$4.95*
NZ $5.95

ELECTRONIC PROJECTS FOR CARS

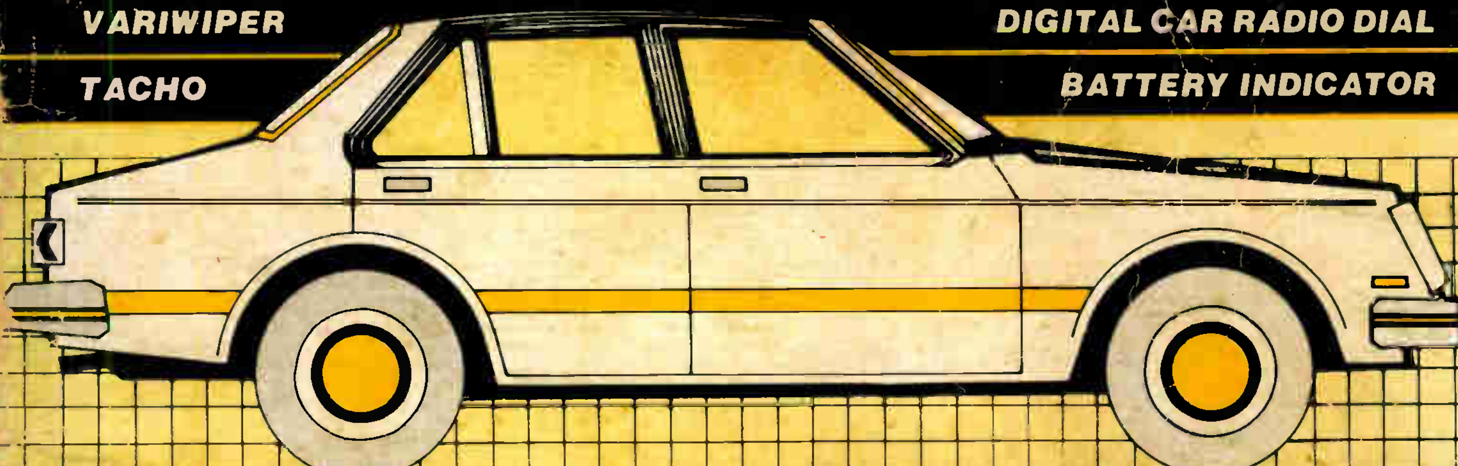
156
HWS

An Electronics Today Publication

eti

DASHBOARD TEMPERATURE METER
COURTESY LIGHT EXTENDER
VARIWIPER
TACHO

TRANSISTOR-ASSISTED IGNITION
LED OIL TEMPERATURE METER
DIGITAL CAR RADIO DIAL
BATTERY INDICATOR



REVERSING ALARM
FUEL LEVEL MONITOR

OVER-REV ALARM
TURN AND HAZARD FLASHER/BEEPER

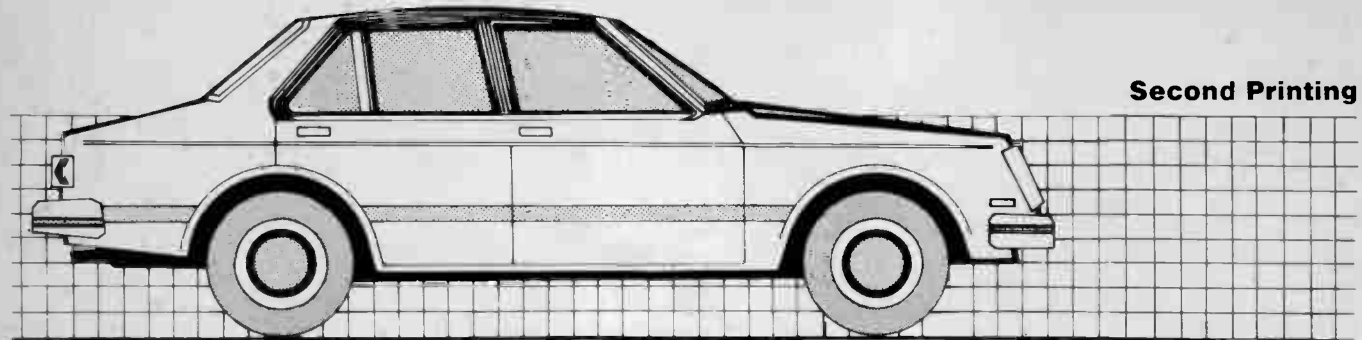
PLUS:

AUTO-PROBE, ELECTRONIC STETHOSCOPE, EXPANDED-SCALE AMMETERS AND VOLTMETERS, CAR ALARM, PORTABLE 'LIGHT WAND', BREAKDOWN BEACON, INSTALLING A TRANSCEIVER, AND 'SCOPE TESTING YOUR IGNITION.

Second Printing

ELECTRONIC PROJECTS FOR CARS

Second Printing



Editor: Roger Harrison
Layout: Bill Crump
Cover Design: Ali White

This second printing of **Electronic Projects for Cars**, originally produced in June 1982, is published by the Electronics Division of the Federal Publishing Company, 140 Joynton Avenue, Waterloo, NSW 2017. Managing Editor: Jeff Collerton. It was printed by ESN — The Litho Centre, 140 Joynton Avenue, Waterloo, in August 1983 and distributed by Gordon and Gotch Ltd. Production by Vernon, Rivers and Associates Pty Ltd.

ISBN 0 86405 002 X

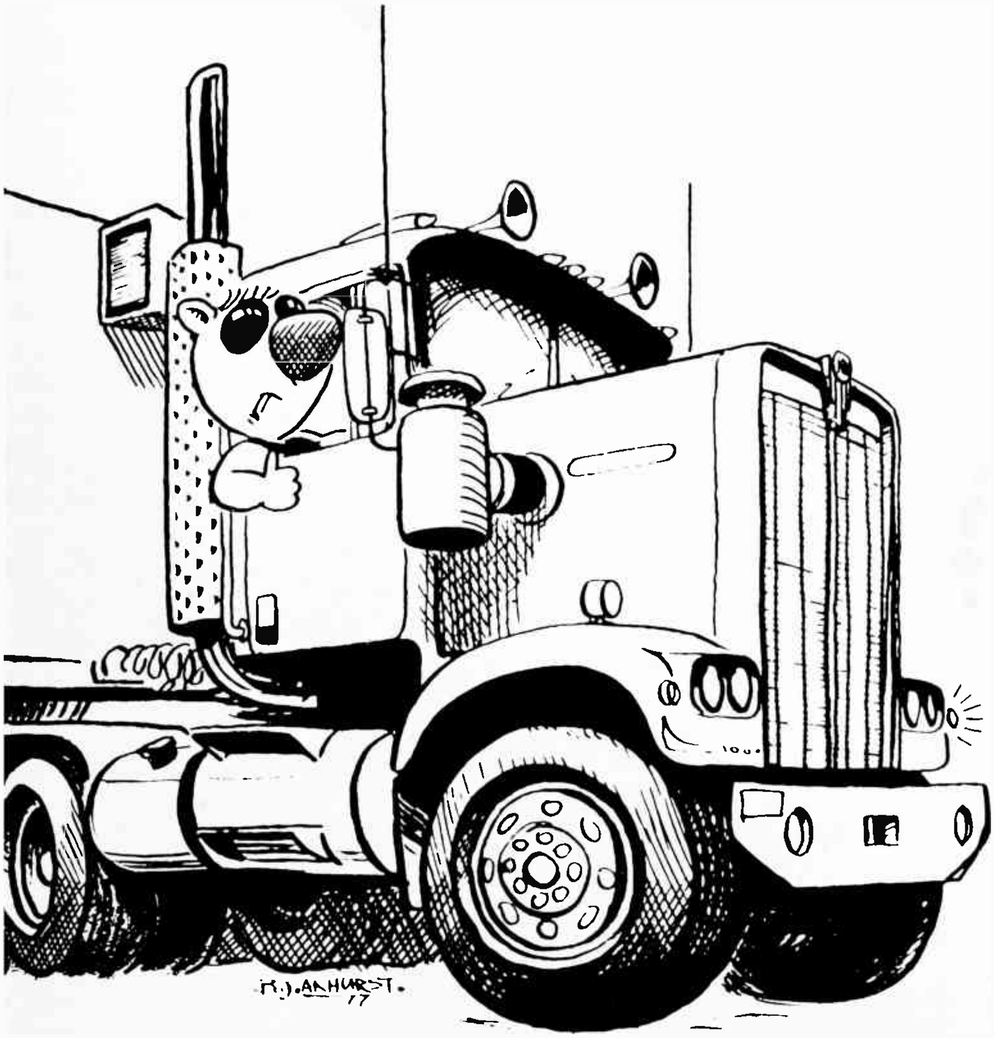
$4.95 is the recommended and maximum price only

Whilst every effort has been made to ensure that all constructional projects referred to in this edition will operate as indicated efficiently and properly, and that all necessary components to build the same will be available, no responsibility whatsoever is accepted in respect of the failure for any reason of the project to operate effectively or at all, whether due to any fault in design or otherwise and no responsibility is accepted in respect of any injury or damage caused by any fault in the design of any such project aforesaid. The articles in this book were originally published in *Electronics Today International, Australian CB* and *Project Electronics*. Prices quoted were, to the knowledge of the publisher, correct at the time of original publication, but may have changed subsequently. It would be advisable to contact suppliers for up-to-date information on prices

Turn and hazard indicator for your vehicle

Staff

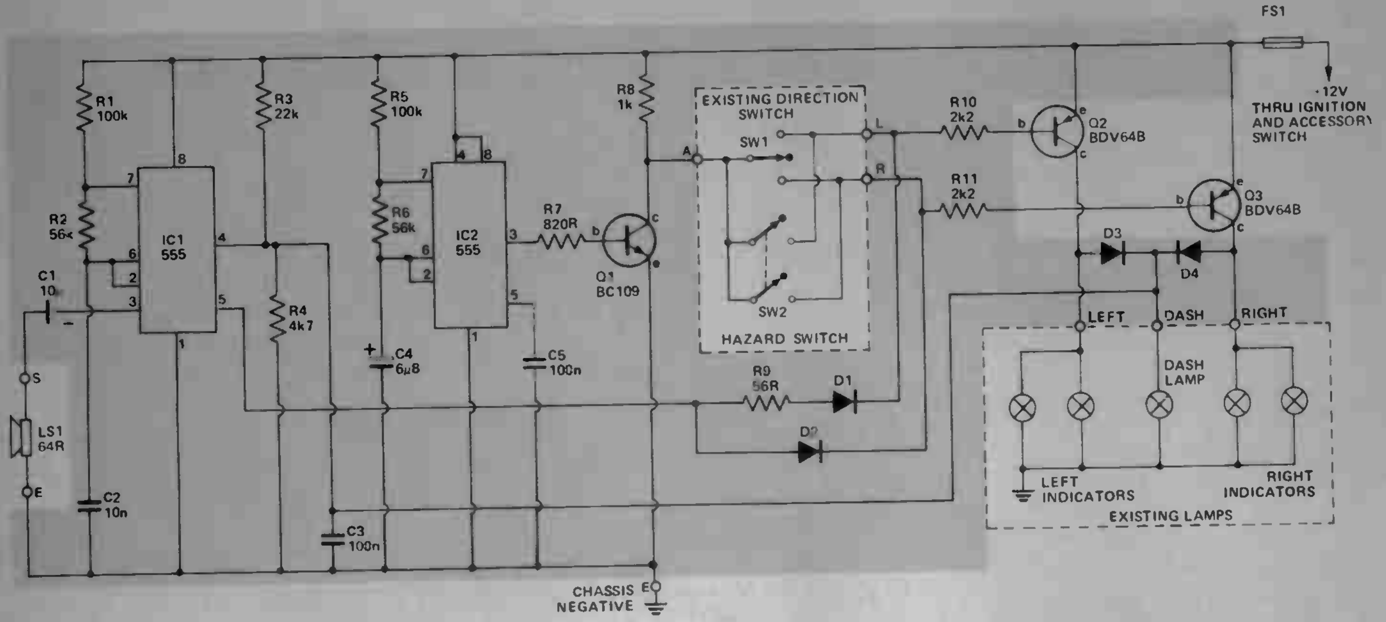
This 'electronic flasher' is a great improvement on the electromechanical flashers fitted as standard equipment on most cars. It features a stable flash rate, high reliability and the ability to drive up to 144 watts worth of indicator lamps !



IF YOUR CAR was made before 1960 it probably doesn't have any kind of indicators, but all cars built after that date are fitted with turn indicators of some sort and post-1970 models have hazard flashers too. However, the conventional bimetallic strip flashers fitted to nearly all cars have a few shortcomings which we have attempted to overcome with our new solid state unit.

The bimetal flashers give only a weak sound indication, which can easily be drowned out by general vehicle noise. They are especially difficult to hear if the ravages of time (or uproarious living, or overindulgence in very loud music etc.) have left you with less than perfect hearing. Another disadvantage of conventional units is that they cannot cope with the extra power drained by the turn/hazard indicators on a trailer or caravan. Also the flash rate of bimetallic units is preset by the manufacturer and cannot be adjusted to compensate for drift caused by battery voltage variations and ageing of the metal strip.

