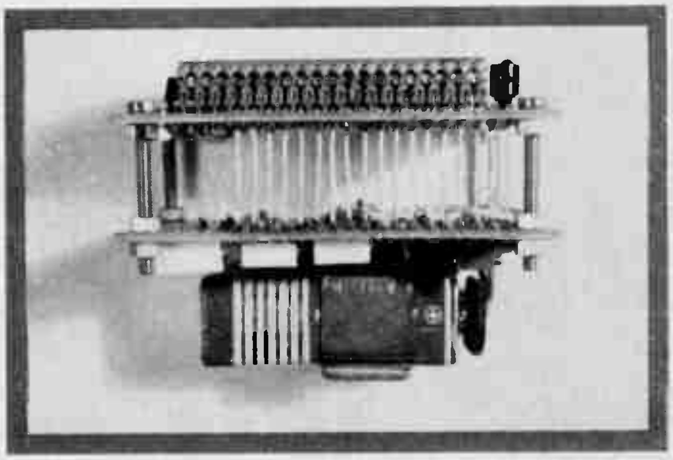
IC1 .... ICL7106
Q1 .... BC549, BC109
Q2 .... 2N5458, MPF106

Miscellaneous

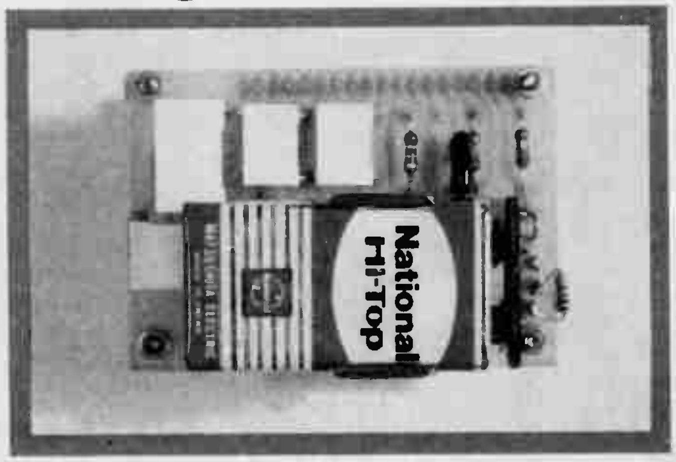
ETI-161 pc board; LAD204 liquid crystal display (from Intersil evaluation kit) or similar; battery holder clip for No. 216 battery (if required); SW1 — SPST switch (if required); two 6 mm long spacers; four 20 mm spacers (if required); nuts and bolts to suit assembly; No. 216 9 V battery (if required).

Price estimate **$30 — $35**

NOTE: many of these components are available in the Intersil Evaluation kit, particularly the 7106, the display and the capacitors.



View of the panel meter with the 'electronics' board mounted behind the 'display' board, showing the connections run between the two boards and how the battery is mounted.



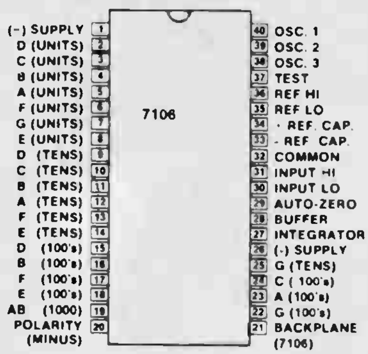
Rear view of the 'electronics' board showing battery positioning. If an external supply is used the battery and battery mounting components can be dispensed with.

ICL7106
3½ Digit Single Chip A/D Converter

FEATURES

- Guaranteed zero reading for 0 volts input on all scales.
- True polarity at zero for precise null detection.
- 1 pA input current typical.
- True differential input and reference.
- Direct display drive - no external components required. — LCD ICL7106
  — LED ICL7107
- Low noise - less than 15μV pk-pk.
- On-chip clock and reference.
- Low power dissipation - typically less than 10mW.

PIN CONFIGURATION



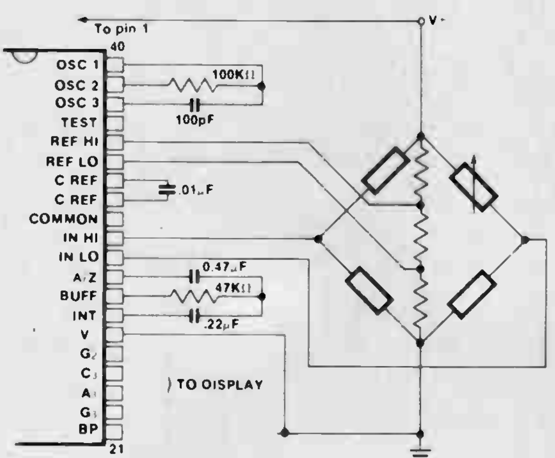
ABSOLUTE MAXIMUM RATINGS

ICL 7106

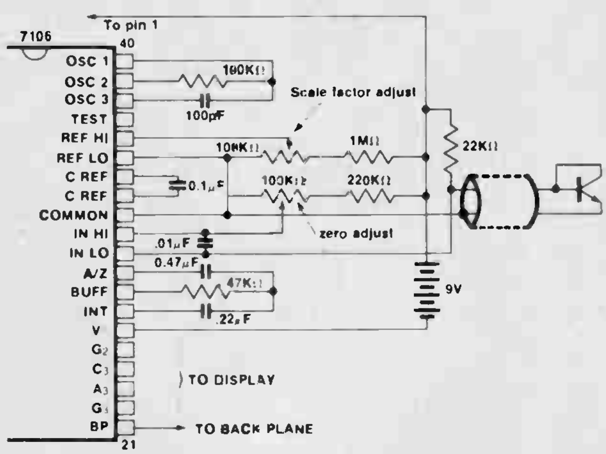
Supply Voltage (V- to V+)	15V
Analog Input Voltage (either input) (Note 1)	V+ to V-
Reference Input Voltage (either input)	V+ to V-
Clock Input	Test to V+
Power Dissipation (Note 2)	
Ceramic Package	1000 mW
Plastic Package	800 mW
Operating Temperature	0°C to +70°C
Storage Temperature	-65°C to +160°C
Lead Temperature (Soldering, 60 sec)	300°C

Note 1 Input voltages may exceed the supply voltages provided the input current is limited to ±100μA

Note 2. Dissipation rating assumes device is mounted with all leads soldered to printed circuit board



7106 measuring ratiometric values of Quad Load Cell. The resistor values within the bridge are determined by the desired sensitivity.



7106 used as a digital centigrade thermometer. A silicon diode-connected transistor has a temperature coefficient of about -2mV/°C. Calibration is achieved by placing the sensing transistor in ice water and adjusting the zeroing potentiometer for a 000.0 reading. The sensor should then be placed in boiling water and the scale-factor potentiometer adjusted for 100.0 reading. ●

Project 162

30 V/1 A fully adjustable, protected power supply

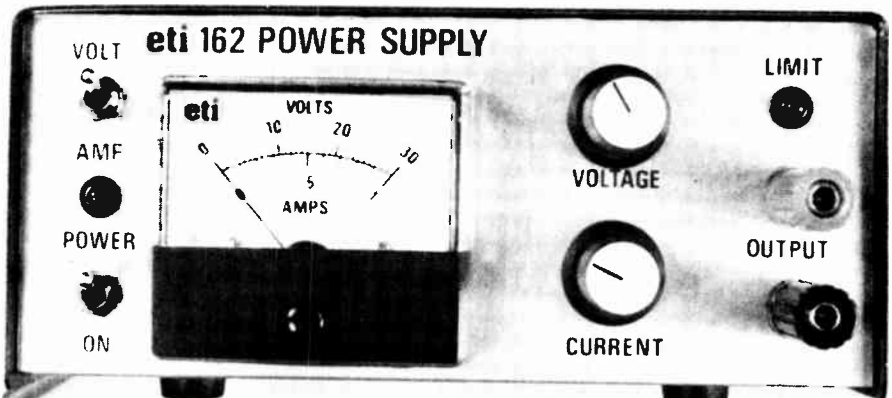
This low cost, easy to build power supply features full protection, variable voltage output from 1.3 to 30 volts, variable current limit from zero to one amp plus metering of both voltage and current output.

David Tilbrook
Roger Harrison

THE FIRST piece of test gear an electronics enthusiast or technician wants after a good multimeter is a *power supply*. But, exactly *what* does that hypothetical person want, we asked ourselves? After much discussion, examining past projects etc, we came up with a specification like . . . A, B, C. As he happened to be a captive in the advertising sales office, which is next door to ETI's lab, we put it to a famous Irish West Australian electronics dealer who walks on water for a hobby (see ETI, April '81, p.11), to 'test the water', so to speak. He said, "No, no, no! What they want is a power supply with D, E, F for XY.Z dollars". Conceding he might be right but that there was an element of pecuniary interest to be deducted, we counter-proposed a power supply with G, H, I but the Irishman said that would cost ZY.X dollars and no electronics person in their right mind would pay that. At this stage we thought compromise would result in a power supply with a camel-hitching rail on the front panel and thought retreat/rethink the wiser move.

Suspecting XY.Z dollars was something like $49.50 ($10 above a current kit supply and $10 below our last low-cost supply project) it was apparent some awful constraints were looming up. Rather than taking a 'better' supply and pruning it to meet a price, we started from the ground and looked at what was necessary and asked could it be done?

Obviously, a 'laboratory standard' power supply with dual digital metering, programmable voltage and current and nuclear blast proofing was not necessary. Most solid-state circuitry requires voltages between 3 V and 30 V and may require currents up to half an amp or so. Any circuitry run from the supply would need to be protected from damage by excess current should there be a fault in it, so current limiting was necessary. Current limiting also has the advantage of providing protection for the power supply if the output should be short-circuited. So, variable output up to 30 V and variable current limit were two prime goals. A pot costs less than a toggle switch so continuously variable current limiting could be included, perhaps.



Our power supply presents a neat, functional appearance. It uses low cost, readily available components and is housed in a standard 184 x 70 x 160 mm metal case. Scotchcals were made up and applied to the front panel and meter scale.

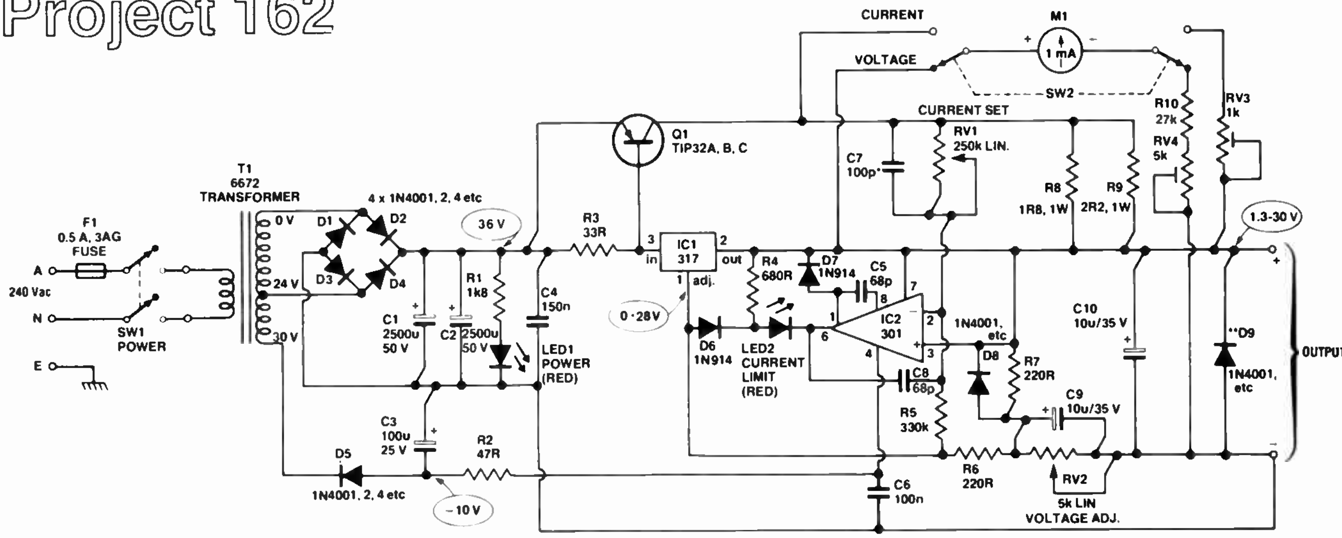
Meters are a relatively expensive item. Assuming the user has a multimeter (you bought that first, remember) then the meter on the power supply only needs to read either voltage or current at any one time. Voltage metering for the supply is an obvious requirement, leaving current to the user's multimeter. But, from experience, you often need an extra meter. Thus, switched metering was desirable. Dual meters are nice, but relatively *expensive*.

Three-terminal IC regulators are cheap, readily available and provide good results. They can also provide thermal overload protection. Internal circuitry turns them off if the case temperature of the device rises above a specified maximum. Getting a variable output from a three-terminal regulator is easy, but providing variable current limit is another matter. Use a specialised regulator? "You'd be in all sort of compost if, and it's inevitable, it was hard to get", said the Irishman-who-walks-on-water. Point there. We looked at some op-amp and transistor regulator circuits, tried one or two, but thermal overload protection was unavailable and the circuits got a little complex — and expensive. Back to the three-terminal regulator and scouring of ▶

SPECIFICATIONS — ETI-162 PROTECTED POWER SUPPLY

Output voltage	1.3— 30 V, variable
Output current	0 — 1 A, variable limiting
Output regulation	better than 0.2% zero to full load
Hum and noise on output	less than 1 mV at full load

- LED indicates current limiting mode
- Output terminals isolated from chassis



application notes. Voila! National Semiconductor's Linear Data Book had something very close to what we wanted. In next to no time (read, close to *deadline*) a circuit was lashed up and working! The project you see before you is the culmination of the aforegoing.

There were a few more parameters to consider. The case? Metal, but cheap. The transformer? Appropriately rated and available *everywhere*. The meter? Ditto. The price? On target.

Specifications are given in the accompanying table.

The design

The power supply is built around an LM317 three-terminal voltage regulator. This device, apart from being inexpensive and widely available, has the following desirable features: internal current-limiting (self-protection), thermal shutdown (more self-protection), adjustable output between 1.2 V and 37 V and excellent regulation figures. We elected to use the TO-220 flat pack style as it's easy to mount (one bolt). National and Motorola designate it LM317T. Fairchild have an equivalent designated uA317UC.