Our solid state flasher connects easily to the car's wiring and is designed to completely replace the existing bimetal unit. It can handle up to 12 amps, which allows it to drive a substantial load (up to 144 W at 12 V). The flash rate will remain substantially the same through-



HOW IT WORKS — ETI 327

The flasher consists of a low frequency oscillator, IC2, producing a pulse at about one Hertz, driving either or both of two Darlington output transistors, Q2 and Q3. These switch the vehicle's battery to the turn indicators and dash light. An audio oscillator, IC1, gives an audio tone through the speaker at a different frequency for *left, right* and *hazard*.

The output of IC2 (a 555) gives the flash frequency. The frequency and duty cycle (on to off time) are set by the values of R5 and R6 and can be made variable by substituting trim pots for these two resistors.

The pulses from IC2 are fed to an inverter, Q1, and then to the vehicle's turn and hazard switches. If the vehicle doesn't have a hazard switch, one can be added. Transistors Q2 and Q3 are Darlington output transistors used here for their very high current gain. Darlington transistors have two transistors in the one package in a gain multiplication configuration.

The pulses are fed to either of the Darlington transistors for turn indication, or to both for the hazard indication. The transistors switch the battery to the appropriate indicator lights on the vehicle.

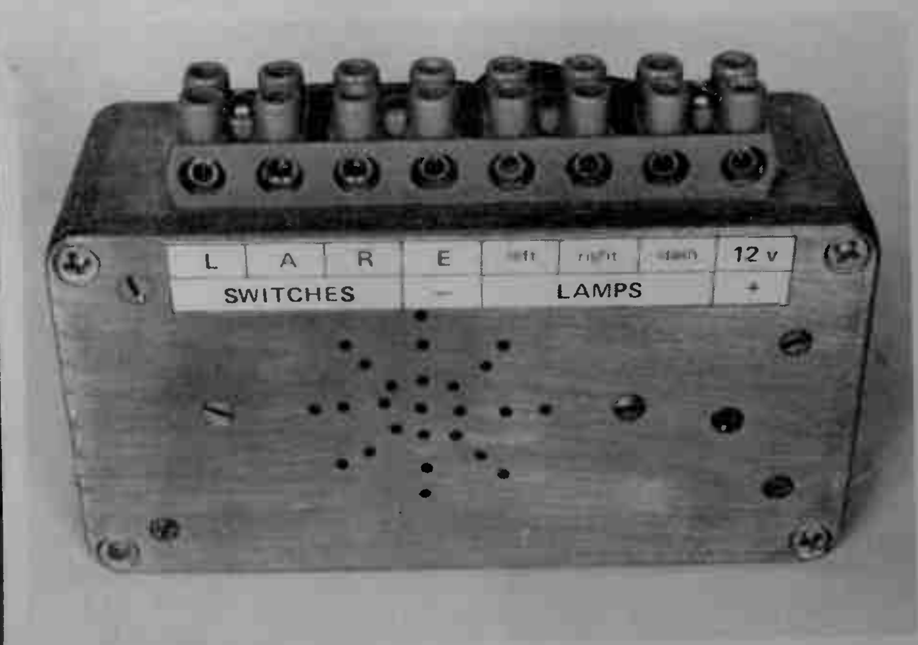
The dash light is illuminated through D3 and D4 whenever either of the Darlington transistors are turned on.

IC1 is an audio oscillator with a variable frequency controlled by the voltage on its control input, pin 5. This pin is tied to the bases of Q2 and Q3 through D1, D2 and R9 in such a way that the oscillator gives a different tone for left, right, and hazard. The oscillator is enabled by the voltage on pin 4 which is normally held low through the dash light. When the dash light turns on pin 4 goes high and the oscillator starts, beeping in time with the flash of the indicators.

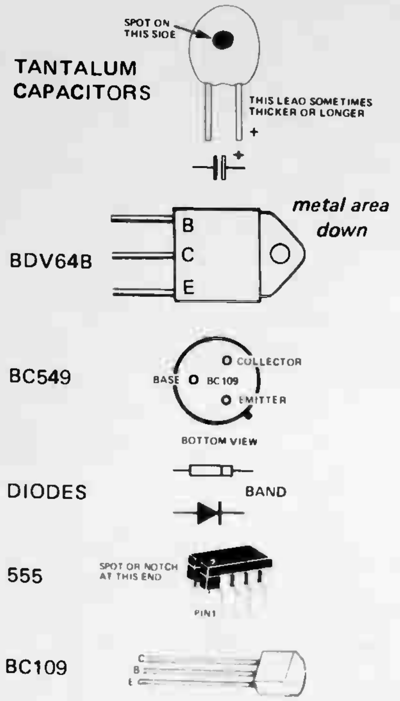
out the life of the unit. A special feature is that it provides an audio tone whose pitch is different for each of the three modes — 'left turn', 'right turn' and 'hazard'. If you want to alter the flash rate, two of the fixed resistors can be replaced by trimpots to allow variation of the frequency and duty cycle.

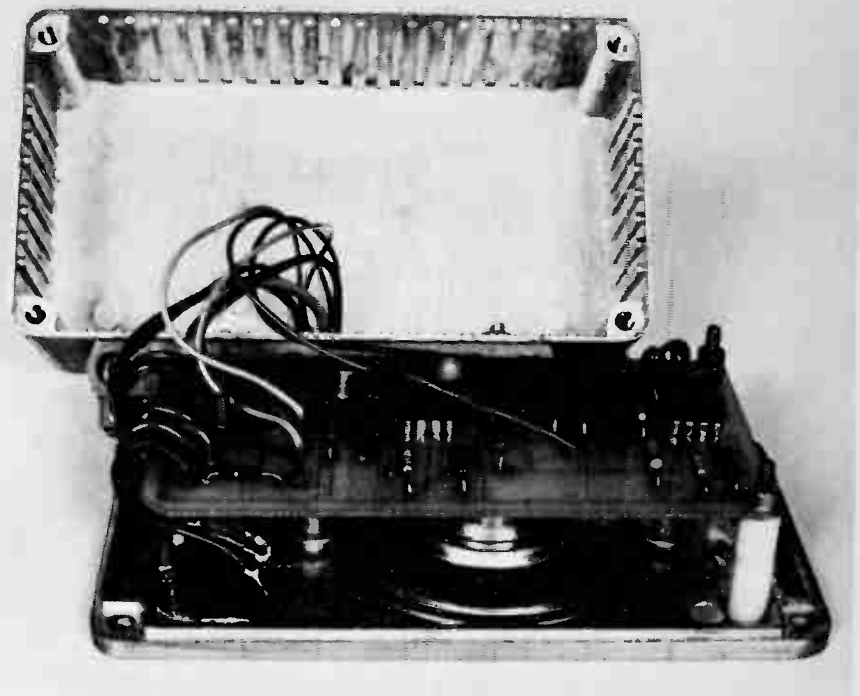
The flash rate is determined by a 555 timer IC, whose output is routed through the car's turn indicator switch on the steering column and turns one of two Darlington power transistors on and off. These transistors are actually two transistors connected in the same package in such a way as to provide a very high current gain. This allows them to be operated with a low base drive current to switch quite high currents, making them ideal for this application.

A second 555 IC is used as an audio oscillator to drive a small loudspeaker. This oscillator is held off until one of the Darlington transistors is turned on and then turns on and off in time with the Darlington, producing a beeping sound which is synchronised to the flashes. ▶



COMPONENT PINOUTS





Our unit was assembled into a diecast box using standoff pillars to support the pc board. If you use an 8 ohm or 16 ohm speaker with a series resistor, the value of the resistor may be varied to alter the speaker volume. With a high impedance speaker, a suitable value resistor may be inserted in series to lower the volume. Try 100 ohms as a start.

Construction

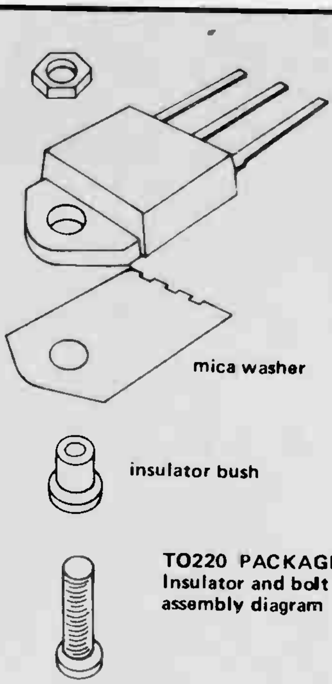
Since the unit is designed to operate inside a car it should be made as rugged as possible. Our prototype was constructed in a diecast aluminium box which doubled as a heatsink for the switching transistors.

Connection to the vehicle's wiring is made via a terminal strip mounted along the outside of the box. The speaker and the pc board are mounted inside the lid of the box to facilitate wiring.

Start by mounting the resistors and non-polarised capacitors on the pc board. Next mount the two tantalum capacitors, the diodes, the ICs and the transistor, paying particular attention to their orientation.

If you wish to vary the flash rate and the duty cycle, the two timing resistors R5 and R6 can be replaced by trimpots as the pc board has been designed to accomodate either trimpots or fixed resistors. Drill holes in the lid of the box for the pc board, the Darlington transistors and the speaker. We drilled a series of small holes in front of the speaker but this may not be necessary in some circumstances because the sound from the speaker is quite loud.

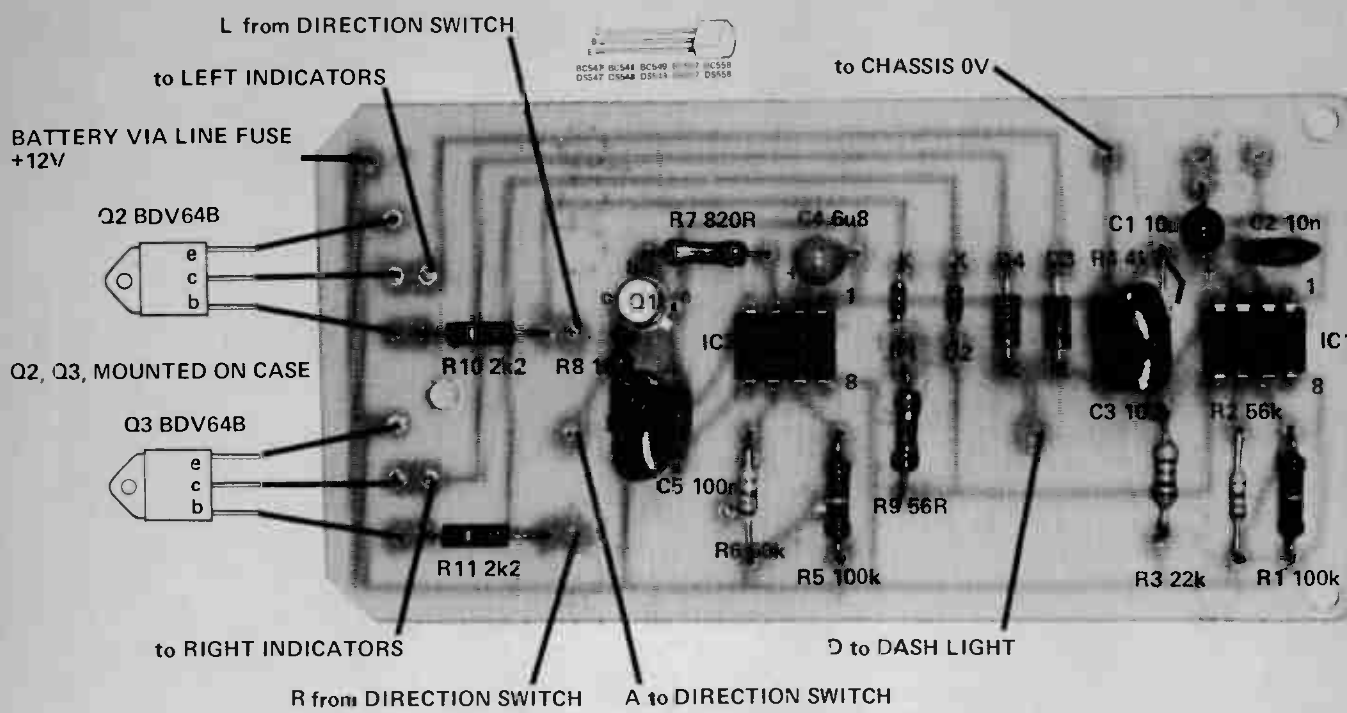
The two Darlington switching transistors are mounted on the lid of the box as shown in the photo of the prototype. The cases of these transistors are connected to the collectors and must therefore be insulated from the diecast lid. Mount the transistors using a mica or plastic insulator and plastic sleeves as shown in the diagram. Use an ohmmeter to check that there is an open circuit between the collectors and the diecast lid after the transistors are mounted.



TO220 PACKAGE
Insulator and bolt assembly diagram

Mount the loudspeaker on the lid, using nuts and bolts with two large washers clamping the edge of the speaker against the lid. If you have an eight ohm speaker you can use that instead, if a 47 ohm, ½ watt resistor is connected in series with one of the speaker leads.

Solder all the connecting wiring from the pc boards and Darlington transistors, using heavy gauge wire to the emitters and collectors of the transistors. Then mount the pc board on 20 mm standoffs above the speaker and transistors. Connections to the car's electrical system are made via a length of screw terminal strip with the wires to the pc board run through a grommet in the side of the box.



Component overlay and external component connections

NOTE: The printed circuit board artwork is reproduced on page 34.

Installation

The flasher unit can be installed in any convenient position under the dash within earshot of the driver. However, it is not a good idea to mount it near the output pipe of the heater as it could get quite hot there. The connection to the battery can be taken from the battery terminal through a 10 A line fuse, or from the accessories position on the ignition switch. This way the hazard flasher can still be used with the engine turned off.

If your car is too old to have turn indicators you can mount a double pole switch on the steering column and run wires under the dash to the unit. You can buy switches with long lever extensions which are ideal for the purpose. The hazard switch should be a push-off/pull-on type (to avoid accidentally knocking it on) and can be mounted in any convenient position on the dash with the dash turn indicator.

External lights are easily mounted and are available from motor accessory stores. Make sure the connection from the light to the chassis is good. If in doubt, run a wire from the light case chassis connection to a good chassis contact point on the vehicle or direct to the battery negative terminal. ●

Flashers and the Law

Flashing turn and hazard indicators fitted to motor vehicles must comply with Australian Design Rule No. 6 (ADR 6), whose provisions are summarised below.

Colour:	Rear and side flashers must be amber or orange. Front flashers on Australian-made vehicles must be orange; on imported vehicles they may be orange or white.
Flash Rate:	Not less than 60 and not more than 120 flashes per minute.
Duty Cycle:	Not specified.

PARTS LIST — ETI 327

Resistors all ½W, 5%

R1	100k
R2	56k
R3	22k
R4	4k7
R5	100k or 250k min. trimpot
R6	56k or 100k min. trimpot.
R7	820R
R8	1k
R9	56R
R10,R11	2k2

Capacitors

C1	10u/25V tantalum
C2	10n greencap
C3,C5	100n greencap
C4	6u8/25V tantalum

Semiconductors

D1,D2	1N914, 1N4148 etc
D3,D4	1N4001, A14A etc.
Q1	BC549, BC109 etc.
Q2 Q3	BDV64B Darlington transistor

Miscellaneous

SW2	DPDT toggle switch
LS1	small, high impedance speaker (48-80 ohms) or eight ohm speaker with 47R series resistor

ETI-327 pc board: line fuse with 10 amp fuse; diecast box to suit (65mm x 120mm x 40mm); eight-connector barrier strip

PROJECT 232

COURTESY LIGHT EXTENDER

Car interior light stays on briefly after the door is closed

ALL MODERN CARS are fitted with door-switch operated courtesy lights. Useful devices, but not *quite* as useful as they might be because they are so arranged that the light is extinguished as soon as you close the door — just when you need light to find the ignition switch, do up your seat belt etc. How much better if the internal light stayed on for a few seconds *after* the door is closed.

This little project does just that. It provides a four-second delay (approx) after which the interior light slowly dims — being finally extinguished after 10 or 12 seconds.

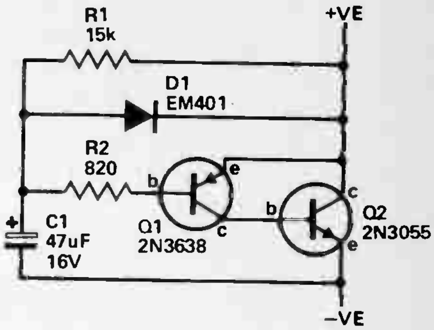
The unit is very simple to construct and once tested and properly insulated it may be wired across one of the car door switches. In operation, after a short delay the lights will gradually dim until they are completely extinguished. There is no battery drain in the off-state as the unit only operates during the delay period after the door is closed.

CONSTRUCTION

In our prototype, as shown in the photograph, all the components are assembled directly onto the 2N3055 transistor. This only requires two "mid-air" joints to be made.

After checking that the unit works correctly the assembly may be placed in a small plastic pill box which is then filled with epoxy. Alternatively merely wrapping the unit in insulation tape will be sufficient.

Due to the fact that the 2N3055 only conducts for a few seconds every so often, a heatsink is not required for cars fitted with a single lamp courtesy light. If your car has *more* than the usual amount of interior lighting operate the unit a number of times in fairly quick succession. Then, if the 2N3055 gets too hot to touch, use a small piece of aluminium as a heatsink. This need should however be rare. ●



HOW IT WORKS

Most car door switches are simply single-pole switches, with one side earthed. When the door is opened the switch earths the other line thus completing the light circuit.

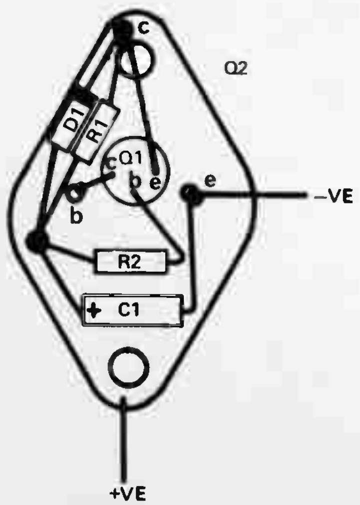
In a car where the negative terminal of the battery is connected to the chassis the negative wire of the unit (emitter of Q2) is connected to chassis and the positive wire (case of 2N3055) is connected to the wire going to the switch. In a car having a positive earth system this connection sequence is reversed.

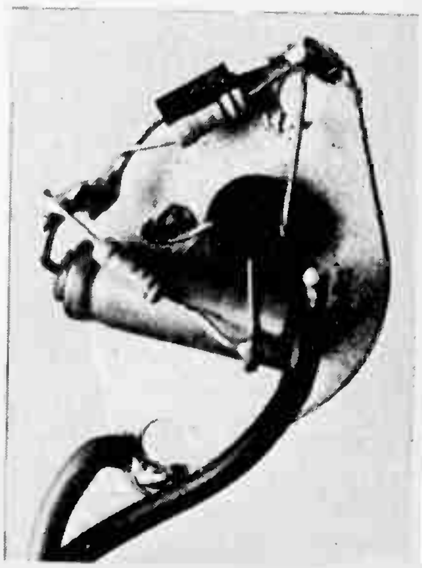
When the switch closes (door open) C1 is discharged via D1 to zero volts and when the switch opens C1 charges up via R1 and R2. Transistors Q1 and Q2 are connected as an emitter follower (Q2 just buffers Q1) therefore the voltage across Q2 increases slowly as C1 charges. Hence Q2 acts like a low resistance in parallel with the switch – keeping the lights on.

The value of C1 is chosen such that a useful light level is obtained for about four seconds, thereafter the light decreases until in about 10 seconds it is out completely With different transistor gains and with variation in current drain due to a particular type of car the timing may vary, but may be simply adjusted by selecting C1.

PARTS LIST ETI 232

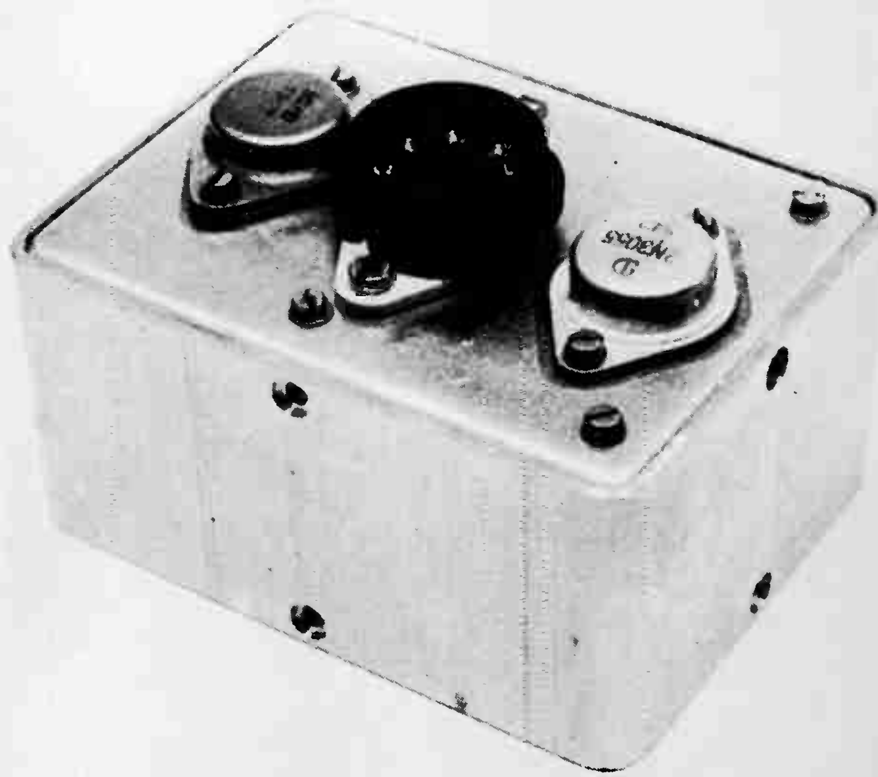
R1	resistor	15 k ½ watt 5%
R2	"	820 ½ watt 5%
C1	capacitor	47µF 16 volt electrolytic
D1	diode	EM401 or similar
Q1	transistor	2N3638 or similar
Q2	"	2N3055





TRANSISTOR ASSISTED IGNITION

A reliable type of electronic ignition which uses the existing points in the distributor.



THE MOST POPULAR project for use in a car must be some type of electronic ignition. The Kettering system (the one used on most cars) is as old as the car itself and has not changed much over the years. It still works by a set of points which close, to allow the current to build up in the spark coil, and then open so that the energy in the magnetic field of the coil is used to generate the high voltage needed to fire the plugs. The system has problems at high speed in that the current does not have time to rise to a high enough level before the points open – resulting in the output voltage falling as the speed increases. At low speed (when starting) the points open too slowly and some energy is lost in arcing across the contacts. The use of a ballast resistor (usually about 1-1.5 ohm) and a lower inductance coil helps the high speed performance and shorting the ballast resistor while starting helps.

While this system has performance limitations it is reliable. The points need to be cleaned every 10,000 km or so but the system is unlikely to suddenly fail without warning.

Electronic Ignition

Electronic ignition has been around for about 15 years, but until recently no major car manufacturer has used it in production. This is due not only to the additional cost but mainly to the reliability problems (how many NRMA men carry spare transistors?).

The first electronic ignition system simply used a transistor to switch the main current – giving longer points life. Unfortunately in those days a high voltage transistor could handle a maximum of about 150 V and special transformers (ignition coils) had to be wound and a large ballast resistor was needed. These normally consumed about 10 or 15 A from the battery.

Soon afterwards dwell extenders made a brief appearance and these used an SCR to close the points about 1 ms after they opened, giving a longer time for the current to build up. This helped the high speed performance but did not help starting or points life.

Another system which has been around for many years is CDI, where the required energy is stored in a capacitor and when required is dumped into the spark coil, which is used only as a transformer (not for energy storage). These systems are capable of generating extremely high secondary voltages — with sharply rising waveforms. This enables them to fire quite severely fouled spark plugs but equally will cause insulation

(text continued page 12)

TRANSISTOR ASSISTED IGNITION

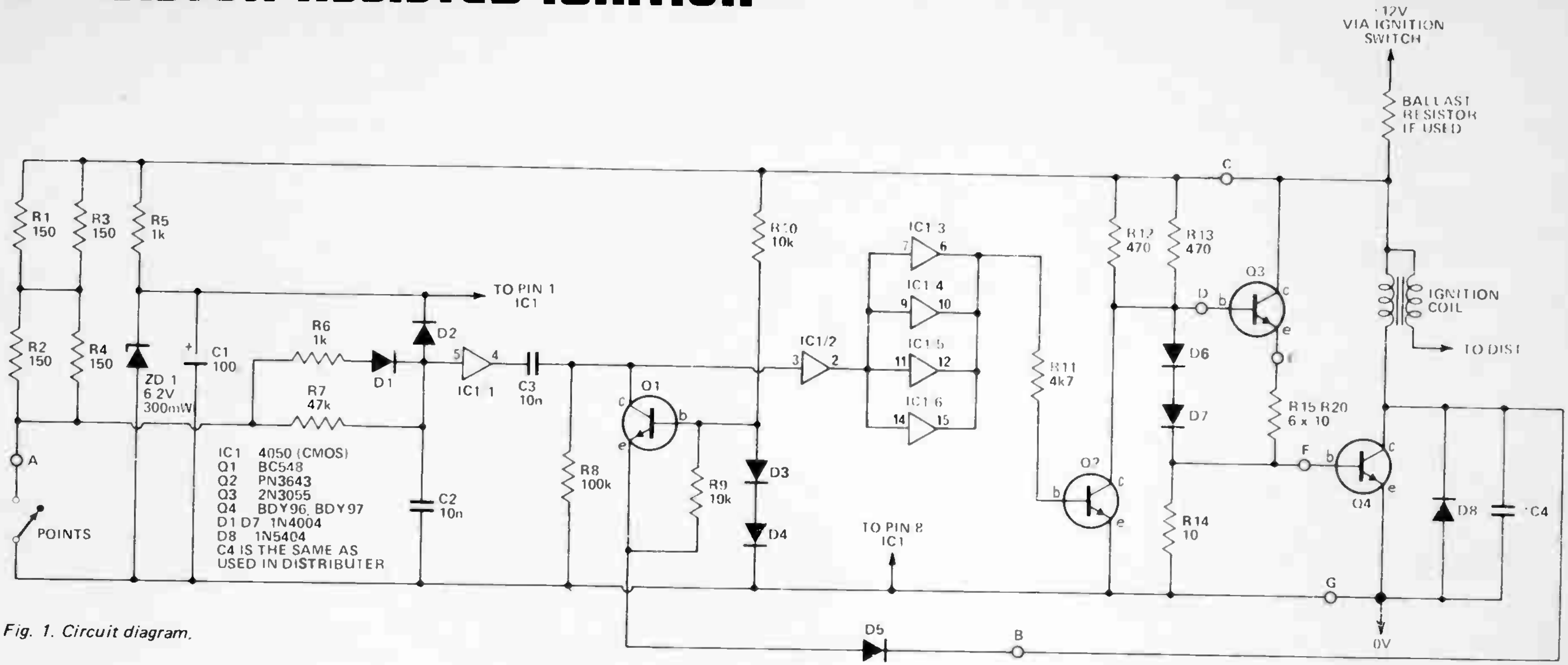


Fig. 1. Circuit diagram.