The regulator serves two purposes in this design — to provide a regulated voltage reference and thermal overload protection. The output current is supplied by a transistor. We used a TIP32, which also comes in a TO-220 package. This is a pnp device connected here as a 'collector follower'. This sort of circuit provides current amplification, but no voltage gain. The regulator and transistor are mounted side by side on a heatsink. If the output voltage and current limit are set to maximum and a short circuit occurs on the supply's output for a lengthy period, then a considerable amount of power will be dissipated in the transistor. The temperature of the heatsink will rise considerably, but before it can rise destructively, the internal thermal overload circuit of the regulator will operate and limit the maximum dissipation. You'll burn your fingers on the heatsink by the time that happens.

In normal use, at maximum dissipation the heatsink only gets warm to the touch.

Output voltage variation is provided more or less in the normal manner by 'tapping' the 'adj.' terminal across a resistive voltage divider connected across the regulator output (this involves R7 and RV2). Current limiting is provided by an op-amp. This senses the output current and 'short circuits' the voltage applied to the regulator's 'adj.' terminal. The regulator output, and thus the supply output, drops and only the predetermined current flows in the load on the supply output.

HOW IT WORKS — ETI-162

The heart of the project is the LM317 regulator, IC1. This device is used in conjunction with the main 'pass' transistor, Q1. The IC regulator compares the voltage in its output pin with that — on the 'adj.' pin and regulates the output voltage accordingly. The bias for the pass transistor is derived across resistor R3 and is due to the current drawn by the IC regulator. If the 317 detects excess voltage, for example, on its output pin, it decreases the current pulled through R3, hence decreasing the bias to Q1. In this way the 317 controls the ouput voltage and ensures good regulation for the output.

The control voltage for the 317 is derived from a potential divider formed by R7 and RV2. The electrolytic capacitor (C9) connected across RV2 is to reduce noise on the output. Diode D8 is there to discharge this capacitor in the event the output is short circuited, otherwise it will attempt to discharge via IC1 and IC2, possibly causing some damage.

Capacitor C10 is placed directly across the output to provide both circuit stability and to supply short term peak currents often required by some circuits. It also functions as a low impedance ac bypass.

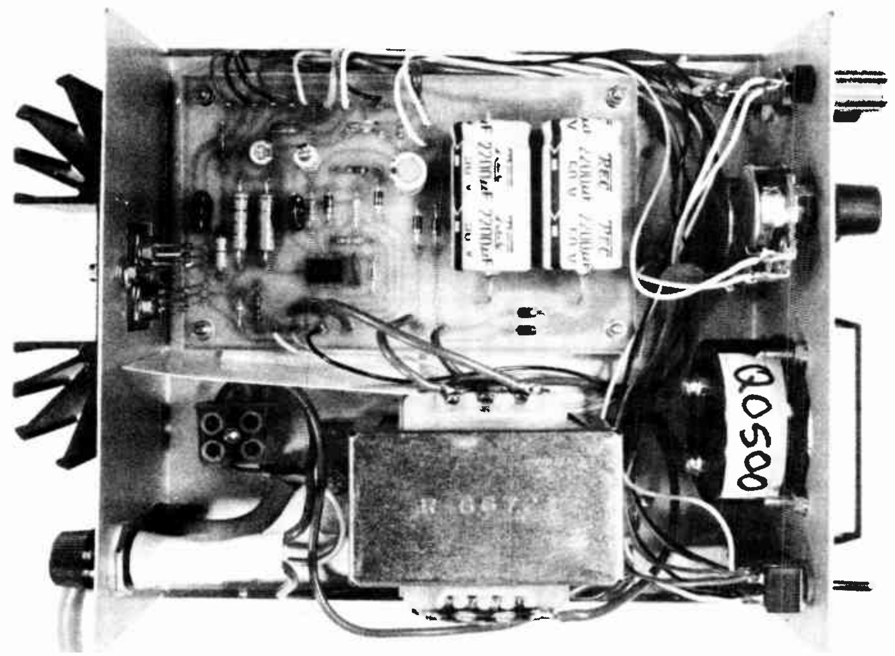
Since multiple power supplies are often used to power a single circuit, it is possible for the power supply to be supplied with a reverse voltage from an external source. To protect against this, diode D9 is included. The 1 A continuous current rating of this diode should be sufficient in most cases, and it will stand very high peak forward currents.

The remaining components are related to the variable current limit feature of this supply. The main device involved is the 301 op-amp, IC2. This device compares the output voltage, which is connected to its non-inverting input pin 3, to the voltage dropped by a potential divider formed by the CURRENT SET potentiometer (RV1) and R5. For any given setting of the CURRENT pot, the voltage on pin 2 of IC2 is proportional to the output current.

When the output current rises high enough, the voltages on pin 2 of IC2 will be 'pulled' above that on pin 3 (which is at the output voltage). The output of IC2, pin 6, then swings toward the negative rail, drawing current via D6 and LED2. LED2 will light, indicating current limit is in operation. The output of IC2 pulls down the voltage on the 'adj.' pin of IC1, lowering the output voltage.

Capacitors C5, 7 and 8 and diode D7 are included to ensure stability in the current limit stage when it is operating. This circuit uses a feature of the LM301 whereby it is capable of working as a differential amplifier with its inputs driven right up to the positive supply rail. The positive supply for the op-amp can therefore be the main output of the power supply and vary as the output voltage is varied. To ensure that the op-amp always has a supply across it, a negative supply rail has been derived by D5 and C3, a half-wave rectifier system that generates about 10 V from a tap on the secondary of T1.

The meter switch, SW2, allows the meter to be connected either as a voltmeter or a current meter. In the voltmeter position, the meter circuit is placed directly across the output with R10 and RV4 in series with M1. RV4 allows voltage calibration of the meter. When SW2 is in the current position, the meter measures the voltage drop across R8 and R9, which have the output current flowing through them. RV3 permits current calibration of the meter.



Overall internal view of the power supply. Note the cardboard 'shield' separating the mains terminal block and leads from the pc board.

Construction

For most electronic enthusiasts the mechanical work involved in a project is usually the tedious bit. We would expect most constructors to purchase a pre-punched and drilled chassis, but if you want to do it yourself or plan to use a different chassis, then start by carefully laying out and marking up the metalwork. Component placement is not critical, but we would suggest you keep a strict division between the mains components and wiring and the rest of the circuitry and components. If you're using the same chassis, or something similar, then our Scotchcal front panel artwork can be used as a template for the front panel. General placement of components can be determined from the photographs. The 184 x 70 x 160 mm chassis we used could have done with some bracing of the front and rear panels. Some small brackets could be made up from scrap aluminium pieces to do this job, if you wish. If you do this, tackle it first, but make sure the brackets won't foul any components attached to the panels.

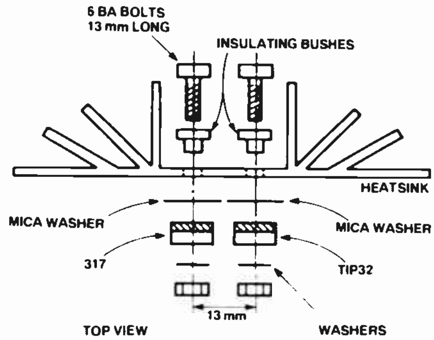
If you're using the same chassis we used and all holes are prepared, first thing to do is apply the Scotchcal front panel. We made up a metal Scotchcal, rather than plastic, as it's more durable. Carefully lift the backing from one edge and align the edge on the chassis panel. Peel off the backing and carefully smooth the Scotchcal into place across the panel making sure it's correctly aligned as you go. When it's in place, smooth out any bubbles by carefully rubbing them toward an edge. You can cut out the holes with a sharp penknife or modelling scalpel.

We also made up a metal Scotchcal label for the meter scale. Disassemble the meter and carefully apply the Scotchcal to the original scale, trim the edges if necessary and then re-assemble the meter.

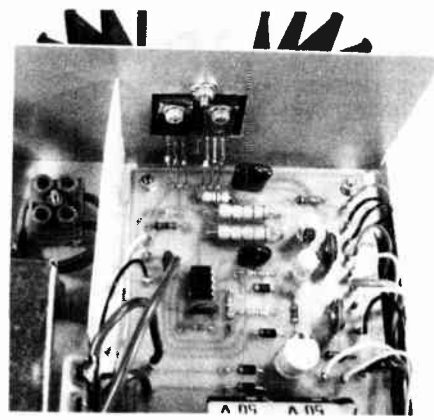
Mount the meter to the front panel first, otherwise you will have great difficulty reaching the nuts that secure it as they will be obscured by other components. Then mount the LEDs, switches, pots (and their knobs) and output terminals. On the rear panel, mount the mains fuse and install the mains cable with its clamp grommet, leaving enough of the cable protruding inside the case so that it reaches the terminal block. Mount the terminal block on the chassis bottom next, then terminate the mains cable. Make sure the green and yellow earth lead is the longest so that it's the last to break in the event of a catastrophic accident.

Insert the four pc board mounting bolts next. We used 13 mm long 6 BA bolts. Put two nuts on them to space the pc board up from the chassis. Cut a 'shield' for the mains wiring from a 70 x 70 mm piece of heavy cardboard, bend up one edge about 8 mm in and secure it under the rear mounting nut nearest the mains terminal block by punching a hole in the appropriate place in the bent-up piece — see the internal photograph.

Assemble the 317 regulator and TIP32 transistor to the heatsink next. Insulate each with a mica or plastic thermal washer and bolt insulators. Using a multimeter, check that the metal tag of each device is not shorted to the heatsink. Bend the leads of each device up from the heatsink.



Mounting the 317 regulator and TIP32 transistor to the heatsink.

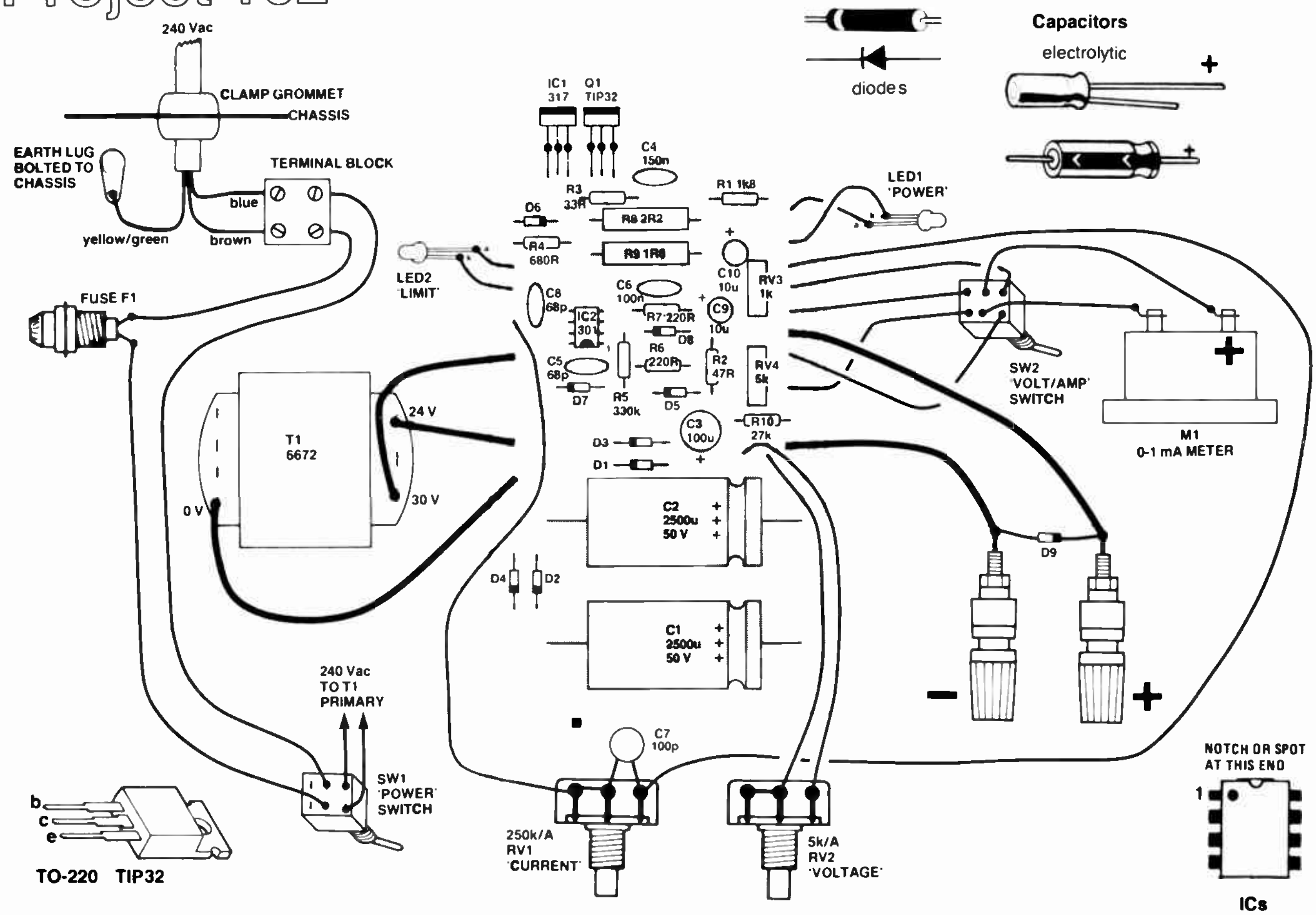


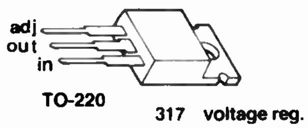
Internal view of the power supply showing mounting and terminating details for the regulator and transistor. These are assembled to the heatsink as shown above and the heatsink mounted to the rear panel using bolts above and below the cutout visible here.

Now you can attach flying leads to all the components mounted on the front panel and between the mains terminal block and fuse to the mains switch. Put heatshrink tubing over the mains fuse and mains switch, ensuring they are well covered. Make sure all leads are long enough to reach their destination. Solder C7 to the terminals of RV1 and D9 to the output terminals, as shown in the overlay and wiring diagram.

Mount the power transformer next, oriented such that its 240 Vac input terminals are away from the pc board. Terminate the leads from the mains switch to the transformer primary connections, using heatshrink tubing again to shroud the terminals. ▶

Project 162





PARTS LIST — ETI-162

Resistors .... all ½W, 5% unless noted

- R1 .... 1k8
- R2 .... 47R
- R3 .... 33R
- R4 .... 680R
- R5 .... 330k
- R6, R7 .... 220R
- R8 .... 1R8, 1W
- R9 .... 2R2, 1W
- R10 .... 27k
- RV1 .... 250k lin. pot.
- RV2 .... 5k lin. pot.
- RV3 .... 1k min. vertical mount trimpot
- RV4 .... 5k min. vertical mount trimpot

Capacitors

- C1, C2 .... 2500u/50 V axial electro
- C3 .... 100u/25 V RB electro
- C4 .... 150n greencap
- C5, C8 .... 68p ceramic
- C6 .... 100n greencap
- C7 .... 100p ceramic
- C9, C10 .... 10u/35 V RB electro

Semiconductors

- D1-5, 8, 9 .... 1N4001, 1N4002, 1N4004, EM401 etc
- D6-D7 .... 1N914, 1N4148
- IC1 .... LM317T, uA317UC
- IC2 .... LM301, uA301
- Q1 .... TIP32A, B or C
- LED1, 2 .... TIL220R red LED

Miscellaneous

- F1 .... 0.5 A, 3AG fuse
- M1 .... 1 mA MU-45 meter, or similar
- SW1, SW2 .... DPDT miniature toggle switches, 250 Vac/1 A rated.
- T1 .... 6672 transformer, 240 V primary, 30 V/1 A multi-tapped secondary.

ETI-162 pc board; two binding posts — one red, one black; case — metal, U-chassis & lid type; 184 x 70 x 160 mm (e.g: D.S.E. H2744, Altronics H0444, Electronic Agencies HE1742); two small knobs; mains cable, clamp grommet and terminal strip; fuseholder; Scotchcal panel and meter scale; heatshrink tubing; heatsink — flat sided radial fin type, 30 mm long (e.g: Rod Irving HS1); nuts, bolts, hookup wire etc.

Price estimate
$45 — $50

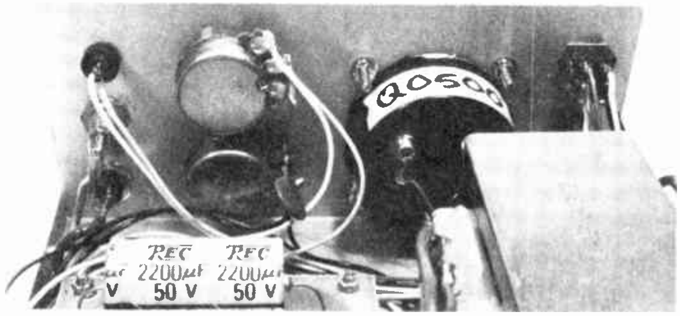
Note that this is an **estimate** only and **not** a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components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

Now you can tackle the pc board. Start with all the resistors. Then mount the two trimpots. Next, solder all the semiconductors in place. It is *most important* you get all of these the right way round, especially the rectifier diodes. The capacitors can be mounted next. There are five electrolytics and all have to be mounted with the correct orientation. Note that the two filter capacitors are given as 2500 uF in the parts list but the photograph shows 2200 uF types. Either can be used without affecting circuit operation at all. Remember, electrolytic capacitors have a very wide tolerance (like +80%, −20%). We used pc stakes to terminate the leads from the off-board components. You could use short lengths of 22 gauge tinned copper wire with a loop bent at the top, if you wish. Six 30 mm lengths of tinned copper wire are needed to connect the 317 and TIP32.

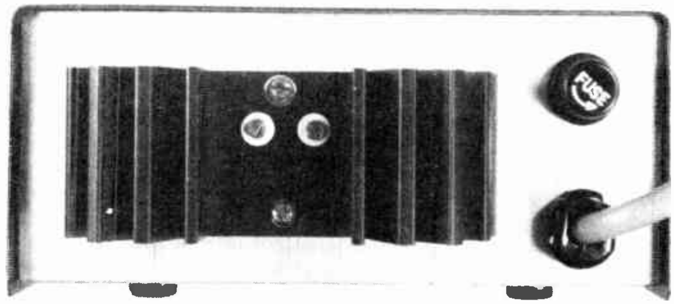
Carefully check the pc board to see that all components are mounted and the semiconductors and electrolytics are correctly polarised. Mount the pc board and terminate the flying leads from all the off-board components. Use heavy duty hookup wire from the transformer secondary to the board and from the output terminals to the board.

All OK? *Check it!*

Now you're ready to switch it on and try it out. ▶



Internal view from the rear of the front panel.



View of the rear panel showing heatsink and mains fuse placement.

Switch on

Set the CURRENT and VOLTAGE control to about half rotation and the VOLT/AMP switch to read volts on the meter. Hook your multimeter to the output, switched to the 30 V range or a higher one, plug in and switch the power supply on. If all is well, the POWER LED should light and the multimeter will read some voltage. The power supply meter will probably read something quite different. If you don't get these indications, switch off and look for a wiring error or components misplaced or incorrectly oriented.

If all is well, set the VOLTAGE control so that you get a reading of 20 V on your multimeter. Then, adjust RV4 (the trimpot nearest the front panel) until the power supply meter reads the same. Vary the VOLTAGE control and check that the supply's meter corresponds closely with the multimeter. See that you get around 1.3 V at minimum and 30 V (within 0.5 V) at maximum.

Turn the power supply off. Wind the VOLTAGE control fully anticlockwise and set the CURRENT control half way. Set the VOLT/AMP switch to read current on the supply's meter. Switch your multimeter to the 1 A range, or higher. Turn the power supply on. The LIMIT LED should light and the multimeter should indicate about half an amp of current flowing. The supply's meter will likely read something quite different. Wind up the CURRENT control so that your multimeter reads one amp. Adjust RV3 (nearest the back panel) so that the supply's meter reads the same. Vary the CURRENT control and see that the supply's meter corresponds closely to your multimeter. The LIMIT indicator should go out when the CURRENT control is at minimum.

If at any time you don't get the correct indications, or worse still — burning smells!, switch off and hunt for a fault.

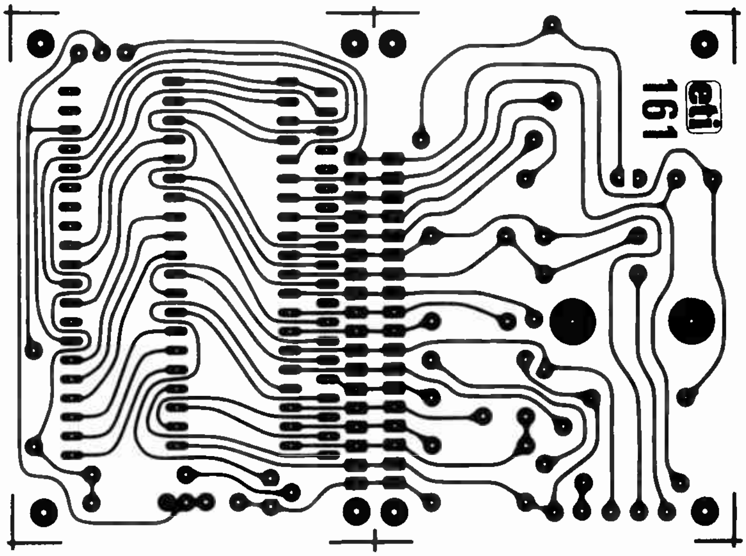
If all is well, you can put the lid on your supply and put it proudly on your workbench.

Using it

In use, you set the output voltage to what is required by the circuit you are working on then apply a short to the output terminals and set the current limit to something a little above what you judge the circuit will draw. With most CMOS circuitry, even that containing many ICs, 100 mA is a good safe limit. Allow for relay and indicator (LEDs, lamps etc) currents. A little experimentation will teach you what to expect under a wide range of circumstances.

We trust you get many useful years of use from your ETI-162 power supply. ●

NOTE: this supply is not meant to be used as a battery charger so don't connect lead-acid batteries to it. Accidental reverse connection of a lead-acid car battery will likely destroy D9 and maybe other components. Nickel-cadmium batteries could be charged from the supply operated in the constant-current mode and D9 will prevent damage to the supply if you accidentally reverse-connect them. However, take the usual precautions regarding the charging period and charging current.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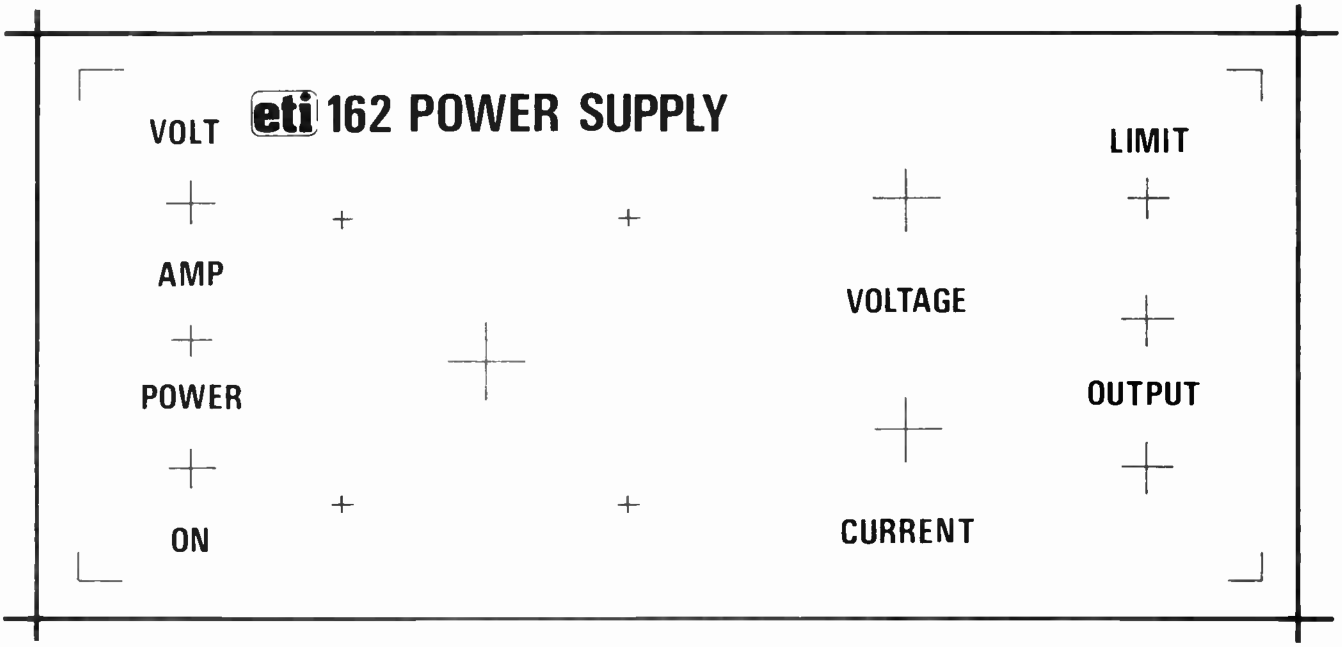
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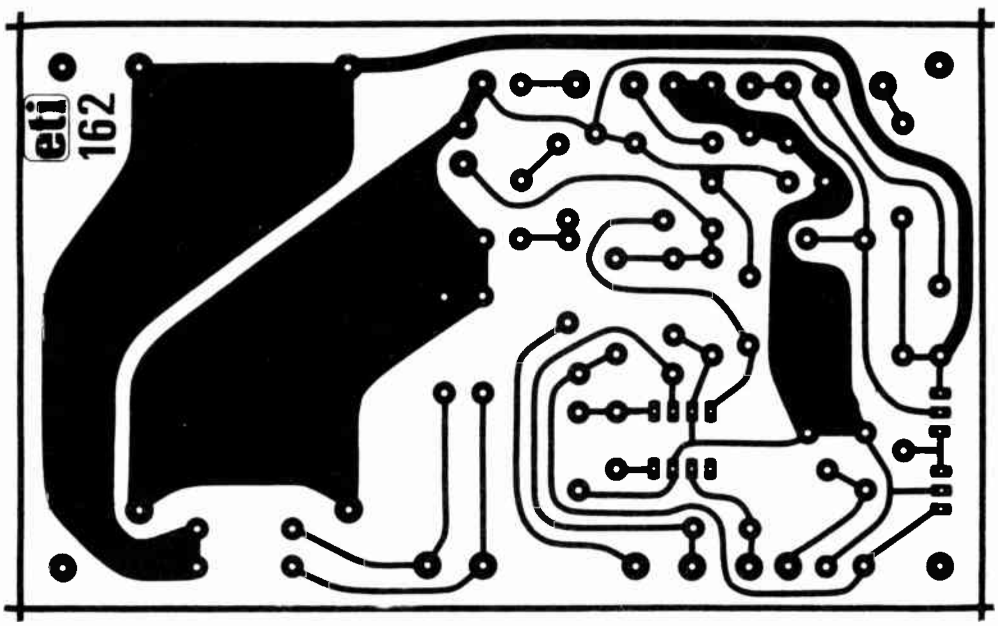
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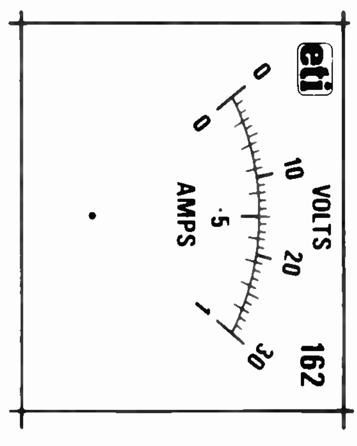
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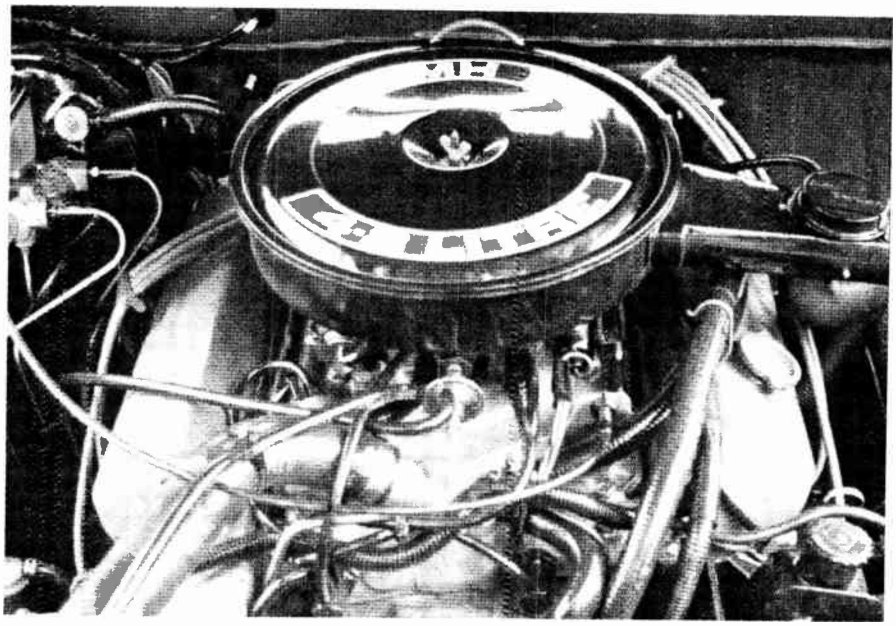


The 'Auto Tester'

Graeme Teesdale

This handy little test gadget will help you sort out all those little bugaboos that can go wrong in automotive electrics. With this, you can check voltage drops, on and off charge battery voltages and resistances.