HOW IT WORKS ETI 316

The main current in the coil is switched by Q4 which is a 750 V 10 A transistor. The base current, of which about 500 mA is needed, is provided by Q3, which acts as a constant current source. We used this instead of a resistor as the supply voltage can vary from 6 to 12 volts (and the power dissipation would be too high). The current source is switched on and off by Q2 (the output transistor being off if Q2 is on). Diode D8 prevents reverse voltage damaging Q4 while C4 prevents the output voltage rising too high.

The points are supplied with a current, by R1-R4, of about 60 mA, which keep them clean, and when they open C2 is charged rapidly via R6 and D1. This is buffered by IC1/1 (IC1 is a CMOS hex buffer) which triggers the monostable made up of C3 and R8. This is then buffered by IC1/2 then by IC1/3-6 and this then controls the output stage. This will turn the output transistor off for about 1 ms (normal dwell) unless Q1 intervenes. This transistor operates if the output voltage falls to, or below, zero and resets the monostable, turning Q4 on again. This occurs after the first transient and ensures that Q4 is not turned on when there is high voltage across it.

When the points close C2 discharges more slowly via R7 and if the points open again quickly (ie, bounce) this is ignored. The supply voltage of IC1 is regulated by ZD1 and C1 to 6.2 V.

Construction

We made our prototype in a metal box — Horwood type 34/2/D. The two power transistors are mounted on the lid along with the changeover socket, capacitor C4, and the diode D8. All other components are mounted on the pc board which is mounted on 20 mm spacers.

The pc board should be assembled with the aid of the overlay in Fig 2. Ensure the transistors are oriented correctly — also check the diodes, IC1 and C1. The IC should be installed last. Mount the power transistors using insulating washers. The capacitor C4 should be the same type as used in the distributor. If desired it can be removed from the distributor and fitted on the coil itself, between earth and the negative terminal. In this place it will

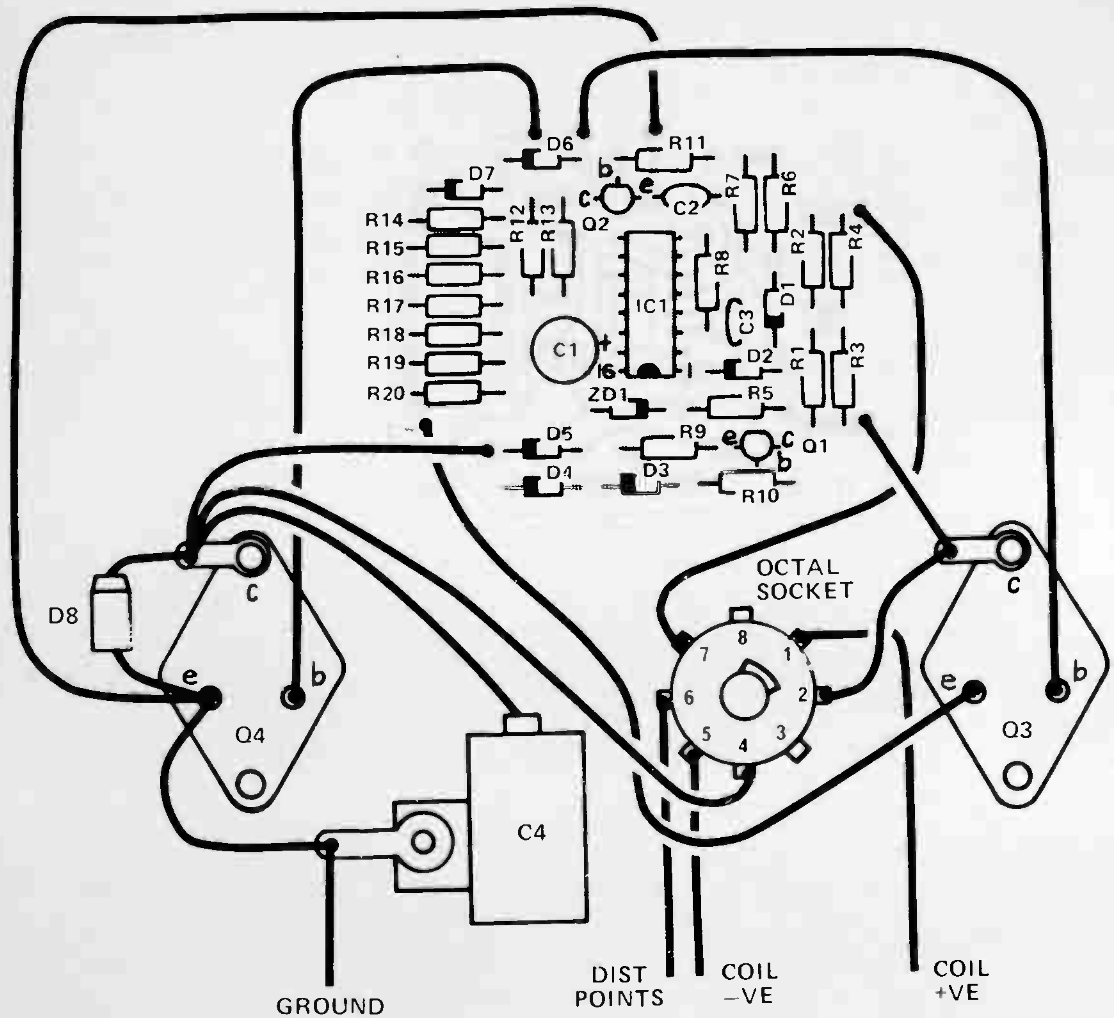


Fig. 2. Overlay and wiring diagram.

work for standard or assisted ignition.

The external wiring can now be done according to Fig 2. Ensure that the outer surface of C4 is connected to the emitter of Q4. When mounting the pc board ensure that the spacers do not touch any of the tracks if they do use a piece of insulation under the end.

As the octal plug has to be capable of plugging-in in two positions, ie, standard or assisted ignition, the socket has to be modified slightly. This entails making a new slot between pins 1 and 2 similar to the one between pins 1 and 8. This can be either a new slot or the existing slot can be widened. There are three links required in the plug, these being between pins 1&8, 3&4 and 5&6. With the plug in the normal position standard ignition is selected and in the second position transistor assisted ignition is operational.

PARTS LIST — ETI 316

Resistors all ½W 5%

R1-R4	150 ohm	
R5,6	1 k	
R7	47 k	
R8	100 k	
R9,10	10 k	
R11	4k7	
R12,13	470 ohm	
R14-R20	10 ohm	
Capacitors		
C1	100 μ 16 V electro	
C2,3	10 n polyester	
C4	see text	
Semi conductors		
Q1	Transistor	BC548
Q2	"	PN3643, 2N3643
Q3	"	2N3055
Q4	"	BDY96, BDY97

(If you have trouble locating a BDY96 or BDY97, A BUX80 may be substituted without changing any other components).

D1-D7	Diodes	1N4004
D8	"	1N5404
ZD1	Zener	6.2 V 300 mW
IC1	4050 (CMOS)	

Miscellaneous

PC board ETI 316
Case, Horwood 34/2/D or similar
Octal plug and socket
Four 20 mm long spacers

break-down if plug leads and other secondary components are in other than perfect condition. Long term reliability has also been a problem with many CDI systems

Most car manufacturers offering electronic ignition use transistor-assisted systems generally similar to the system described here.

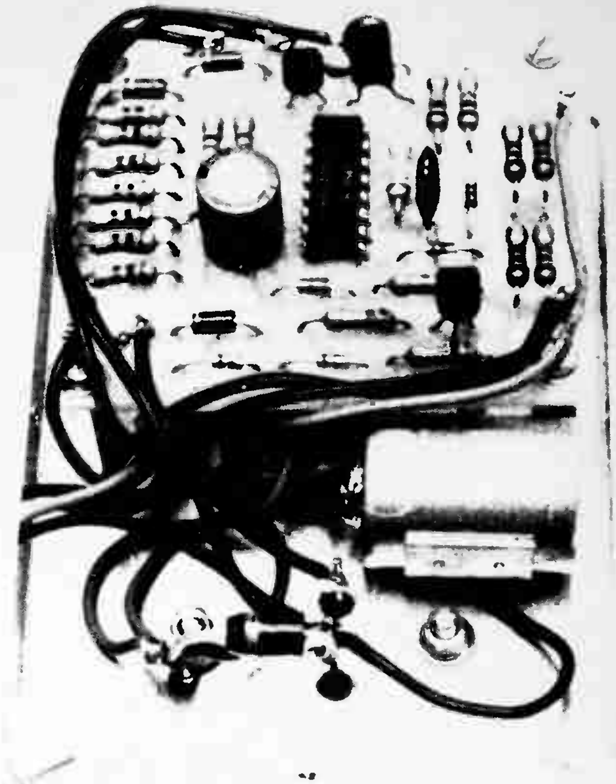
The system described here is a transistor switch type but with dwell extension built in. The unique circuit can provide a spark rate beyond that needed by most motors and will give a good spark at speeds which some CDI systems will stop. It is simple to install and we have provided a change-over plug (just in case you have problems).

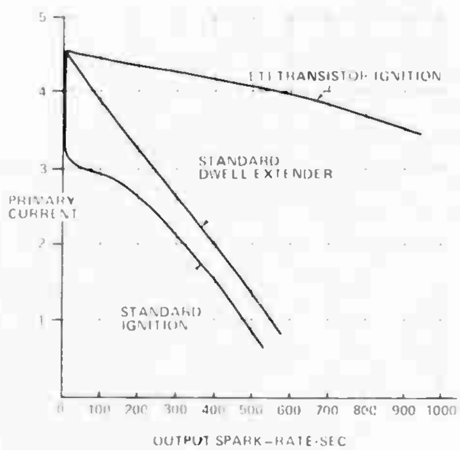
Design Features

The output transistor and the case are the major expenses and both are necessary. We therefore decided to see what other facilities we could add to make the project more worthwhile without making it much more expensive.

Adding dwell extension improves high speed performance but with the standard design method the voltage still falls somewhat at high speeds. After examining the primary waveform it was realised that when the points open a lot of energy is wasted in ringing and that the main spark energy occurs only in the first positive going transient. It was decided therefore to turn on the switching transistor (thus in effect reclosing the points) immediately after this transient. This provides a more stable spark of higher energy and allows very high speeds (over 1500 sparks per second) to be obtained. The primary current remains much more constant as the coil does not completely discharge each cycle.

Since the design was published a few readers found that this early switch-on caused misfiring. This occurs only with a very few, and generally older vehicles. If encountered it will almost certainly be cured by deleting diode D5.





Graph showing relationship between average coil current and spark rate for the different systems.

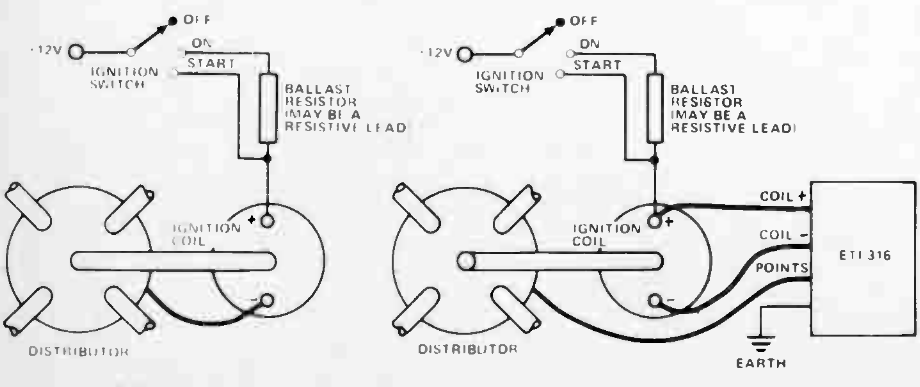


Fig. 4. Diagram showing how to connect the unit to the car.

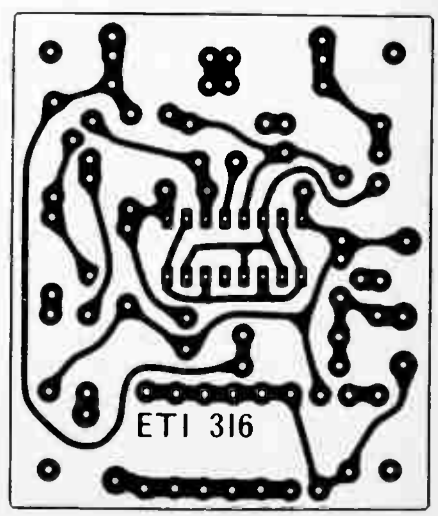
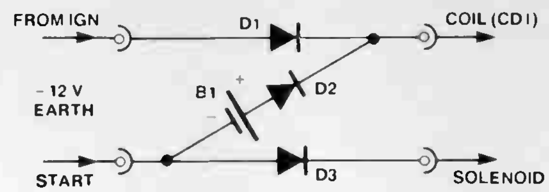


Fig. 3. Printed circuit board. Full size 65 x 55 mm.

Ideas for Experimenters

The cold start booster



D1, D2, D3 400 V, 5A 1N5625 or sim.
B1 6 V lantern battery type 509 or 609
Reverse all polarities for +ve earth

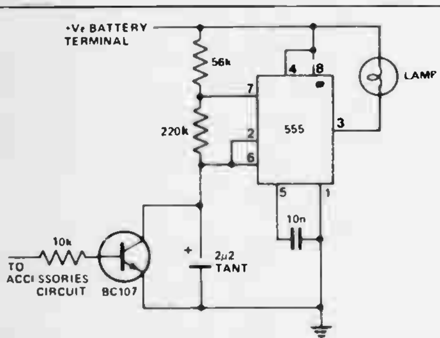
If you're a skiing enthusiast and you've been caught in sub-zero temperatures with a reluctant ignition then you'll appreciate this little circuit. Originally designed to cure cold starting problems encountered with a CDI kit, it adds an extra six volts to the ignition circuit potential just at the time when the battery voltage is likely to be at its lowest. The circuit uses a diode switching network to provide an alternative starting circuit to the ballast resistance and low resistance coil circuit found in various makes of cars.

It works as follows. The battery voltage, B1, is switched in series with the car battery when the starter solenoid is energised, providing the extra boost. Diode D1, being reverse biased, isolates the boosted voltage from the rest of the car's 12 V circuitry. Diode D3 prevents B1 discharging via the coil (or CDI) and the starter solenoid. Diode D2 prevents B1 being charged via the starter solenoid.

Fail-safe operation is assured because if B1 fails the ignition circuit is energised the normal way via D1. In my circumstances I had a lantern battery on hand which fitted snugly under the dash and was connected via alligator clips for easy replacement. I used automotive terminals for the connections to the car's electrics, enabling the booster circuit to be inserted between the ignition switch terminals and the normal leads.

A possible modification for those who wish to use a rechargeable battery would be to add a bleeder resistor in parallel with D2 to trickle-charge B1 while the car was running.

The circuit has been running reliably since last winter with sure-fire starts every time.



Dummy car alarm

A flashing light on your car dashboard could be an effective deterrent to thieves, leading them to believe that an alarm system lurks behind it.

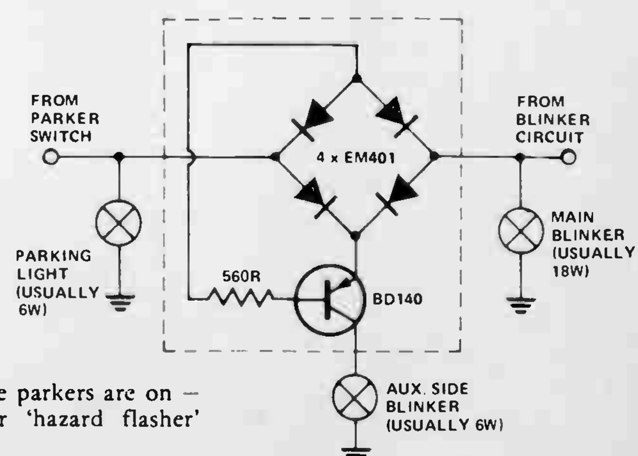
This circuit, from **Gregory Smith of Meadowbank NSW,** uses a 555 timer (what would we do without them?) to flash a small lamp. When the key is in the ignition and the accessories circuit is completed, the BC107 conducts and the 555 is inactivated. As soon as the accessories circuit is opened (by removing the ignition key), the transistor is cut off and the 555 activated. So the dummy alarm is set every time you leave the car.

Blinker Controller

Having fitted a set of auxiliary blinker lights to his car, **Kris McLean VK2ZKL** of Granville Tech. was faced with the problem of how to turn them on and off. No problem, you say, put them in parallel with the main blinker circuitry.

That is all very well if all you want them to do is blink on and off, but what if you want:

1) The auxiliary lamps to go on when the parking lights are on.
2) The auxiliary blinkers to light at the same time as the main ones when the parkers are off.
3) The auxiliaries to go on in an inverted cycle (ie to light up when the main blinkers go out and vice versa) when the parkers are on — presumably for 'hazard flasher' operation.

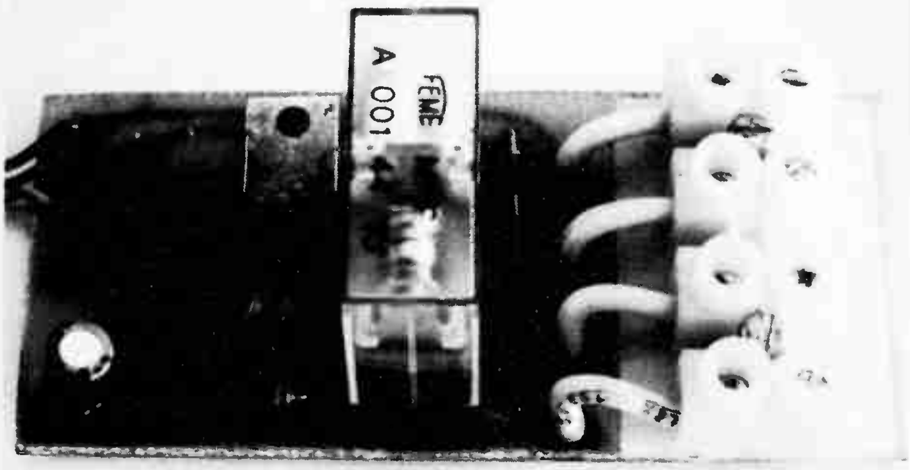


Kris spotted the fact that this was an exclusive-or function, the auxiliaries coming on when either the main blinkers or the parking light was lit, but not if both were lit. He devised the circuit here which he then fitted into a plastic pill bottle (useful things) and inserted into the wiring at each side of his car.

Project 319

Vari Wiper Mk2

This pulsed windscreen wiping circuit can be used on cars fitted with most types of modern wiper motors.



The assembled units.

WHEN OPERATING IN heavy rain windscreen wipers often have difficulty providing adequate visibility However, during light rain or mist all that is necessary is an occasional sweep of the blades at intervals of a few seconds.

Turning them on and off repeatedly takes the driver's concentration off the road, and his hands off the wheel, increasing the risk of an accident. Alternatively, if the wipers are kept working all the time in such conditions the blades tend to scrape on dry glass, wearing out the rubber inserts, your nerves, and worse still, the screen itself.

The answer is obvious; have the wipers operate intermittently at a duration which can be varied to suit the conditions.

This project is an updated version of the popular ETI 301 Vari-Wiper which appeared in the May 71 edition.

Figure 1 shows the circuit of a modern wiper assembly. Dynamic braking is achieved by applying a short across the armature, by a cam-actuated change-over switch synchronised with the wiper blades. When the wipers are switched off, the change-over switch shorts out the motor armature via the main wiper ON/OFF switch.

The circuit of fig. 2 is suitable for use with negative earth cars fitted with permanent magnet motors. Some early model cars are fitted with wound field coil motors and are not suitable for use with this circuit (more about them later).

Some types of permanent magnet wiper motors, especially those on British cars, have a fifth wire extended to the wiper switch. These motors are designed to operate independently of an earth to allow for their use on either positive or negative earth vehicles. The circuit of fig. 2 can also be used with these motors provided they are fitted to a negative earth car. However, some more expensive imported cars have wiper motors which are reversed in the parking sequence to lower the blades below the bottom of the windscreen when not in use. The Vari-Wiper unit described cannot be used with these wipers.

Before installing the Vari-Wiper unit make sure that you have one of the types of permanent magnet wiper motors described. If necessary remove the cover of the motor and identify the wire to the centre contact of the cam-operated switch.

Normal Wiper Operation

Conventional operation of the wipers is obtained by using the vehicle wiper switch in the normal way. Figure 2 shows the sliding contacts of this switch in the correct position for each function. Note that in the off position the switch shorts lead B to lead C. In the SLOW position the short is removed and an earth is extended to B, while in the FAST position the earth is removed from B and extended to A. For single speed wipers slide contact A will be omitted.

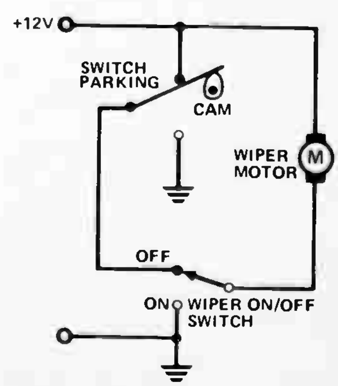


Fig. 1. Circuit of modern wiper motor assembly. Dynamic braking is achieved by applying a short across the armature.

HOW IT WORKS - ETI 319

The timing circuit is energized by operating switch SW1, which is part of switch/potentiometer RV1. This switch applies power to the unijunction/SCR circuit via the still-closed parking switch contacts.

Capacitor C1 charges via RV1 and R1, at a rate determined by the setting of RV1, until the unijunction 'fires', producing a positive going pulse which triggers the SCR into conduction. Resistor R4 ensures that the SCR latches on, thus energizing relay RL1.

Relay contacts RL1 (1) now change-over, removing the short circuit from the motor armature before energizing the motor by extending an earth via the now-closed relay contacts.

As the motor gathers speed, the associated cam-actuated switch changes over, removing power from the timing circuit (causing the relay to drop out) and extending an earth to the wiper motor via wiper switch contacts B and C, the now de-energized relay contacts, and the cam-actuated switch.

The wipers continue their sweep across the screen, but on their return the cam-actuated switch cuts in just before the end of the sweep. This removes power from the wiper motor and places a short circuit across the armature.

Operation of the ETI319A unit is similar except the motor, which does not require dynamic braking, can be driven directly from the SCR, saving the cost of a relay. Note that either D1 or D2 become redundant depending on the polarity of the vehicle.

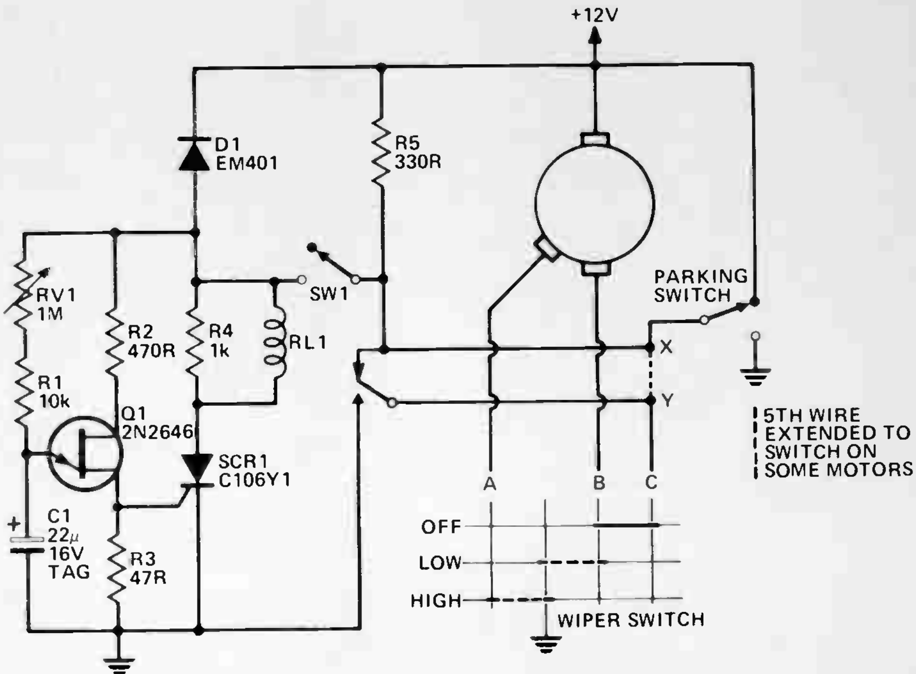
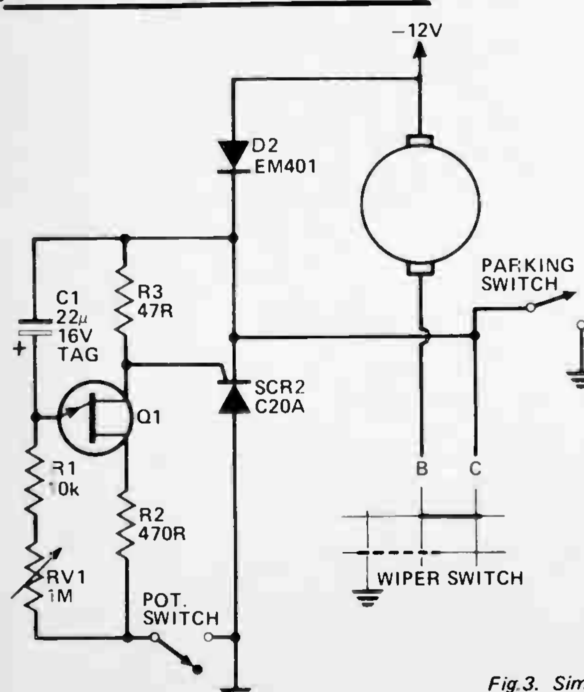


Fig. 2. The ETI319B Vari-Wiper circuit using relay output for use with permanent magnet motors.