BUDDING MECHANICS are very often bamboozled by the electrics of a modern motor vehicle. An automotive or electronic type multimeter with its combination scales all crammed together simply adds to the confusion. This project was developed to make fault-finding a little easier by providing simple LED indication of 'set' points in voltage or resistance.

In a vehicle, voltage drop in cables of more than 0.5 volt can bring problems. The Auto Tester provides a clear indication of voltage drops less or greater than 0.5 V. The battery system, to perform up to scratch, must deliver at least 12 V on load and the battery should have a terminal voltage of more than 13.5 V when charging.

Resistances encountered in vehicles tend to have fairly well defined limits. Many devices have resistances under 10 ohms, a few range up to 150 ohms. Thus the first resistance 'set' point is at about 150 ohms. Much higher resistances are encountered in HT suppressors, etc. Generally, these are around 10k or 15k. Trouble can occur if they go faulty and exhibit a high resistance, generally greater than 50k. Thus, two other 'set' points for resistance are at 10k and 50k.

The unit was housed in a small, conveniently-sized jiffy box. The pc board designed for this unit will just fit comfortably into several different types on the market. Four indicator LEDs are provided; a

Pragmatic. Simple, but functional. The project was housed in a small jiffy box with a Scotchcal panel added.

POLARITY indicator, followed by one for each of the three set points in voltage and resistance. Two pushbuttons select which 'mode' you wish to use — VOLTS or OHMS.

Where battery polarity is unknown, or in instances where the Auto Tester may be incorrectly connected, the POLARITY LED will light when the red, or positive, input lead is connected to the battery negative.

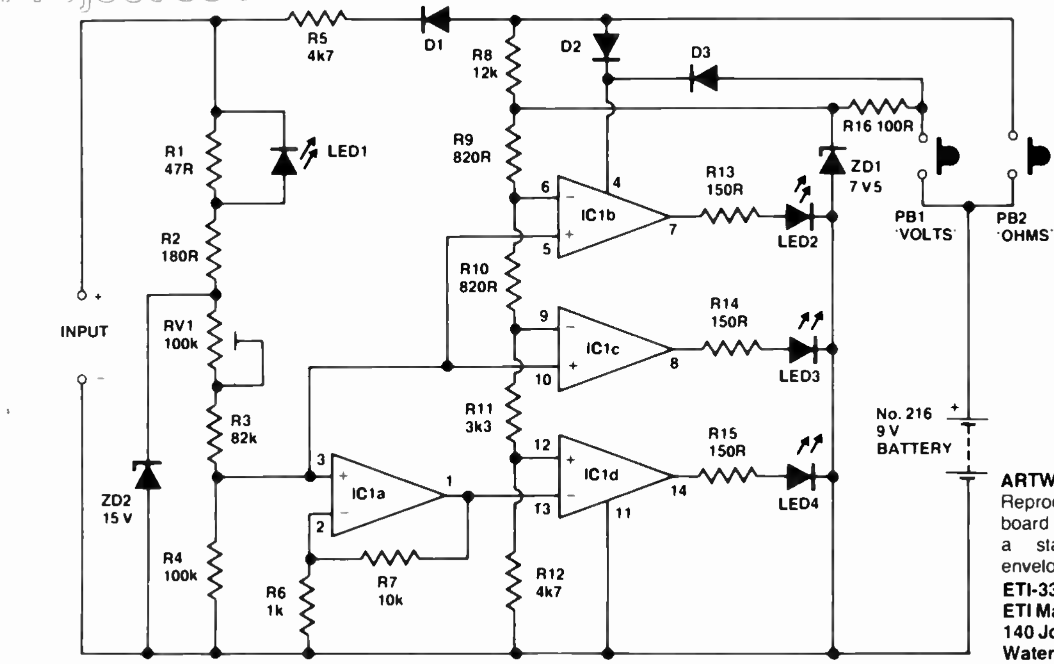
Protection against input overvoltage damage has been incorporated, so that voltage inputs of greater than 15 V are 'clamped' to avoid damaging the IC.

The Auto Tester, unlike most multimeters, will not be damaged if a dc voltage is applied to the input when it is being used in the resistance mode.

The unit is powered from a No. 216, 9 V battery mounted in the jiffy box. The circuit is based around the commonly available, low cost LM324 or uA324 quad op-amp. The battery will likely last its shelf life (probably a year or more) as consumption is only ever momentary, when you take a reading.

Construction

The project pc board has been designed to fit into almost any of the small jiffy boxes available. These are generally all-plastic or plastic cases with a light gauge aluminium 'lid'. We designed a Scotchcal front panel which will suit those boxes measuring 52 x 100 mm or a little larger. ▶



ARTWORK.
Reproductions of the front panel and pc board artwork can be obtained by sending a stamped, self-addressed A4-sized envelope to:
ETI-334 ARTWORK
ETI Magazine
140 Joynton Ave
Waterloo NSW 2017

Before assembling the components to the board, check that is has no breaks or shorts between tracks, particularly between the IC pins. Also check that components like RV1, the zener diodes and LEDs have the correct lead hole sizes drilled. The board can be mounted by soldering the two pushbutton switches directly to the board and letting the board hang from their leads — it's quite a robust arrangement. If you're going to do this, see that the holes in the pc board for PB1 and PB2 are drilled the right size.

Next, check that the pc board fits inside the box. Make sure you orient the board correctly when you do this. If the board doesn't fit in without jamming you may have to carefully trim a little off one or both sides with a file until it fits properly. If it doesn't fit at all, get a bigger box!

Using the front panel artwork, mark out and drill the front panel, or lid, of the box. Fit the four LED mounts.

Once the board is ready to go, commence assembly by soldering all the resistors in

HOW IT WORKS — ETI 334

The clearest way of seeing how this circuit works is to break it down into simplified sections. The Auto Tester performs three main functions: voltage drop measurement, 12/13.8 V measurement and resistance measurement. In addition, an indication of reverse polarity connection is provided along with input overvoltage protection.

The whole circuit is built around an LM324 (or uA324) quad op-amp, IC1. Three op-amps from this are arranged as comparators and one as an amplifier. Let's look at the voltage drop measurement stage first. This portion of the circuit is shown in Figure 1.

Only the relevant components are included. When PB1 is pressed, power is supplied to IC1 via D3. Note that R1, LED1, R2 and ZD2 play no part here. RV1, R3 and R4 form a voltage divider. IC1a is arranged as an amplifier and IC1d as a comparator.

If the input leads are then connected across a cable having a voltage drop of less than half a volt, say 0.2 V, the voltage appearing at the non-inverting input of IC1a will be about 0.1 V (half the input volts) due to the divider action of RV1, R3 and R4. RV1 is set to provide this division ratio of about two. IC1a provides a gain of 10, and thus the output will be 1 V. This is lower than the 2.6 V on the non-inverting input of IC1d and thus its output will be driven high, lighting LED4.

If the voltage drop on the cable you have connected the input leads across reaches a little over a half a volt, say 0.55 V, the voltage on the non-inverting input of IC1a will be 0.275 V. The voltage on the output of IC1a, and thus the inverting input of IC1d, will be 2.75 V which exceeds the 2.6 V on IC1d's non-inverting input. The output of IC1d will thus go low and LED4 will extinguish, warning you of excessive voltage drop in the cable.

Note that, when performing voltage drop measurements, the positive lead must be connected at the end of the cable closest to the positive terminal of the vehicle battery.

When the input leads are open circuit and PB1 is pressed, D1 will be forward biased as it is connected to the 7.5 V rail (from ZD1) via R8. Thus, something a little under 7 V will appear at the 'top' of RV1, and about 3.5 V at pins 3, 5 and 10 of IC1. This will drive the output of IC1d low, and LED4 will be unlit. It won't change the condition of either IC1c or IC1d, so LEDs 2 and 3 will also be unlit. Thus, nothing happens if you press PB1 ('VOLTS') when the leads are not connected to anything.

Let us look at the other voltage measurements now. This section of the circuitry is shown in Figure 2. IC1b and IC1c are connected as comparators. Each has their inverting input connected to the voltage divider R9, 10, 11 and 12. This voltage divider is supplied from a regulated 7.5 volts, derived by ZD1 and R16. Thus, battery voltage variations will not affect circuit operation, provided the battery voltage doesn't fall to about 8 V or less. IC1b and IC1c have their non-inverting inputs connected together and these are attached to the input voltage divider.

Figure 1. Voltage drop measurement.

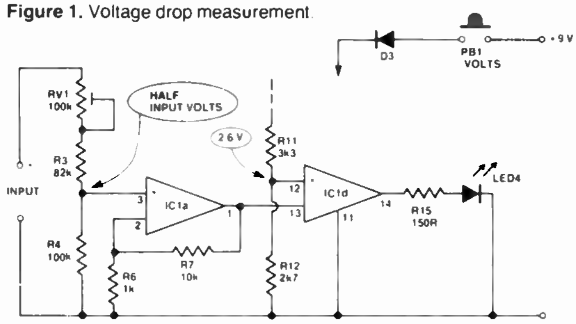
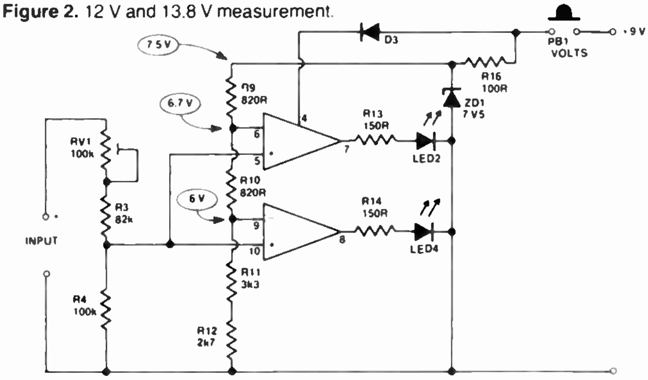
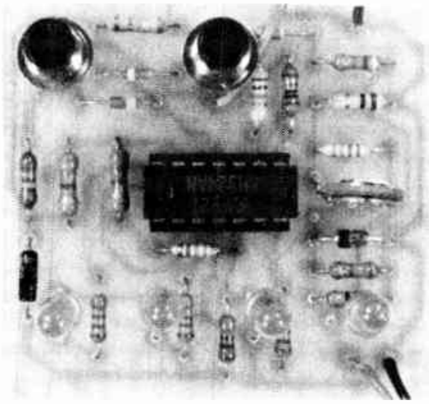


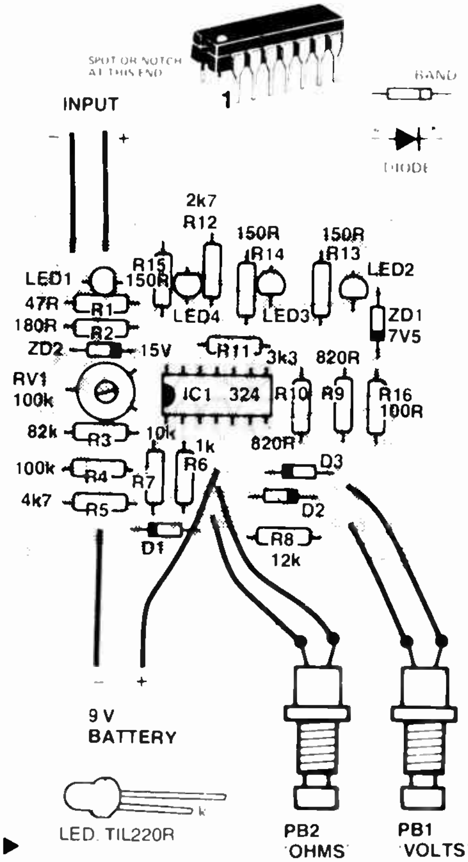
Figure 2. 12 V and 13.8 V measurement.





place, then the diodes D1, 2 and 3, followed by the two zener diodes. Make sure you get all the diodes in the correct way round.

If you're mounting the board to PB1 and PB2, solder these in place now, making sure their mounting 'shoulders' are level. Insert the four LEDs next, but don't solder them in place. Make sure you orient them correctly and don't trim off their leads. Temporarily mount the board to the front panel of the case. Push the LEDs into position and then solder and trim their leads. De-mount the board from the panel and fit IC1, RV1, the battery clip lead and the two input leads. ▶



PARTS LIST — ETI-334

Resistors .... all ¼W, 5% unless noted

R1	47R
R2	180R
R3	82k
R4	100k
R5	4k7
R6	1k
R7	10k
R8	12k
R9, R10	820R
R11	3k3
R12	4k7
R13, 14, 15	150R
R16	100R
RV1	100k min trimpot, horizontal or vertical mount

Semiconductors

D1, 2, 3	1N914, 1N4148 etc
IC1	LM324, uA324
LED1, 2, 3, 4	TIL220R red LEDs
ZD1	7V5 zener diode
ZD2	15 V zener diode

Miscellaneous

PB1, PB2	press-on pushbutton switches

ETI-334 pc board, jiffy box 52 x 30 x 100 mm or thereabout; No. 216 battery and battery clip lead, two alligator clips and leads, one red, one black, Scotchcal front panel, etc.

Price estimate $15 — $17

When PB1 is pressed, power is supplied to IC1 via D3, as before. With no input voltage, the outputs of IC1b and c will both be low and LEDs 2 and 3 will be unlit. When the input leads are connected to a voltage a little over 12 V, the voltage on pin 10 of IC1c will be a little over 6 V. This will drive the output of IC1c high, lighting LED3. When the input voltage rises above about 13.5 V, the voltage on the pin 5 of IC1b will be a little over 6.7 V, driving the output of IC1b high, now lighting LED2 also.

Look at resistance measurement now. For this explanation, refer to the complete circuit diagram. As before, R1, LED1, R2 and ZD2 play no part here.

When PB2 is pressed, power is supplied to IC1 via D2. Some current is supplied to the resistive divider network, R9-10-11-12, by R8. This establishes a different set of voltages on the three comparator inputs. Pin 6, IC1b will now have about 3.8 V on it, pin 9, IC1c about 3 V on it and pin 12, IC1d about 1.3 V on it.

When the leads are connected to a resistance, current will be supplied to the resistance via D1 and R5. Say the resistance is 100 ohms. About 1.8 mA will be driven through it because there is about 8.5 V on the cathode of D1 and 8.5 divided by 4800 ohms gives about 1.8 mA. Thus, there will be a voltage drop across the 100 ohms of resistance of about 0.18 V. About 0.09 volts will appear on pin 3, IC1a. The output of IC1a will drive the inverting input of IC1d to about 0.9 V which is less than the 1.2 V on IC1d's non-inverting input. Thus the output of IC1d will be high, lighting LED4. If the resistance across the input is say 180 ohms, the voltage across the input leads will be about 0.32 V. About 0.16 V appears on pin 3, IC1a and 1.6 V on pin 13, IC1d. The output of IC1d will therefore go low, and LED4 will not light.

If the resistance across the input terminals is between 150 ohms and 10k, say 5000 ohms or so, then the voltage across it will be about 4 V. The voltage on pin 10, IC1c will be about 2 V, which is less than that on pin 9 and the output of IC1c will be low and LED3 will be unlit. If the resistance across the input leads is about 15k, say (such as a spark plug suppressor resistor), then the voltage across the input will be about 6.4 V and the voltage presented to pin 10, IC1c will be about 3.2 V. This is above the 3 V on pin 9 and the output will thus go high, turning on LED3.

If the resistance across the input leads is about 50k, then the voltage across the input will be about 7.8 V. The voltage on pin 5, IC1b will be about 3.9 V and the output of IC1b will therefore be high, turning LED2 on. Note that LED3 will also be on as the voltage on pin 10, IC1c is above that on pin 9 and IC1c's output will be high also. Thus, for all resistances above 50k (including an open circuit) LED2 and LED3 will light.

Followed that so far? Alright, let's look at the reverse polarity indication. The relevant portion of the circuit is shown in Figure 3.

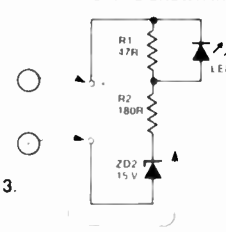


Figure 3.

If the input leads are transposed while trying to measure voltage, ZD2 will conduct as a diode in the forward direction (as shown by the arrow), passing current through LED1, which will turn on. It will also pass some current through R1, but that's immaterial. R1 is there so that current can pass to RV1 when the leads are correctly connected, otherwise no current would pass through LED1 as it would appear as a reverse-biased diode.

If you reverse the input leads while attempting to measure voltage drop, LED1 will only come on if the voltage drop is above about 1.3 V or so. Thus, it is important to watch lead polarity when measuring voltage drop in cables.

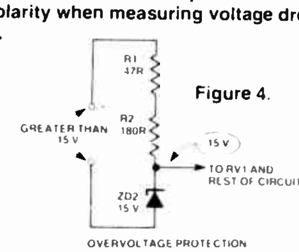
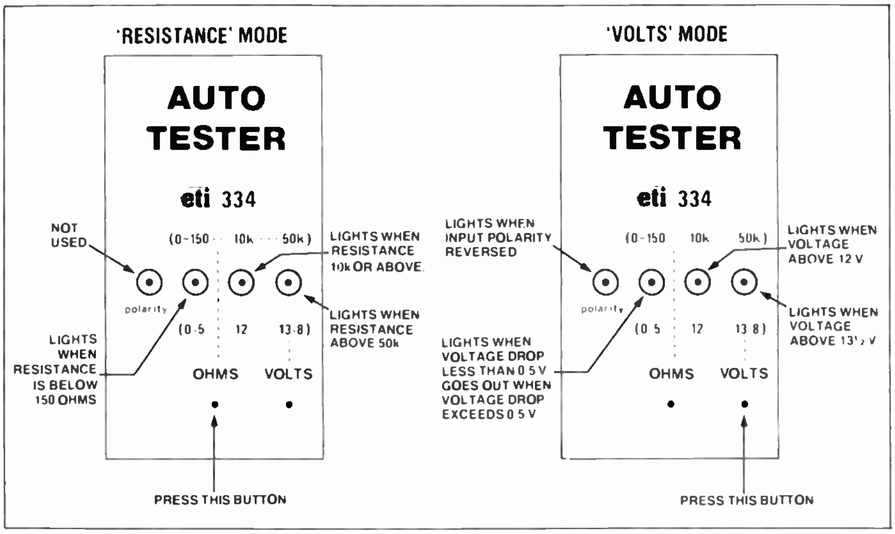


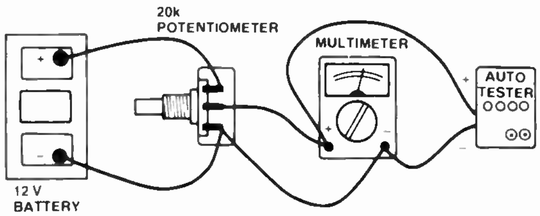
Figure 4.

Overvoltage protection is provided by ZD2. Why have it? Well, if a battery cable comes adrift and you're attempting to measure voltages while the motor is running the generator/alternator can quite easily deliver outputs of 20 V or so. This can possibly destroy the LM324. In addition, it is not unusual to get inductively-produced voltage 'spikes' on the supply lines in a vehicle, which can also destroy the IC. If a voltage of greater than 15 V appears on the input leads to the Auto Tester, ZD2 will ensure that the voltage delivered to the LM324 does not exceed 15 V.

The various voltages and resistances given here can vary by +/− 10% or so without grossly affecting your interpretation of readings. What you are after, after all, is 'ballpark' measurements which will indicate if all is well, or not.



Now you're ready for testing. But first, check *everything* carefully. See that the IC, all diodes and LEDs are correctly orientated, according to the component overlay.



Calibration. Test setup for calibrating the Auto Tester.

Testing the unit

Fit a 9 V, No. 216 battery. Short the input clips together and press the VOLTS button. The 0.5 V LED should come on. If not, check component orientations, then resistor values. Fix any faults. Once you have that corrected, try again. When you get the 0.5 V LED to light, unclip the input leads and it should go out.

To calibrate the unit, you'll need to get hold of a multimeter, a well charged 12 V battery and a 20k potentiometer. Hookup the circuit shown here and adjust the potentiometer to give a 12 V reading on the multimeter. Press the VOLTS button and adjust RV1 so that the '12 V' LED just lights. Then, reset the potentiometer to get a 0.5 V reading, or a little more, on the multimeter. The '0.5 V' LED should just light. If it doesn't light, vary the potentiometer slightly until it lights. If the '0.5 V' LED lights when the multimeter reads more than ±0.1 V from 0.5 V, then you may have to change the value of R12. Increase it if the voltage is low, decrease it if the voltage is high. Just take the next highest or next lowest resistor value, you're only after a 'ballpark' indication, after all.

Set the potentiometer fully 'up' (fully clockwise). If the battery is well charged, then the multimeter should read 13.5 V or above and the '13.8 V' LED should turn on, along with the '12 V' LED. Now, reverse the Auto Tester input leads. The POLARITY LED should come on.

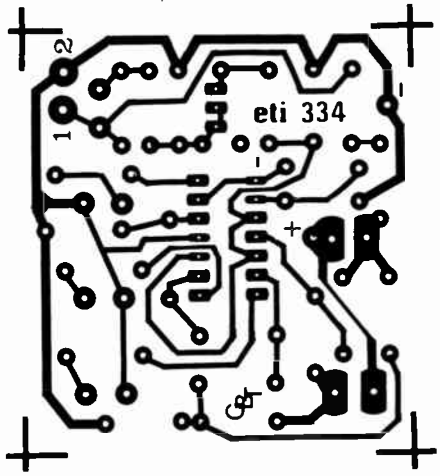
If you can't get the proper indications, check with the multimeter that you are getting 7.5 V (within ±0.3 V) across ZD1 when you press the VOLTS button. Also check the voltages on pins 6, 9 and 12 of IC1 when you press the VOLTS button and see they are close to those given in the How It Works.

If all is well, proceed with testing the OHMS mode. Disconnect the 12 V battery. Set the multimeter to read resistance (should be the X1 scale). Adjust the potentiometer until the multimeter reads about 100 ohms. Press the OHMS button and the '0-150' LED should come on. Turn the potentiometer until that LED goes out and keep turning till the '10k' LED turns on. It should turn on when the multimeter reads somewhere in the vicinity of 10k.

With the Auto Tester leads open circuit, both the '10k' and '50k' LEDs should turn on.

You are now ready for use. Happy fault-finding! ●

Full size pc board artwork.



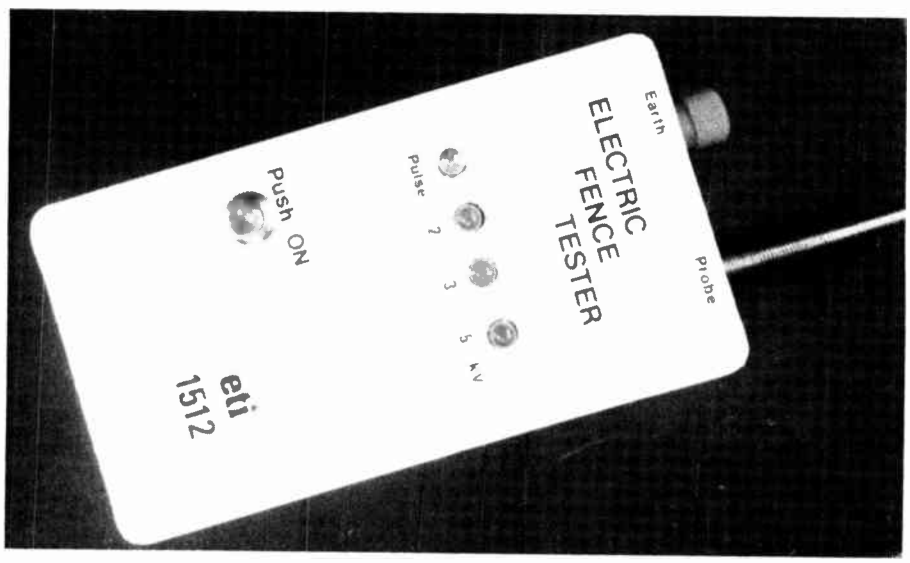
Electric fence tester

This project was developed to take some of the guesswork out of testing or checking an electric fence. Many factors can influence the operation of an electric fence energiser and fence, reducing its effectiveness. A common method of testing a fence is to hold a blade of grass near the wire and get the 'feel'. Get it wrong and you'll find yourself dusting off the seat of your pants!

Graeme Teesdale

ELECTRIC FENCES are now a common 'tool' of farm management. Cattle which escape from an enclosure can cause considerable injury to themselves and other property. An electric fence is an effective, non-injurious barrier when properly erected and maintained. But they have to be maintained! Checking if an electric fence is operating by grabbing it is one method to prove it's working — but few relish the substantial 'jolt' delivered. Another method is to hold a blade of grass near the fence wire. At a few centimetres distant, you should feel a 'tickle'. But, that's dependent on the moisture in the grass, your contact with the ground, etc. If you fail to feel the tickle and approach more closely, you're liable to receive quite a jolt! None of these methods is quantitive, nor can results be compared day-to-day or along the length of a fence.

This project was devised to provide a more quantitive indication of fence/energiser operation and avoid the pitfalls of the 'grass roots' methods.



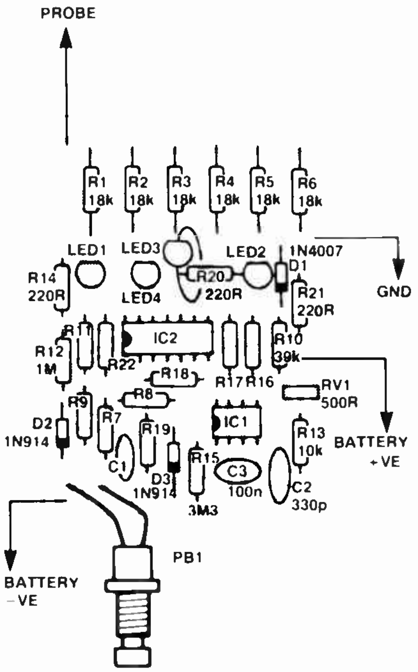
The unit indicates the presence of each pulse from the energiser and shows when the pulse voltage on the fence wire exceeds an amplitude of 2 kV, 3 kV and 5 kV, once calibrated. If used in an uncalibrated mode, the unit will indicate pulse amplitudes on the fence of 40%, 60% and 100% of energiser output.

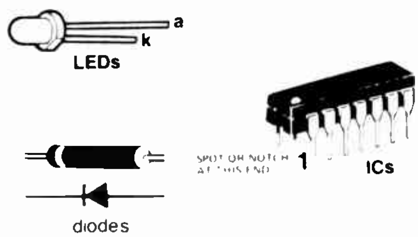
The electronics for this project has been deliberately kept simple, so that the cost is low and reliability good. Construction, too, is simplified. Only two IC's, a handful of resistors and capacitors, four LEDs and very little else is used. The LEDs are used as indicators. So that they can be readily seen in sunlight, we recommend you use the common yellow LEDs or the recently introduced 'high brightness' types.

Our tester was housed in an all-plastic case — so that you can't possibly come in contact with anything carrying the high voltage pulses! The case is held in one hand and the probe protruding from the end touched on the live wire from the fence after the 'ground' probe or lead is literally 'earthed'. Pressing the pushbutton on the front panel turns the unit on. One LED indicates the presence of a pulse. The '2 kV' LED lights to indicate the unit is on and goes out when a voltage pulse exceeding 2 kV is present. When the voltage pulse exceeds 5 kV, the 2 kV LED goes out and the '3 kV' and '5 kV' LEDs flash on. If there is a problem with the fence or the energiser, and the voltage does not exceed 2 kV, the 'pulse' LED only will flash, indicating that the energiser is working but that the voltage is low. More details on checking out a fence are given later.