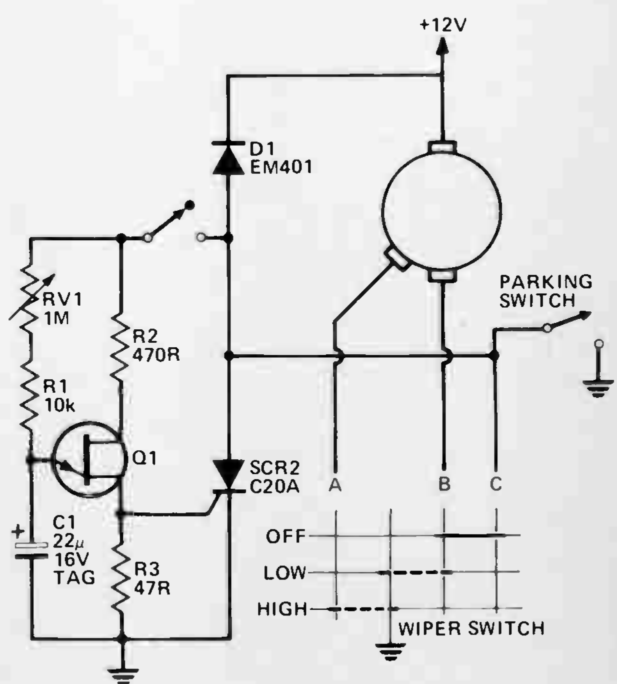
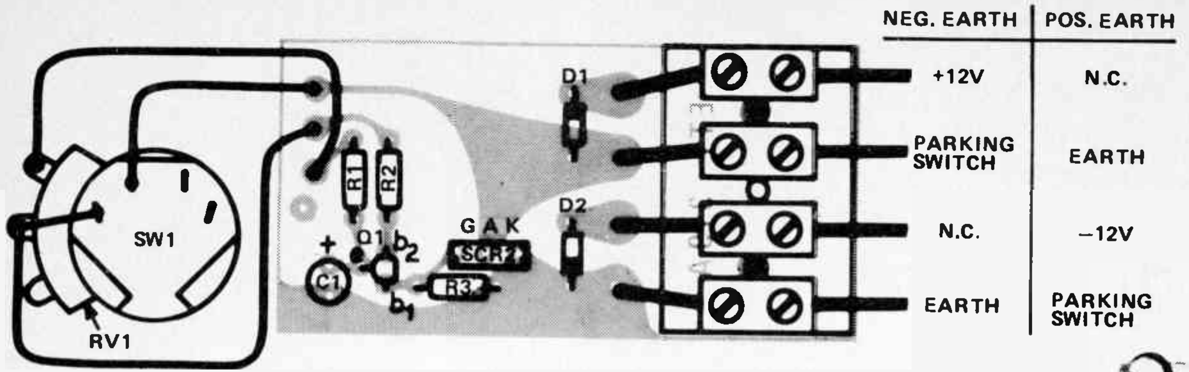
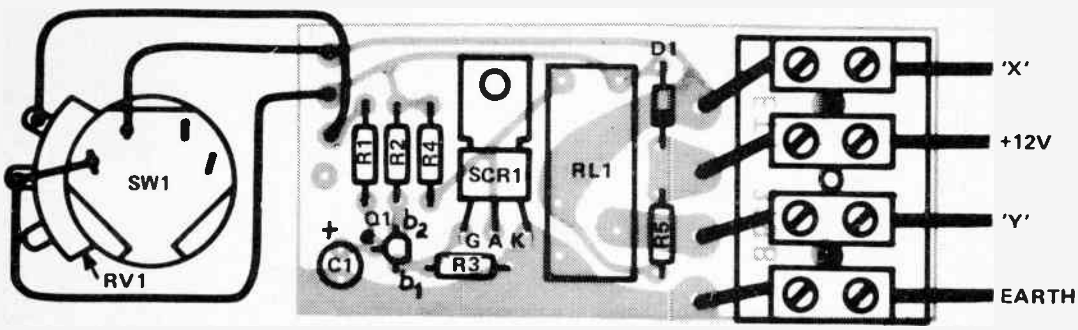


Fig.3. Simplified ETI 319A Vari-Wiper for use with wound field coil motors. The right circuit is for use with negative earth vehicles, and the left for positive earth. Both share the same PCB.





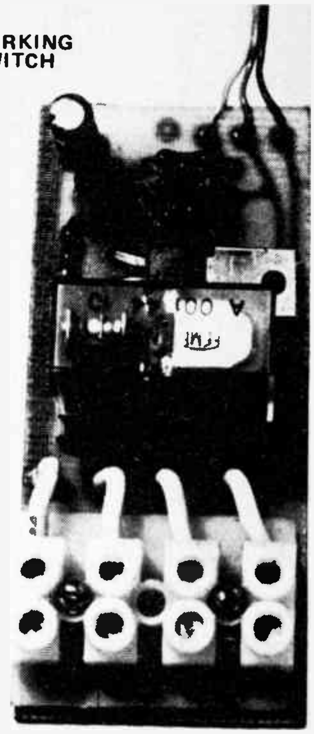


Fig. 5. Component overlays. Note that the same PCB is used for both earth polarities on the ETI 319A. (The PCB pattern is on page 34).

Delayed Operation

When delayed operation is required, the upper switch is left in the OFF position and the timing circuit energised by operating SW1 which is part of the switch/potentiometer RV1.

After a time which is set by the position of RV1 (0.5-25 secs.) the relay contacts RL1 (1) change over, removing the short circuit from the motor armature before energising the motor by extending an earth via the now closed relay contacts.

As the motor gathers speed the associated cam-operated switch changes over, removing power from the timing circuit (causing the relay to drop out), and extending an earth to the wiper motor via the wiper switch contacts B and C, the now de-energised relay contacts, and the cam-activated switch.

The wipers continue their sweep across the screen, but on their return the cam-operated switch cuts in just before the end of the sweep. This removes power from the wiper motor and places a short across the armature. The motor is thus dynamically braked and remains stationary until the next relay closure from the timing circuit. When this arrives the sequence is repeated.

Wound Field Coil Motors

Because wound field coil motors do not use dynamic braking, the Vari-Wiper can be made without a relay. Figure 3 shows the simplified Vari-Wiper circuit and its connections to either a positive or negative earth vehicle. The same printed circuit is used for both arrangements. Operation is similar to the previously described unit, having an earth extended through the SCR to start the motor.

Construction

Assemble and solder all components on the printed circuit board as shown in fig. 5. Do not bend the lugs of the SCR too close to its case and ensure all semiconductors are the right way round.

To connect the unit to the wiper motor circuit, the existing lead from the centre pole of the wiper motor change-over switch to the wiper ON/OFF switch (shown in dotted lines in fig. 2), should be broken at points X and Y and these leads taken to the normally closed contacts on the relay. Ensure that point X goes to the fixed contact and point Y to the moving one.

The potentiometer should be connected to the unit with just enough wire to allow the printed circuit to be mounted in a convenient position under the dash. The potentiometer can be mounted through a 10 mm hole drilled in the facia panel or by attaching it to a bracket mounted in a convenient place.

PARTS LIST – ETI 319

Relay Output Unit

Resistors all ¼W 5%

R1 . . . . 10k
R2 . . . . 470R
R3 . . . . 47R
R4 . . . . 1k
R5 . . . . 330R

Potentiometer

RV1 . . . . 1M switch pot

Capacitor

C1. . . . . 22μ 16 V electro

Semiconductors

D1 . . . . EM401
Q1 . . . . 2N2646 or MU10 unijunction
SCR1. . . . . C106Y1

Miscellaneous

RL1. . . . . Mini PC heavy duty 12 V relay
PCB ETI 319B
Nylon terminal strip

SCR Output Unit

All components identical, except:

R5 . . . . deleted
D1/2 . . . . EM401
SCR2 . . . . C20A
RL1. . . . . deleted
PCB ETI 319A

Project 321

Fuel level monitor sounds alarm when your fuel runs low

Have you ever been caught with your fuel level down (to zero)? Despite the inclusion of fuel gauges in dash panels, many motorists still get caught. It's understandable under circumstances where great concentration is required and the fuel gauge is forgotten. Don't you get caught — build our low-fuel warning project.

THIS PROJECT is a medically non-approved ulcer generator. It's designed to make you *worry* for twenty minutes or so before you are finally stranded through lack of fuel!

This alarm is designed for use in modern vehicles fitted with 12 V electrical systems only. It is driven from the vehicle's existing fuel gauge system and operates a LED and an alarm (optional) when the fuel level falls below a pre-set value.

Design

The fuel metering system in a modern car consists of a rheostat 'transmitter' in the fuel tank with its wiper mechanically linked to a float, an instrument regulator, and the fuel gauge. The current through the gauge is controlled by the float and the voltage supply is regulated to ensure reliability of calibration and to avoid the meter varying with battery voltage. The regulator output to the instrument is usually five or ten volts.

The fuel gauge is a bi-metallic type of meter with a coil of resistance wire wound around a strip of two dissimilar metals. When the current is passed through the coil it heats up and heats the bi-metal strip which bends, moving the pointer. This type of meter is used for its ruggedness and damping effect. When the ignition is switched off the gauge is returned to empty by a return magnet inside the gauge, otherwise it would show a reading when the ignition was turned off. The voltage across the rheostat increases as the level in the tank drops, developing typically three to four volts when the tank is empty.

The circuit monitors the voltages across the rheostat (wire C) and compares it to a reference voltage taken from the instrument regulator (wire B). The trigger point can be adjusted so the alarm will switch at any level on the fuel gauge by adjusting the pc-mounted trim pot, RV1.

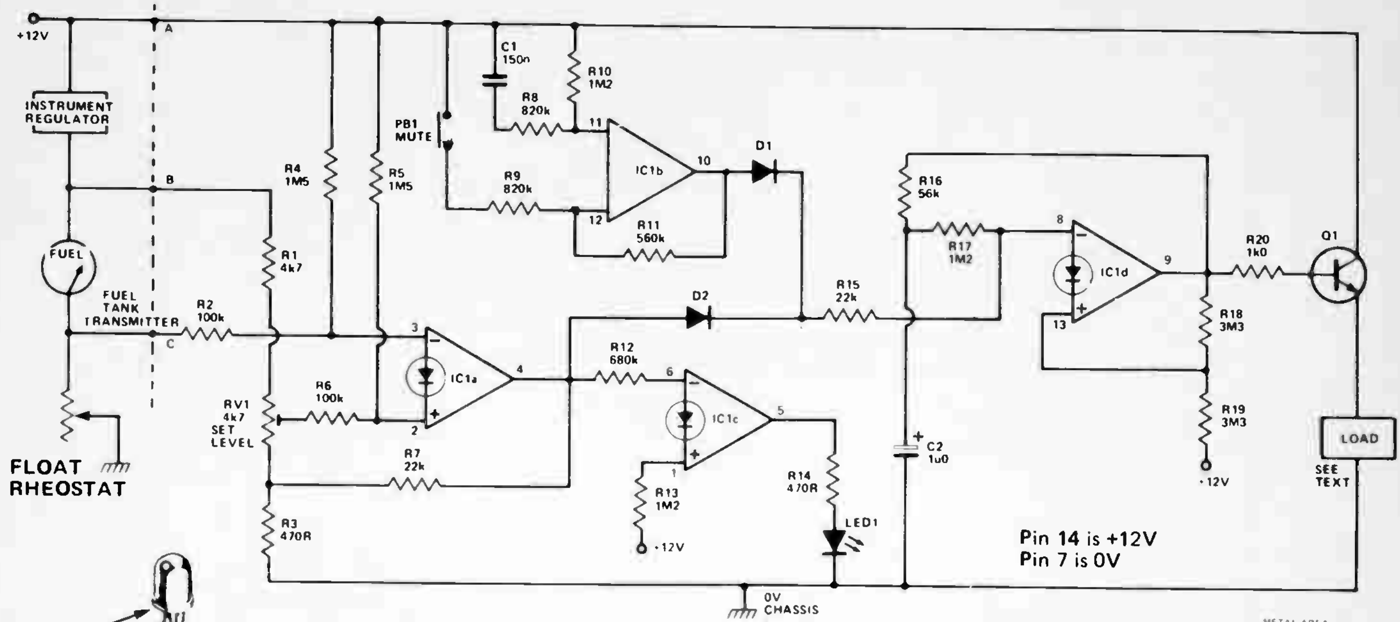
When the fuel level drops below the pre-set point the alarm sounds and the LED lights. The alarm output is a low frequency oscillating voltage which can be used to drive any 12 V alarm device greater than 100 ohms impedance. We used a Sonalert piezo-electric alarm, which is very loud and should be heard readily over quite high noise levels that may occur inside a vehicle.