Construction

For ease of assembly and reliability, it is recommended you use our pc board design. This board will fit in a standard, commonly stocked plastic case measuring at least 60 mm wide by 30 mm deep by 110 mm long. A number of models have been made, but the one shown in the photograph measured 65 x 36 x 121 mm (w-d-l). The front panel was dressed up with a *plastic* Scotchcal label. Don't use a metal type as pulses from the fence probe may 'track' across the case to the panel and you may receive a little surprise. You can make your own pc board using our artwork or buy one ready made, that's up to you. ▶





PARTS LIST — ETI-1512

Resistors .... all ½ W, 5% unless noted

R1-6	18k, 1 W
R7, R12	1M
R8, R15	3M3
R9	100k
R10	39k 1 W
R11	2M2
R13	10k
R14, 20, 21, 22	220R
R16	4k7
R17, R19	2k2
R18	1k2
RV1	500R min. vertical mount trimpot.

Capacitors

C1, C3	100n greencap
C2	330p ceramic

Semiconductors

D1	1N4007
D2, D3	1N914, 1N4148
IC1	CA3140
IC2	LM324, uA324
LED1-4	TIL220Y yellow LEDs

Miscellaneous

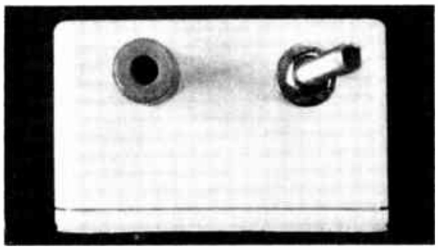
PB1	pushbutton

ETI-1512 pc board; all plastic zippy box 121 x 65 x 36 mm or similar; No. 216 9 V battery and clip lead; Scotchcal front panel; wire, alligator clip etc.

Price estimate
$18 — $22

When you've gathered all the components together, first thing to do is check the pc board. See that all the holes are drilled the correct size and that there are no broken tracks or shorts between tracks — particularly between the IC pins. Commercially made boards don't suffer such problems in general, but do check the hole sizes. If you mount the pushbutton switch on the pc board, like I did, then see that the holes where it mounts are of the right diameter. Leads on the LEDs on the trimpot are usually of greater thickness than most other components and their mounting holes should be checked too.

At the 'top' of the case, mark out and drill two holes for the fence and ground probes. The fence probe shown on the model in the photographs was a 50 mm long 2 BA bolt. The ground probe was plugged into a standard 'banana' socket.



Top. Fence probe and ground socket.

If, or when, all's well with the pc board, mark out and drill the case. Tackle the front panel first. You can use the Scotchcal artwork as a template to mark out the front panel, pricking through the artwork with a sharp-pointed instrument such as a scriber. Drill the holes carefully. It's easier to use the lid of the plastic case as the front panel. No clip holders for the LEDs were used as they're unnecessary, really. Just drill the LED holes slightly larger than the diameter of the body of the LED — 5 mm will do nicely. The pushbutton will require a 6.25 mm (¼") hole.

Now you can put the Scotchcal on the front panel. Position it carefully, having peeled away the backing. When you've got it in position, smooth it down rubbing from the middle toward the edges, taking care to avoid getting bubbles under it. If you do get some bubbles or small wrinkles, these can be smoothed out by rubbing them away towards the nearest edge. Using a modeller's scalpel or other sharp blade, carefully cut out the holes in the Scotchcal.

With the case prepared, you can tackle the pc board assembly. Refer to the accompanying overlay. Solder all the resistors and capacitors in place first, including RV1. Then solder all the diodes in place, making sure you get them the right way round. Note that D1 is a 1N4007 and D2, D3 are 1N914s or 1N4148s. Solder the two ICs in place next, taking care to orient them correctly. Solder the pushbutton to the board next, making sure it sits perpendicular to the board. Last of all come the LEDs. Place them in their positions, making sure you get them the right way round, but don't solder the leads yet. Temporarily mount the board to the panel using the pushbutton. Then, pushing each LED into place in turn, solder their leads to the board. Disassemble the board from the front panel and solder flying leads of adequate length from the fence probe and ground probe pads on the board and attach the battery clip lead. Use heavily insulated wire for the probe leads and space them well away from each other.

Assemble the board to the panel once again and terminate the two probe leads from the board. Plug in a No. 216 9 V battery and you're ready to test and calibrate the unit.

Testing it

This method is guaranteed non-dangerous as you don't get anywhere near an electric fence or fence energiser! For this test you will need one 470 ohm resistor. Solder one lead to the battery positive pad on the board. Set RV1 so that its wiper is at the R10 end of its travel (toward IC1). Press the pushbutton. The '2 kV' LED should come on. Now touch the other end of the 470 ohm resistor to the junction of R10 and RV1. The '2 kV' LED should go out, the '3 kV — 5 kV' LEDs should light and the 'pulse' LED should give a flash. When you disconnect the 470 ohm resistor, the '3 kV — 5 kV' LEDs should go out in reverse order (5 kV LED first) and the 2 kV LED light briefly. If you don't get these indications, look for an error in component orientation or placement. Check that you're getting the supply to the circuit when you press the pushbutton, too.

Correct any errors and try again.

Calibration

You can go about this in several ways. The display can be calibrated to read fence voltage as a percentage of energiser voltage output or it can be calibrated to read directly in volts.

If you're going to calibrate the display to show percentage of energiser output then this should be done with the energiser connected to either a 'known good' fence or to a ▶

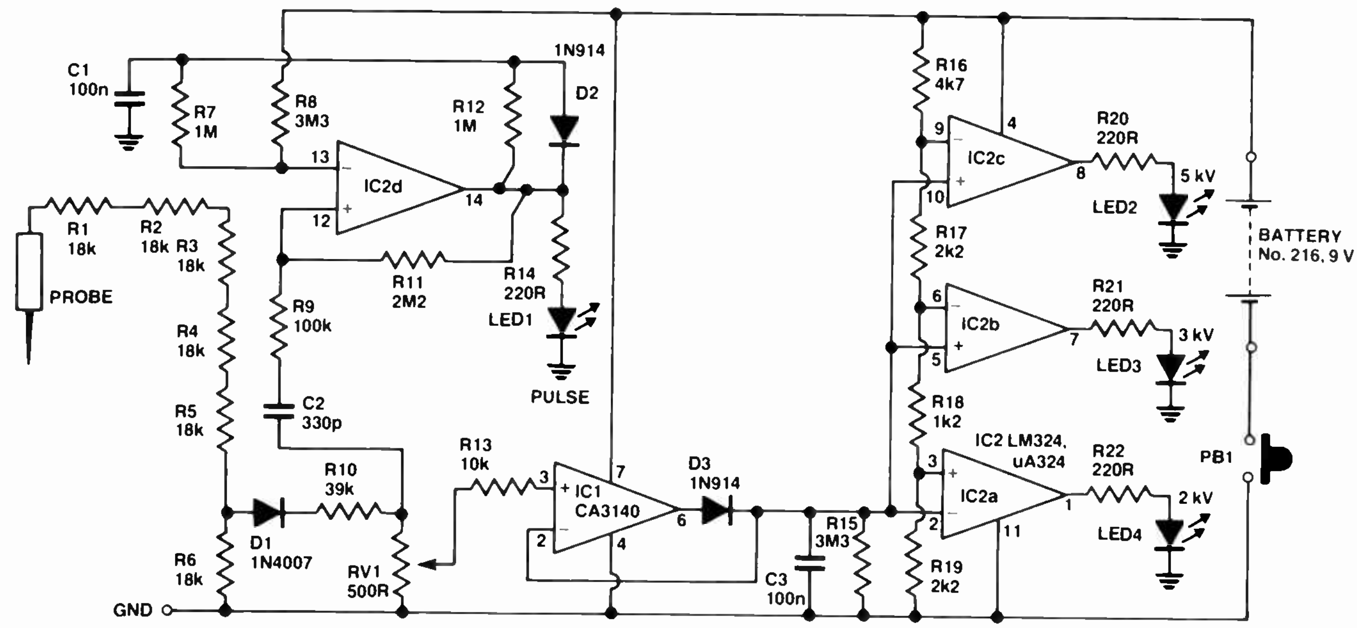
RESISTORS R1 TO R6 AND R10

These seven resistors require special mention. In use, they will experience a pulse voltage across them of around 800 to 1000 volts. Power dissipation will never be a problem as the pulse duration is too short and pulse timing too long to cause any significant dissipation.

However, all resistors have a voltage stress rating for both continuous operation (max. dc working voltage) and for pulse operation. The reaction of resistors to voltage stresses is almost instantaneous. Carbon film resistors — commonly stocked by component suppliers — can withstand about twice to 2.5 times their rated dc working voltage under pulse conditions. A 1 W carbon film resistor generally has a dc working voltage of 500 V and thus will withstand 1 kV to 1.25 kV under pulse conditions. Thus, we recommend resistors of 1 W rating for R1 to R6 and R10.

At a pinch, ½ W resistors could be used. These generally have a dc working voltage rating of 350 V and, at best, will withstand 875 V under pulse conditions.

(For more information, see *Resistors and Film Resistors*, by Roger Harrison, ETI September '76 page 90 and November '76 page 15, respectively.)



HOW IT WORKS — ETI 1512

The circuit can be divided into four sections: the input divider, the peak voltage detector, the display and the pulse indicator.

INPUT DIVIDER

The input divider comprises R1 to R6, plus R10 and RV1. Diode D1 is for protection, and I'll get around to that shortly. Assuming a positive-going input pulse of 5 kV peak, the voltage appearing across R6 will be about 830 V. This will be conducted to R10/RV1 via D1 and a pulse of about 10 V peak will appear across RV1. When calibrated to indicate voltage on the display LEDs, RV1 will be set to about mid-travel and a pulse of about 5 V peak will appear on the wiper of RV1. What happens to that, I'll get around to in a minute, but first, what's the reason for D1?

Should the input pulse on the fence probe be negative-going, as it sometimes is, then D1 will not conduct as it will be reverse-biased. This prevents a large negative-going pulse being conducted to the rest of the circuit. If the peak pulse voltage developed across R6 in this situation should be greater than 1000 volts, D1, which is rated at 1 kV PIV, will likely go into reverse, or 'zener', breakdown the current passed through it being limited by R10. The voltage across RV1 will be very low, thus ensuring the rest of the circuit is still protected.

PEAK VOLTAGE DETECTOR

IC1 and D3 are arranged as a peak voltage detector. The positive-going input pulse from RV1 is applied to the non-inverting input of IC1, pin 3, via R13. As the input impedance of IC1 is very high, R13 does not drop the input voltage and simply provides input current limiting. The output of IC1 will be driven toward the positive supply rail and D3 will conduct. Negative feedback from the cathode of D3 to the inverting input of IC1, pin 2, ensures that IC1 has only unity gain (x1). The output of IC1 charges C3 to the same value as the peak voltage applied to the input. If the peak pulse voltage on the fence probe is 5 kV, and the voltage on the wiper of RV1, when calibrated, is 5 V then C3 will be charged to 5 V.

When the input pulse falls to zero, C3 will discharge slowly via R15 and the combined input impedance of op-amps IC2a, b and c.

THE DISPLAY

The display circuitry consists of IC2a, b and c arranged as voltage comparators, LEDs 2, 3 and 4 and resistors R16 to R22.

The resistive divider formed by R16, 17, 18 and 19 provides three fixed voltage points. The junction of R16-17 will be at 5 V (with respect to the common rail), the junction of R17-18 will be at 3 V and the junction of R18-19 will be at 2 V. Thus the inverting input of IC2c will be held at 5 V, the inverting input of IC2b will be held at 3 V, but the non-inverting input of IC2a will be held at 2 V.

With the non-inverting input of IC2a (pin 3) held at 2 V, the output, pin 1, will be driven high (toward +9 V) and LED4 will light, the current through it being limited by R22. That is, assuming PB1 is pressed! LED4 thus acts as an 'ON' indicator, one part of its dual role.

If the voltage on C3 reaches a little over 2 V, the inverting input (pin 2) of IC2a will cause the output to go low and LED4 will go out, indicating that the peak pulse voltage on the fence probe has reached 2 kV.

As the inverting inputs of IC2b and c are held at a lower voltage than their non-inverting inputs, the outputs of these two op-amps will be low and LEDs 3 and 4 will be off.

When the voltage on C3 reaches a little over 3 V, the non-inverting input of IC2b will be at a higher voltage than its inverting input and its output, pin 7, will be driven high, lighting LED3. Note that LED4 will remain off. Thus, LED3 lighting indicates that the peak pulse voltage on the fence probe has reached 3 kV.

When the voltage on C3 reaches a little over 5 V, the non-inverting input of IC2c will be higher than its inverting input and LED2 will be turned on, in the same way as LED3 was turned on. Thus, when LED2 lights, you know the peak pulse voltage on the fence is at least 5 kV. Note that, in this case, LED4 will be out and LEDs 2 and 3 will be lit.

The pulse from the fence falls to zero very rapidly, but the charge on C3 will be maintained, slowly leaking away via R15 and the combined input impedances of the op-amps IC2a, b and c. Thus, the display will 'hold' for longer than the duration of the fence energiser pulse, allowing you to see the action more readily.

THE PULSE INDICATOR

This circuit comprises IC2d, LED1 and associated components. The input pulse is used to trigger IC2d which is connected as a one-shot multivibrator. The output of IC2d drives LED1 which will flash, indicating the presence of a pulse, regardless of the amplitude, so that if the pulse has insufficient amplitude to drive LED4 off, you can still check that the energiser is supplying pulses to the fence.

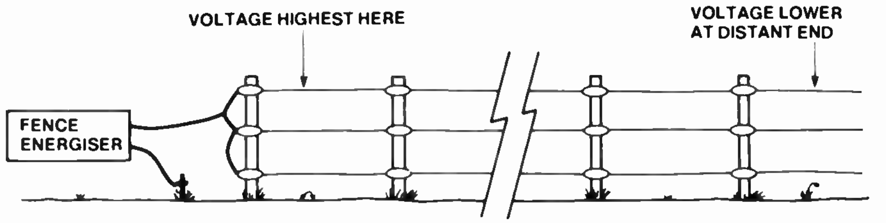
In the absence of an input pulse, resistor R8 keeps the output of IC2d in a low state (0 V) as it holds the inverting input (pin 13) at a higher voltage than its non-inverting input (pin 12). Thus, LED1 will be off.