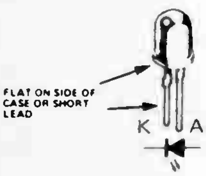
A mute circuit is included to stop the noise at the push of a button. However, the LED remains lit as a reminder. When the ignition is switched off the mute is re-set, and the alarm is activated immediately the ignition is turned on if the fuel level is still low.

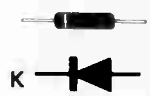
Construction and installation

Construction is quite simple as all the components are mounted on the pc board, except the LED, push button and alarm. Be careful to orient the diodes and the tantalum capacitor the right way round. The unit can either be mounted under the dash with the LED, push button and alarm mounted on a bracket, or the complete unit built into a small box. We used a good looking slim box by PacTec, distributed by Associated Controls (see Shoparound) with the LED, pushbutton and alarm mounted on the front panel. The connections to the car's wiring are taken from a plastic terminal strip mounted on the rear of the box.

Connection into the car's wiring system may be a lot more difficult. Make sure that you know what you're getting yourself into before you think about building the unit! The dash in





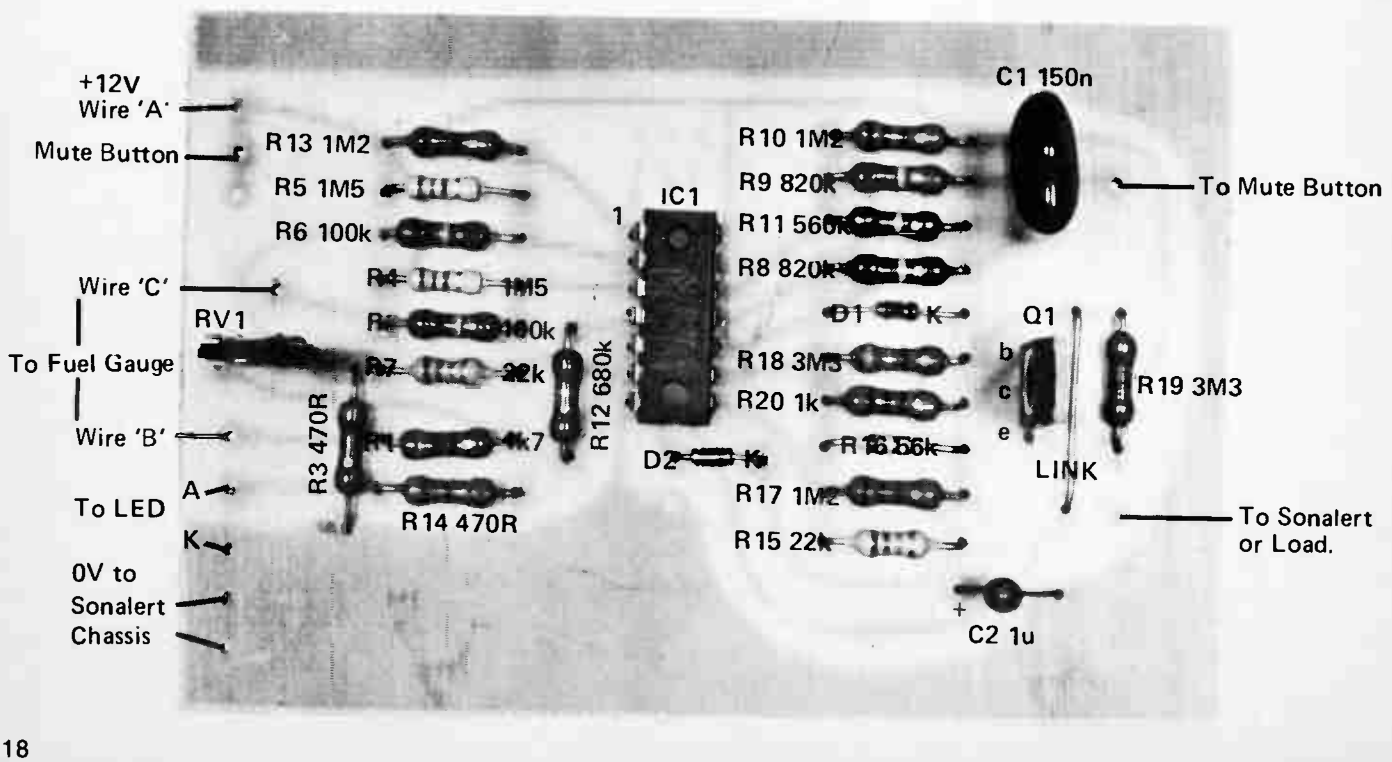


most cars will have to be removed and the wires to the fuel gauge identified and tapped. This can take the best part of a day, so give yourself plenty of time. Some cars use a printed circuit dash instead of a wiring loom and the connections can be soldered onto the back of the pc board, taking care not to damage it.

The other two wires, 12 volts and earth, can be taken to any convenient point in the car's wiring, however the 12 volts must be switched via the ignition switch.

After the unit has been assembled and installed the fuel alarm level must be set. Run the fuel in the tank down to the desired level and adjust the trimpot until the alarm just sounds. The adjustment should allow you to do this at any fuel level for a check of correct operation after the unit is installed.

When the fuel gets near the pre-set level the alarm will 'blip' as the fuel sloshes around in the tank, making quite a fuss if you let the fuel drop below the set level. ●



PARTS LIST - ETI 321

Resistors	all ½W, 5%
R1	4k7
R2	100k
R3	470R
R4, R5	1M5
R6	100k
R7	22k
R8, R9	820k
R10	1M2
R11	560k
R12	680k
R13	1M2
R14	470R
R15	22k
R16	56k
R17	1M2
R18, R19	3M3
R20	1k
RV1	5k or 4k7 min vert mounting trimpot
Capacitors	
C1	150n greencap
C2	1µ tantalum
Semiconductors	
D1, D2	IN914 or similar
LED1	TIL 220R Red Led or similar
Q1	BC139, BC184 or similar
IC1	LM3900

Miscellaneous
ETI 321 pc board, Sonalert or similar warning device, box to suit (see text), pushbutton (push to make), terminal strip.

BELOW LEFT is the pc board overlay. Take care with the orientation of the diodes and tantalum capacitor (C2). Initially, we cut the board for behind-dash mounting and had to secure it in the PacTec case with a strip of double-sided tape. The pc board artwork is below.

HOW IT WORKS – ETI 321

The circuit consists of a voltage comparator, IC1a, an LED driver, IC1c, an astable multivibrator used as a low frequency oscillator, IC1d, and a mute circuit, IC1b.

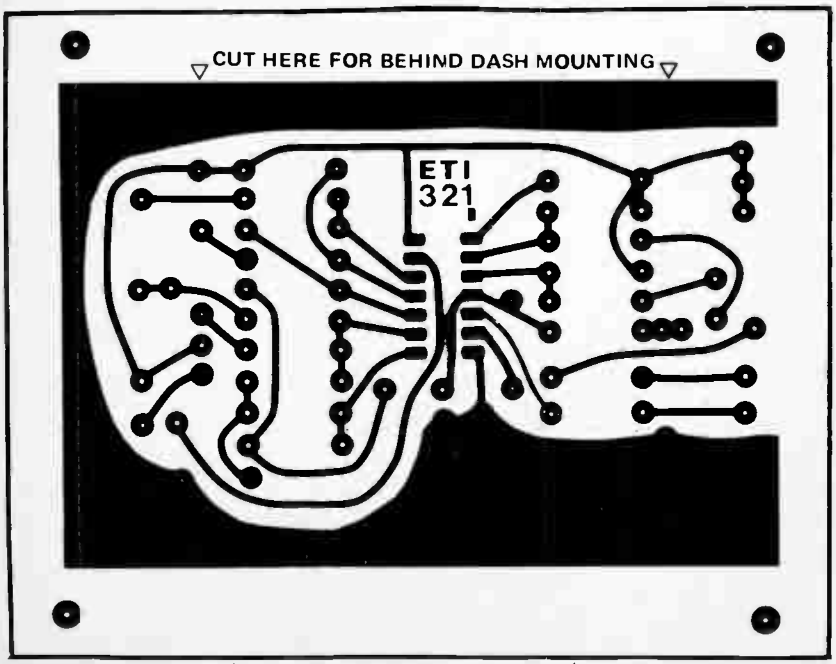
IC1a is wired as a voltage comparator with a small amount of hysteresis provided by R7 and R3. When the fuel level in the tank drops, the voltage across the rheostat rises. This voltage is fed to the inverting input of IC1a and is compared to the preset voltage level from RV1 on the non-inverting input. When the voltage across the rheostat is low, the output of IC1a is high. When the tank empties to the point where the voltage on the inverting input is just higher than the reference, the output of IC1a goes low.

The output of IC1a is connected to the inverting input of IC1c. When the output of IC1a goes low, the output of IC1c goes high, lighting the LED.

The low from IC1a is also fed to the negative input of IC1d, through D2 and R15, enabling the oscillator. The output of the oscillator is fed to an emitter follower, Q1, which drives the alarm.

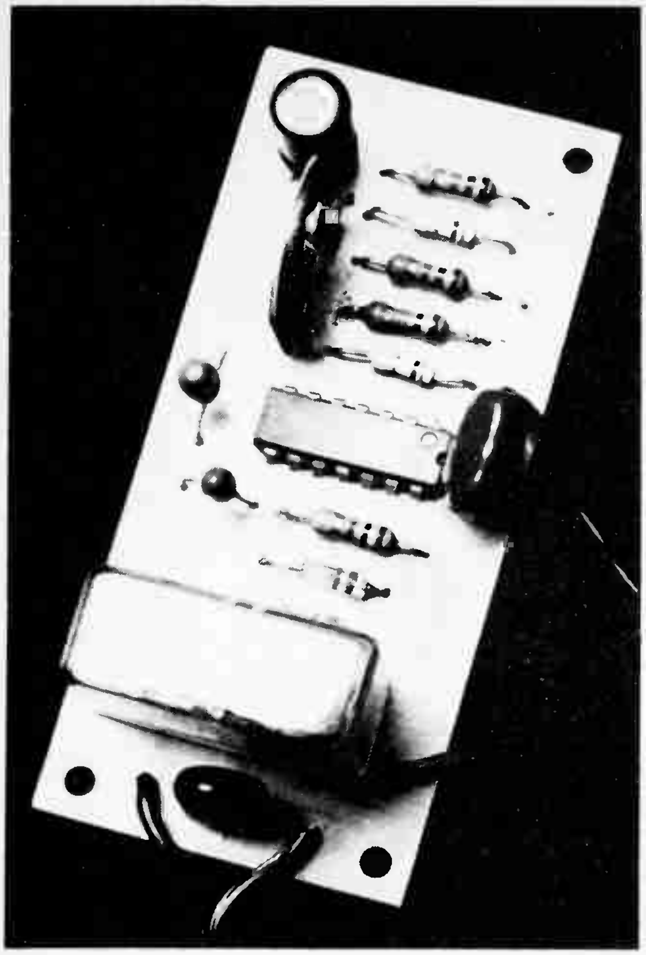
When the ignition is first turned on the mute circuit, IC1b, is automatically set to have a low on its output (pin 10) by C1 charging via R8. D1 is reverse biased and the circuit is isolated from the oscillator. When the mute button is pressed the output is latched high, D1 is forward biased and the inverting input of IC1d is held high disabling the oscillator. Diode D2 is reverse biased when this occurs and the output of IC1a remains low. The LED will still be lit.

When the power is turned off and reapplied the mute circuit is reset to a low output and the circuit is ready to be retriggered.