When an input pulse arrives, it is coupled to the one-shot via C2, and R9. The positive-going pulse drives the non-inverting input of IC2d (pin 12) more positive than its inverting input (pin 13), driving the output (pin 14) high. LED1 will turn on and positive feedback via R11 will cause IC2d to 'latch' in this state. At this time, C1 will charge from virtually zero volts towards the supply rail, via R7-R8. When the voltage across C1 reaches the value on pin 12, the op-amp will switch back to its previous state with the output low. LED1 will then go out. This action takes a few hundred milliseconds, time enough for you to see LED1 light.

So that the one-shot reacts to rapid pulses, diode D2 is included to discharge C1 quickly, so that IC2d rapidly resets to its quiescent state, ready to receive the next incoming pulse.

If the energiser provides a negative-going pulse to the fence, reverse the energiser connections, NOT the Fence Tester connections or you'll be applying the fence pulse to the common rail of the Tester and you might get a wee surprise via PB1 when you try to test the fence.

Shock. Horror. Probe! Gentleman about to receive shock from incorrectly connected Fence Tester (note ground lead going to live fence wire!)



Indications. An electric fence doesn't deliver the same punch over its entire length. This diagram shows you what to expect.

dummy fence'. A dummy fence can be made up quite simply. You'll need two 10n/3 kV ceramic capacitors, which are widely available. These should be connected in series and then connected directly across the energiser output along with the Fence Tester, thus placing a load of about 5 nF on the energiser. Nothing else should be connected across the energiser output. Make sure all the connections are well above the bench top, or whatever. Set the energiser going, then press the pushbutton on the Fence Tester. Adjust RV1 back until the '5 kV/100%' LED just goes out, then advance it until it comes on again with each pulse. This doesn't necessarily indicate that the energiser is delivering 5 kV. Some energisers will only provide an output around 4 kV on load. This procedure assumes your energiser is working correctly in the first place, so you'd better be pretty sure of that!

By far the best method is to calibrate the Fence Tester so that it actually indicates voltage. For this you'll need an oscilloscope with a x10 or x100 probe. Set the Y-input attenuator to read 200 volts/div. (i.e: 2 V/div. or 20 V/div., depending on what range the input attenuator covers). Connect the CRO input across R6 and set the sweep to a low rate. Set the Y-amp input to 'dc'.

Again, your energiser should be connected either to a known good fence or a dummy fence. Connect the Fence Tester to the energiser's output, set the energiser going, and measure the pulse amplitude directly from the oscilloscope's face. At 200 V/div., multiply by six to give the energiser's output directly in volts. Say you get a pulse amplitude of 4½ divisions on the CRO. The energiser's output is 4.5 x 200 x 6 = 5400 volts.

Note the polarity of the pulse. Generally, it will be positive-going. However, some energisers give a negative-going pulse. If such is the case, you'll need to reverse the energiser output leads for the next step.

This time, connect the oscilloscope across C3. (Don't use a x1 probe or you'll upset the C3/R15 time constant.) Set the Y-input to read, say, 1 V/div. on the screen (taking the probe division into account). Turn on the energiser and adjust RV1 so that the peak pulse voltage on the screen is 1000th that previously determined. If the energiser output was determined to be 5400 volts, then the peak pulse amplitude across C3 should be 5.4 volts when RV1 is correctly adjusted.

The unit is now calibrated and ready to use.

In use

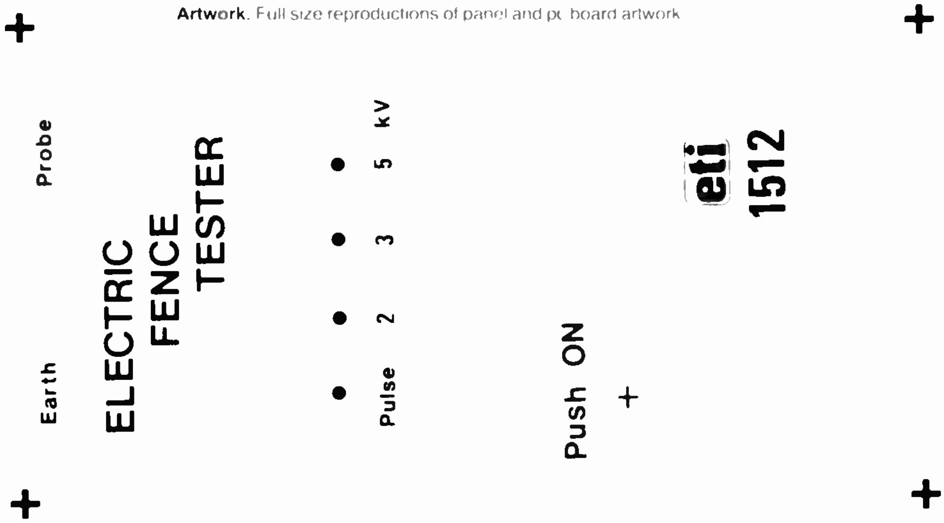
When using the Fence Tester, *always* remember to *connect the ground probe first*. You can use a pointed metal stake to drive into the ground or a large, strong alligator clip to get a good 'bite' on the star pickets often used to support elecric fences. Touch the fence probe on one of the 'live' fence wires and then press the pushbutton. Keep your hands and the Tester dry and keep your big fat pinkies away from the top end of the box.

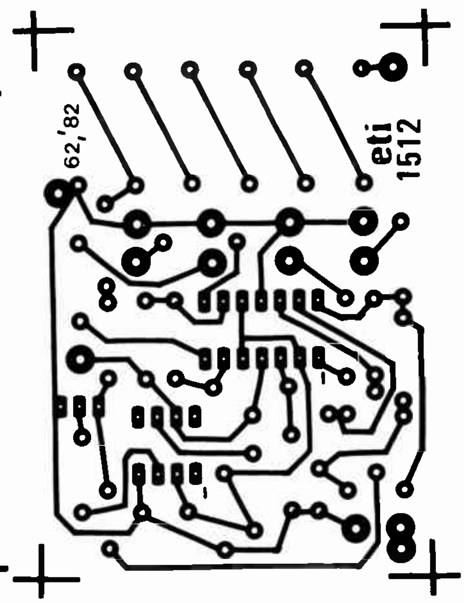
You will find that the voltage on the fence will be highest closest to the energiser, decreasing the further down the fence you move from the energiser end. If the fence is 'shorting to ground' somewhere, then the voltage will fall off rapidly as you approach the fault. If the live wire is open (i.e: broken) at some point, the voltage will remain high within the vicinity of the break, but disappear on the side of the break away from the energiser.

To be effective, the fence voltage should be generally no lower than 3 kV at its distant end. ●

BATTERY CHOICE

As this project will probably experience considerable periods of idleness, a battery having a long shelf life is recommended. Alkaline batteries have by far the longest shelf life, being about two years, and are thus recommended. Standard carbon-zinc batteries have a shelf life somewhat less than half that of Alkaline types and would need replacing at six to eight month intervals — if you could remember!



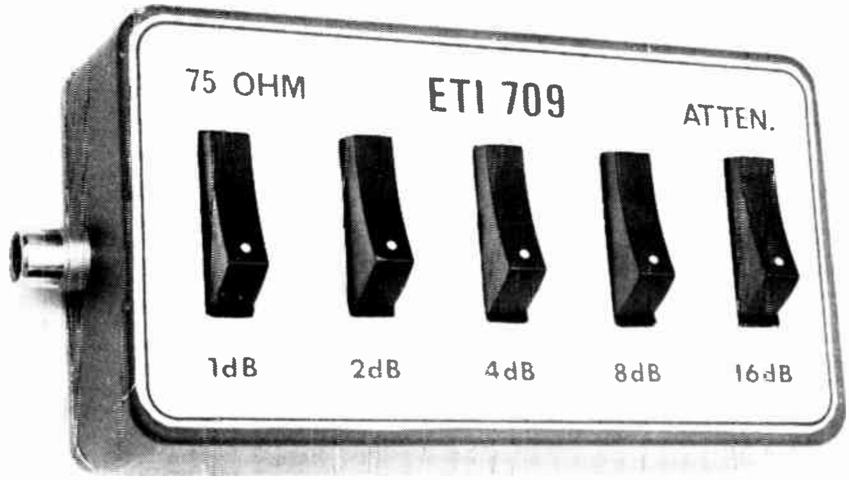


Artwork. Full size reproductions of panel and pc board artwork

PROJECT 709

EVERYONE experimenting with RF circuitry will sooner or later need an RF attenuator. Some of the typical uses of such attenuators are listed below.

- Checking intermodulation on HF, FM, and TV receivers.
- Checking if incoming signals are high enough to allow splitting — to feed more than one receiver.
- Changing signal levels when checking the performance of receivers.
- Evaluation of filters, RF amplifiers, and other electronic devices.
- To find the loss in coaxial cable by the substitution method (as well as the gain of amplifiers). This method is convenient as a calibrated detector is not required: merely one that will give the same reading for two successive inputs of the same level.



RF ATTENUATOR

0 to 31 dB attenuation in 32 steps of 1 dB — useable to more than 200 MHz.

DESIGN FEATURES

An RF attenuator should have a useable frequency range of dc to 200 MHz. It is also necessary for the attenuator to be adequately shielded so that signals may only enter or leave via the coaxial connectors. For this latter reason a diecast box has been used to house the attenuator.

To obtain the wide frequency response required it is necessary to use resistors that have low inductance and capacitance — ¼ to ½ watt carbon types are the most suitable. If higher power handling is required one or two watt carbon types may be used but with these accuracy will start to fall off at around 100 MHz.

The switches should also have low inductance and capacitance but specially designed switches are prohibitively expensive. Many Japanese slide switches were evaluated and initially gave good results. However the ingress of dust and dirt was found to cause faulty operation after a time. The types specified were found to give good and reliable operation over a long period.

Many commercial attenuators have switched values of attenuation — such as 3, 6 10 and 20 dB. Although such values are commonly used this arrangement does not make maximum use of the switch capacity. In our attenuator we have used binary weighted values of 1, 2, 4, 8 and 16 dB. We can combine two or more of these switches to obtain values of attenuation from 0 to 31 dB in 1 dB steps. With the addition of one more switch and a 32 dB pad it would be possible to extend the attenuator to sixty four 1 dB steps. However at high frequencies the leakage of signal around switches becomes excessive and the accuracy at high frequency and large attenuation is thereby drastically reduced.

The sockets used for input and output are RCA types which are normally used with audio equipment. These are inexpensive and easy to obtain. These sockets are quite suitable for use in the low VHF region and are very rugged. Of course if proper 75 (or 50) ohm connectors are available they may advantageously be used instead.

Most RF systems are designed to work into 75 or 50 ohm with 300 ohms coming a poor last. Since TV and FM have standardized on 75 ohms we chose to design our attenuator for this impedance. Since other people may wish to work with 50 ohms we have included a chart showing exact and nearest preferred values for this impedance. It would pay to search with a multimeter to find the resistors having the value nearest to the exact value as specified.

CONSTRUCTION

Construction is simple and straight forward but to obtain optimum results we suggest that you follow our method as closely as possible.

Examine the photographs carefully, the method of construction may readily be seen from them. The unit is housed in an Eddystone diecast box having dimensions of 110 by 62 by 31 mm. The switches are mounted flush onto the bottom of the box. Those at either end of the box are mounted so that the centre pin of the switch is in contact with the centre pin of the socket. This allows the connection to be made without the use of hookup wire. Evenly space the remaining three switches between the two outer ones. Note that a thin strip of tin plate is run the full length of the box and is held in place by the lugs and screws at one end of each switch. To this strip are soldered the ends of the resistors which go to ground. The resistors are held in such a position by their leads that the metal body of the switch acts as a shield between the resistors mounted on either side of it.

The centre poles of the switches are interconnected by first bending the centre lugs of the switch outward towards the next switch and then by soldering lengths of 3 mm wide tinplate between them as shown in the photos.

For general purpose use we recommend the RCA type connectors but if the unit is to be used solely for FM and TV the Belling and Lee type would be more suitable.

If difficulty is experienced in obtaining the exact type of switch specified select one that has a minimum amount of metal internally so that capacitance between switch contacts is not excessive. Also ensure that the switch is of sealed construction so that dust and dirt cannot enter and interfere with the operation of the switch.

Continued.

RF ATTENUATOR

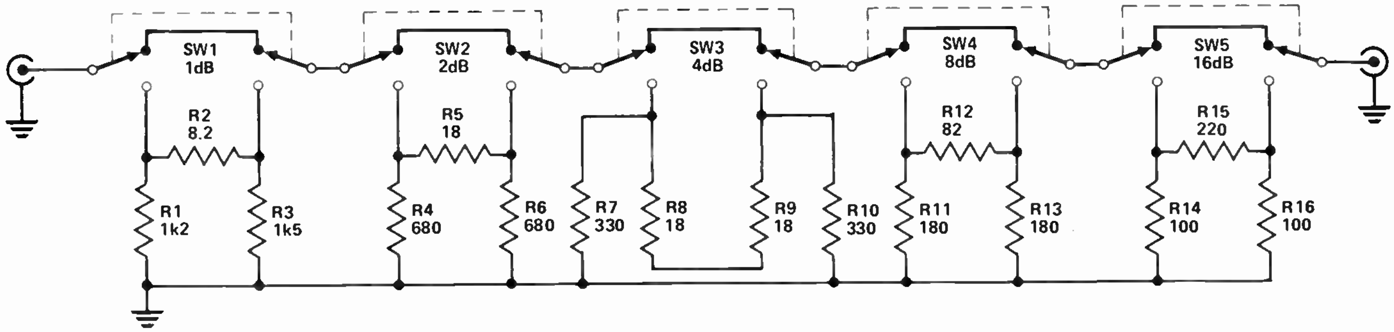


Fig. 1. Circuit diagram of the 75 ohm attenuator.

HOW IT WORKS – ETI 709

The ETI 709 attenuator works by switching into the signal path a selected network or group of networks that reduces the signal strength by known amounts. The networks are specially designed so that they do not disturb the characteristic impedance of the line. That is, they appear to both the source and the load as a single parallel resistor equal in value to the respective source or load impedance. In our case the networks have been calculated to provide matching to 75 ohm impedance.

As can be seen from the circuit diagram each section of the attenuator has a characteristic shape that has led to the use of the name 'pi network' for this attenuator section.

The steps of attenuation are expressed in decibels. The voltage attenuation in decibels is equal to

$20 \log \frac{V_1}{V_2}$. Where V_1 equals the input voltage and V_2 equals the output voltage. Thus if the output is half the input voltage then $\frac{V_2}{V_1}$ equals 0.5 and 20 log 0.5 equals – 6.02 dB. (the minus sign indicating attenuation).

The use of decibels is very convenient as it allows the combined value of two or more attenuators to be found by simply adding their separate values rather than by multiplying the separate attenuation ratios.

Each succeeding attenuator is chosen to be twice that of the one previous. This binary form allows us to obtain a range of 0 to 31 dB in 32 steps with only five switches. Thus for example if we require 5 dB we depress SW1 and SW3 to give us 1+4=5 dB.

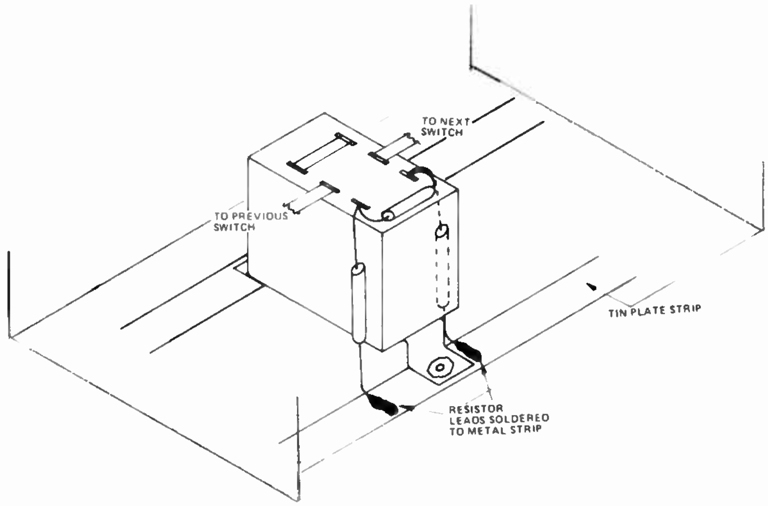


Fig. 2. How the switches are wired up.

TABLE 1

ATTENUATION	R*	ACCURATE VALUES 75 OHM	ACCURATE VALUES 50 OHM	CLOSEST PREFERRED VALUE 50 OHM
1 dB	R1 R2 R3	1304 8.6 1304	869.5 5.8 869.5	820 5.6 820
2 dB	R4 R5 R6	654 17.4 654	436 11.6 436	470 12 470
4 dB	R7 R8 R9 R10	331.5 35.8 0 331.5	221 23.9 0 221	220 12 + 12 0 220
8 dB	R11 R12 R13	174.2 79.3 174.2	116 52.8 116	120 27 + 27 120
16 dB	R14 R15 R16	103.2 230.7 103.2	68.8 154 68.8	68 150 68

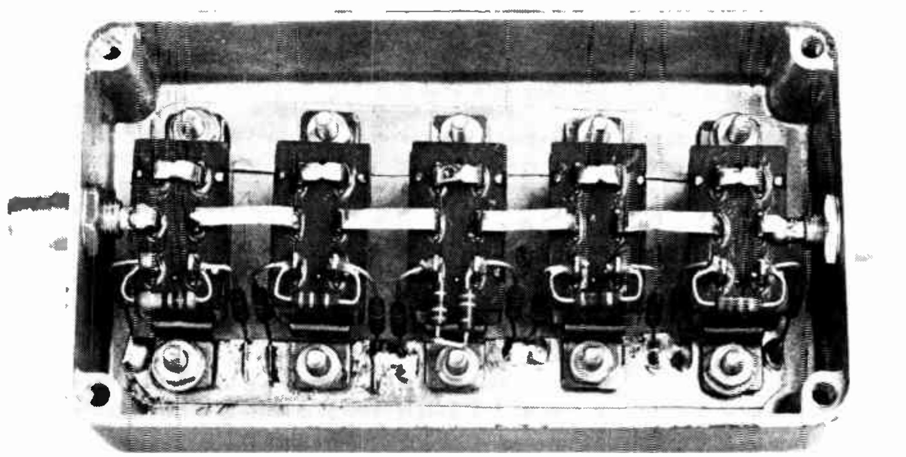
* All values in ohms

PARTS LIST ETI 709

R2	Resistor	8.2Ω	¼W	5%
R5,8,9	"	18	"	"
R12	"	82	"	"
R14,16	"	100	"	"
R11,13	"	180	"	"
R15	"	220	"	"
R7,10	"	330	"	"
R4,6	"	680	"	"
R1	"	1k2	"	"
R3	"	1k5	"	"

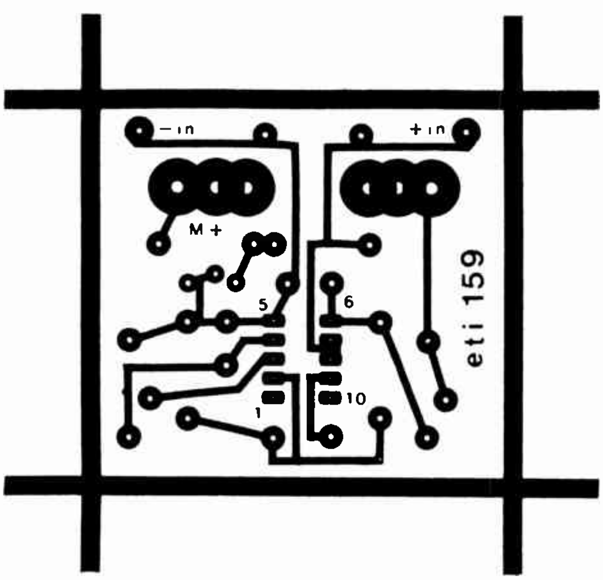
SW1-5 Slide Switch min DTDP

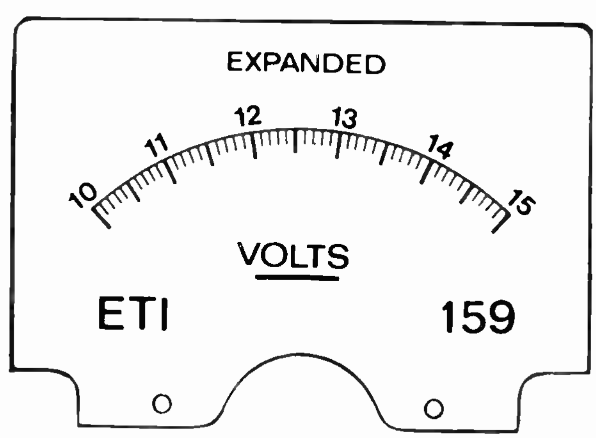
2 RCA Phono Sockets (see text)
Die cast box Eddy stone 7134P
110mm x 60mm x 30mm



Internal view of the attenuator illustrates the method of construction.

PCBs





SHOPAROUND

This page is to assist readers in the continual search for components, kits, printed circuit boards and other parts for ETI projects and circuits. If you are looking for a particular item or project and it is not mentioned here, check with our advertisers.

ETI-147 dummy load

Kits are available from Rod Irving Electronics and may also be available from All Electronic Components. Most of the components are widely stocked. The heatsink can be obtained from either Rod Irving Electronics cat. no. HS4 or Dick Smith Electronics H-3426. You may have to search for a relay: IRH Components (02)750-6444 distribute Fujitsu and Associated Controls (02)709-5700 distribute Takamisawa which will suit the purpose. Phone them to find out their retail outlets.

ETI-150 frequency meter

There are no problems here as all the components required are standard. Kits are available from Rod Irving Electronics and All Electronic Components. The case is an Arlec PC1 and can be obtained anywhere.

ETI-151 ohmmeter

All the components are standard and the 1% resistors are very common. Kits are available from Rod Irving Electronics and All Electronic Components; the Arlec case PC1 is available everywhere.

ETI-152 capacitance meter

All the required components are standard. The kits are available from Rod Irving Electronics and All Electronic Components; the Arlec case PC1 is available everywhere.

ETI-325 auto-probe

All the parts are common; try All Electronic Components for kits.

ETI-560 mains cable seeker

All the parts are common; try All Electronic Components for kits.

ETI-567 core-balance relay

The parts are commonly available; kits can be obtained from Dick Smith Electronics, Electronic Agencies, All Electronic Components and Rod Irving Electronics. The FX2242 potcore can be purchased from Electronic Agencies, Dick Smith Electronics cat. no. L-1436/1437, Rod Irving Electronics, All Electronics Agencies and Radio Despatch. The transformer is available from Jaycar, Magraths, Rod Irving Electronics, Ellistronics, Electronic Agencies and Radio Parts.

ETI-149 two-tone generator

All the components and the bulbs are common.

ETI-572 pH meter

All Electronic Components, Rod Irving and Electronic Agencies have the kits; the Intersil LCDs are available from Rod Irving, All Electronic Components (Victorian agent) and R & D Electronics.

ETI-146 the 'mainsmaster'

All the components are readily available off-the-shelf. The Ferguson transformer can be purchased from Jaycar, Magraths, All Electronic Components or Dick Smith Electronics cat. no. M-0148 (26 V/2 A) which is alright but different.

ETI-156 100 MHz probe

Although nobody carries this project as a kit, parts should be readily available. 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-155 high-power dummy loads

Areol resistors are available from Everest Electrics, 30 Gibbens Rd, Camperdown NSW. (02) 519-3632. The 1% resistors are common and the heatsinks can be obtained from Autotronics, 55 Station St, Engadine NSW. (02)520-9442.

ETI-154 logic probe

The parts for this project are common and should be widely available; there are no kits.

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 mentioned as well as Applied Technology.

ETI-158 low ohms meter

All the parts are readily available and Electronic Agencies, Rod Irving Electronics and All Electronic Components stock kits.

ETI-116 op-amp tester

Parts are stocked everywhere and Rod Irving and All Electronic Components have kits available.

ETI-103 transistor tester

All the parts for this project are common and Rod Irving Electronics and All Electronic Components stock kits.

ETI-164 zener tester

The components are commonly available and several models of the 'transistor audio transformer' were tried out in the prototypes and all worked well. Suitable '1k CT to 8 ohm' transformers are available from many suppliers. Dick Smith Electronics lists one as cat. no. M-0216; Altronics has the M 0216 and M 0226 which are both suitable; Tandy lists one as cat. no. 273-1380. Rod Irving Electronics and All Electronic Components have kits.

ETI-159 expanded scale voltmeter

Parts should be stocked everywhere and kits are available from Rod Irving Electronics and All Electronic Components.

ETI-160 13.8 V/10 A supply

Kits are available from Altronics, All Electronic Components, Dick Smith Electronics and Rod Irving Electronics. Parts are generally common; the K&W case is actually C1066, not C1064 as originally stated.

ETI-145 prototyper

Kits are available from All Electronic Components, Rod Irving Electronics and Altronics. Intersil, who make the ICL7660, are represented in Australia by R&D Electronics, 133 Alexander St, Crows Nest NSW 2065, and 257 Burwood Hwy, Burwood Vic. 3125.

The breadboard strip used in this kit is available in a variety of configurations from a wide range of suppliers. The Atek AT-2N is handled by Emona Enterprises, CBC Bank Building, 661 George St, Haymarket, Sydney. (02) 212-4815. Radio Parts handle the Atek breadboards in Melbourne, Radio Despatch Service in Sydney. The Continental Specialities breadboard is available from a variety of suppliers.

ETI-165 tacho calibrator

Kits are available from All Electronic Components and Rod Irving Electronics. All the components are common; the EC.1001 case is manufactured by Sigea in Melbourne. If you cannot find a local supplier they can be contacted at PO Box 49, Thornbury Vic. 3071.

ETI-161 LCD panel meter

Kits are available from Dick Smith Electronics, Rod Irving Electronics and All Electronic Components. The Intersil parts can be obtained from All Electronic Components in Victoria or R & D Electronics.

ETI-162 30 V/1 A supply

All parts are commonly available off-the-shelf. Kits may be obtained from Altronics, Jaycar, Rod Irving Electronics, All Electronic Components, Electronic Agencies and Dick Smith Electronics.

ETI-334 auto-tester

All parts are standard and can be easily obtained off-the-shelf. Kits will be stocked by All Electronic Components, Altronics and Rod Irving Electronics.

ETI-1512 electric fence tester

Kits for this project will be stocked by Electronic Agencies and Rod Irving Electronics and you could try All Electronic Components. All the parts are generally available.

ETI-709 RF attenuator

There are no kits but all the parts are commonly available.

Printed circuit board and panel suppliers

Almost every pc board ever published by ETI may be obtained from the following suppliers:

All Electronic Components
118 Lonsdale St
Melbourne Vic. 3000

RCS Radio
651 Forest Rd
Bexley NSW 2207

Panels, meter scales and dial faces for almost every ETI project published may also be obtained from the above two firms.

For pc boards produced over the past three to five years, the following suppliers generally keep stocks on hand:

Electronic Agencies
115-117 Parramatta Rd
Concord NSW 2137
and
117 York St
Sydney NSW 2000

Radio Despatch Service
869 George St
Sydney NSW 2000

Rod Irving Electronics
425 High St
Northcote Vic. 3070

James Phototronics
522 Grange Rd
Fulham Gardens SA 5024

Jemal Products
P.O. Box 168
Victoria Park WA 6100

Jaetronics
58 Appian Drive
St Albans Vic. 3021

Sunbury Printed Circuits
Lot 14, Factory 3,
McDougall Rd
Sunbury Vic. 3429

Billco Electronics
Shop 2, 31 Pultney St
Dandenong Vic. 3175

Mini Tech
P.O. Box 9194
Auckland N.Z.

Kits and components

All Electronic Components
118 Lonsdale St
Melbourne Vic. 3000

Altronics
105 Stirling St
Perth WA 6000

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
and
117 York St
Sydney 2000

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

Radio Despatch Service
869 George St
Sydney NSW 2000

Radio Parts
562 Spencer St
West Melbourne Vic. 3003

Rod Irving Electronics
425 High St
Northcote Vic. 3070

R & D Electronics
133 Alexander St
Crows Nest NSW 2065
and
257 Burwood Highway
Burwood Vic. 3125