CUT HERE FOR PAC TEC BOX

PROJECT 313 CAR ALARM



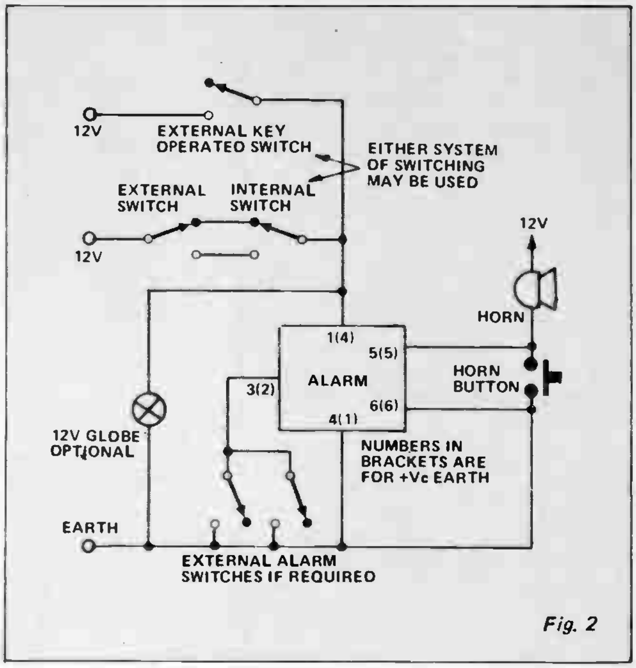


Fig. 2

Protect your car with this simple effective circuit.

ONE OF LIFE'S more devastating experiences is to walk out of your house in the morning and find that your car has disappeared!

But this need not happen to you, for an effective alarm system, as described here, may be quite easily constructed and installed at low cost.

The ETI 313 car alarm uses one single IC and a minimum of other components. It will, when actuated, blow the horn at one second intervals, and will continue to do so until deactivated by means of a key switch etc.

The alarm is triggered by any drop in the battery supply voltage caused by an increase in loading on the vehicle's electrical system. Thus, if a door is opened, the interior light will be activated and the increase in electrical load will trigger the alarm.

This operating principle simplifies installation, for practically all vehicles have courtesy lights activated by switches on at least two of the doors – and it is a fairly easy task to install further switches on the other doors if required.

Both the boot and under bonnet areas may be protected in a similar manner – indeed many vehicles have lights already fitted in these areas, if not, it is a simple matter to fit them into the circuit such that they come on when the boot lid etc is opened.

These lights are of course very useful apart from their alarm function, but remember – they must operate at all times, not just when the ignition is on.

The alarm is sensitive enough to be activated by anyone pressing the brake pedal – or even by opening the glove box (where a lamp is fitted of course).

The unit is designed for use with cars having 12 volt electrical systems. It may be used with either positive or negative earth systems without modification.

In addition to the power sensing alarm mode other precautions may be

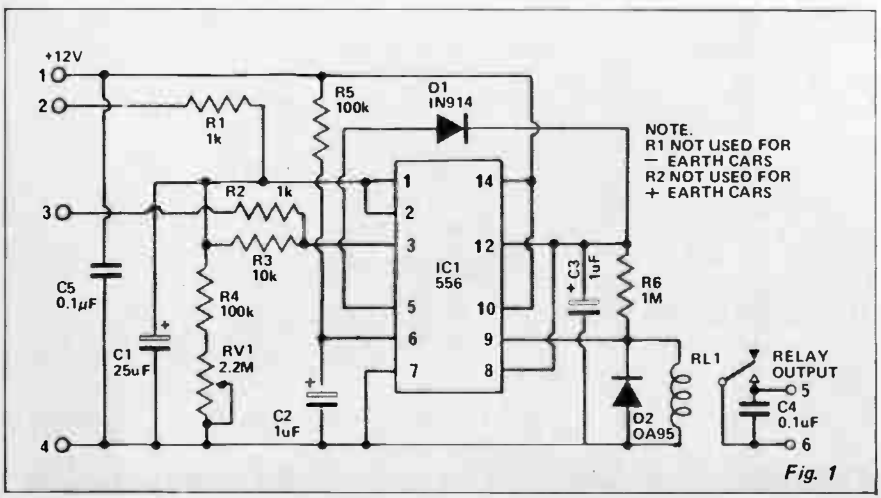


Fig. 1

taken by adding further alarm microswitches. For example microswitches may be fitted to the suspension such that if anyone tries to lift the car, in order to tow it away, the alarm will go off. If such switches are used they should be connected between terminal 2 or 3 or the alarm (see Fig 1 and 2), depending on whether the vehicle has a positive or negative earth system, and earth.

CONSTRUCTION

Construction of the alarm is extremely simple and anyone capable of using a soldering iron should not have any difficulty. All components, including the relay, are mounted on a small PC board as shown in the component overlay diagram.

Note the polarity of electrolytic capacitors, the IC and diodes. In particular make sure that the germanium diode D2 is mounted in the correct position and with the correct orientation. When soldering use a small, light-weight iron and preferably small gauge solder. Solder quickly and cleanly. Only apply the iron for sufficient time to cause the solder to flow around the joint. These precautions will ensure that components are not damaged by excessive heat. The unit should then be mounted in a small plastic, or metal box.

Two different switching systems may be used to enable the alarm. Use either an external key switch mounted in a convenient, but not obviously seen location, or a two way system of concealed switches – one inside and one outside. The switch inside is used to enable the alarm (after opening the door) and the external one to disable the alarm before entering the car. This latter system has the advantage that anyone watching will not see where the external disable switch is located.

PARTS LIST – ETI 313

R1,2	Resistor	1k ½watt 10%
R3	"	10k ½watt 10%
R4,5	"	100k ½watt 10%
R6	"	1M ½watt 10%
RV1	Potentiometer	2.2 meg
C1	Capacitor	25µF 25 volt electrolytic
C2,3	"	1µF 25 volt electrolytic
C4,5	"	0.1µF polyester
IC1	Integrated Circuit	NE556
D1	Diode IN914 or similar	
D2	Diode OA95 (must be germanium)	
RL2	Relay 12 volt 280 ohm coil, 6A contacts. Associated Controls type E3201 or similar.	
PC board ETI 313		
SW1	Switch	SPST key operated
SW2,3	"	SPDT toggle (see text)
metal or plastic box to suit.		

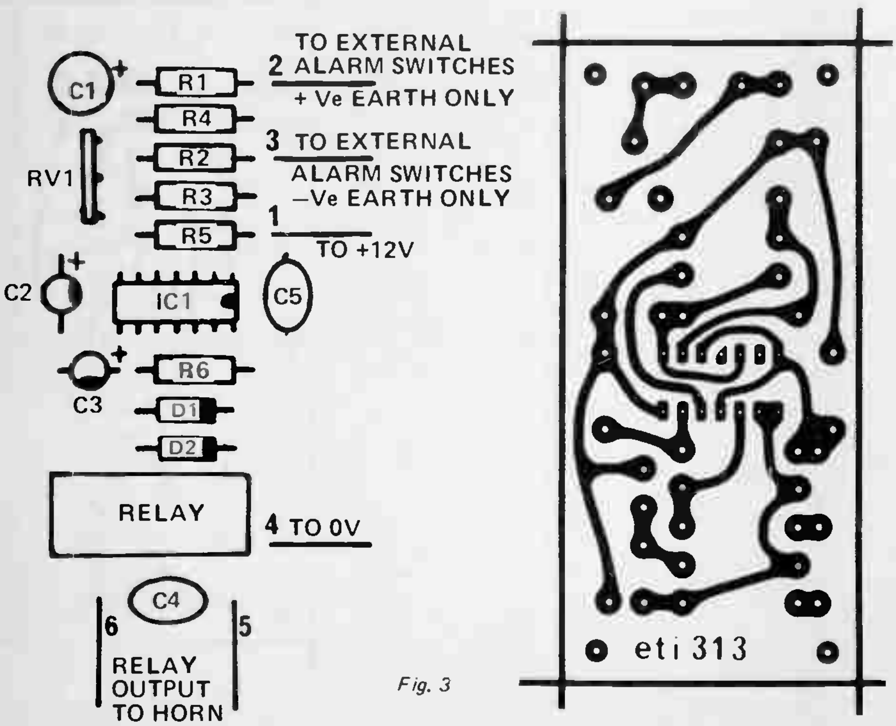


Fig. 3

PLEASE NOTE

When this project was originally published, some constructors experienced incorrect ON/OFF timing relay latching.

This may be caused by diode D2 in that, in some cases, it does not adequately limit the reverse voltage generated across the relay This reverse voltage may trigger the IC. This can be cured in one of two ways.

1 Replace diode D2 with an EM401 or similar. Break the track between resistor R6 and diode D2 and place a second EM401 diode across this break such that its cathode and the cathode of diode D2 are together.

2 Add a 200 ohm 1 watt resistor between the +12 volt line and the output (pin 9) of the IC.

HOW IT WORKS

When a load, especially an incandescent lamp, is switched onto a battery the battery voltage will drop instantaneously and then return to normal. The amplitude and duration of this negative going spike in the supply is dependant on the size of the lamp used but is of sufficient amplitude, even with small globes, to trigger an alarm circuit.

The NE556 IC contains two NE555 timer ICs in a single case. One of the timer sections is used to detect the supply spike and to gate on the second timer which produces a one Hz output to the relay and horn.

Each timer section contains two comparators, a LOW comparator set at 1/3 supply and a HIGH comparator set at 2/3 supply. These comparators set a flip-flop which provides an output.

When the power is first applied, the voltage at pin 6 (input to the low comparator) is initially low for about half a second whilst C2 charges via R5. This sets the output of the flip-flop to a high state where it will remain regardless of further excursion in the voltage at pin 6.

The only way that the output may be set low again is for the input to the high comparator (pin 2) to be taken past its threshold. This threshold voltage is available at pin 3, and by using a voltage divider (R3, R4 and RV1) a slightly lower voltage is derived from it. This is used as a reference level to the HIGH comparator input (pin 2) Capacitor C1 is used to bypass any fast transients which may appear at the input (pin 2).

If the supply falls, the voltage on pin 3 will also fall. If it falls below the voltage at pin 2, the output will fall again to a low state and will stay there. The capacitor C1 will also be discharged via pin 1.

The second half of the IC is connected as a free-running multivibrator having a frequency determined by R6 and C3, of about 1 Hz. If the output of the first stage is high, the diode D1 will force the multivibrator to lock into the low state. When the output of the first stage goes low the multivibrator is freed to oscillate.

This one hertz output switches a relay which in turn controls the horn, or any other suitable device. The diodes across the relay prevent reverse voltages being generated which could damage the IC. This must be a germanium type for correct operation.

This over-rev alarm could save you money!

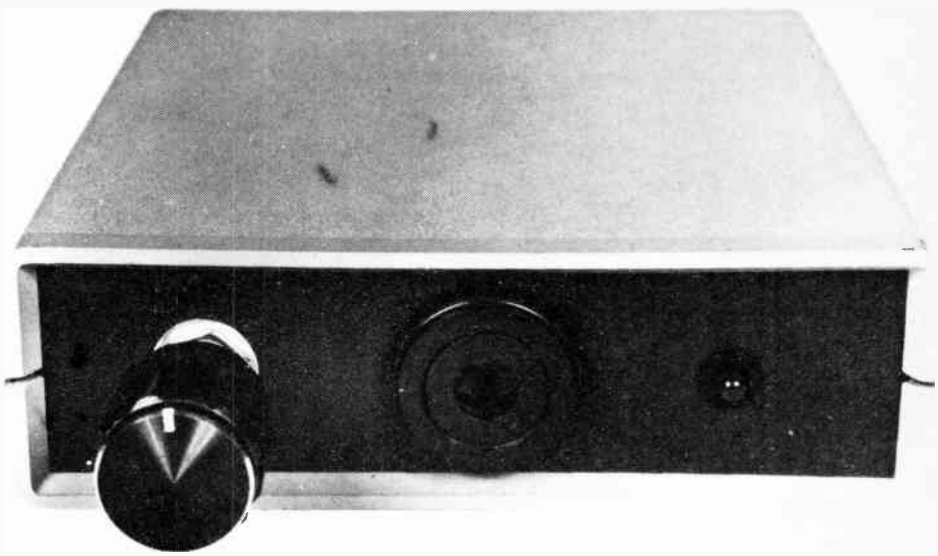
This versatile little project will let you know that you're about to blow up your engine as well as when you're exceeding the speed limit.

IT IS EASY to exceed the rev limit of a vehicle's engine when changing gears at highway speeds, courting danger from an engine failure. This alarm will let you know, in no uncertain fashion, *before* you approach the danger point (i.e: the red line on your tacho – if your vehicle has one). Most tachometers, owing to their construction, have a lag between the actual engine RPM and the RPM they indicate, so that, even if you keep an eye on your tacho you could dangerously exceed the indicated maximum RPM of your engine.

This alarm has no lag problem. When set to sound at an engine speed below the manufacturer's limit, you'll get plenty of warning.

Apart from its usefulness as an over-rev alarm, this project can let you know when you have exceeded a set road speed . . . and it's cheaper than a radar detector and can never be fooled!

The alarm specified is loud enough to be heard in even the noisiest of vehicle cabins.



The circuit

This alarm is designed for vehicles fitted with a 12 volt electrical system and is driven from the ignition system's contact breaker points. The alarm can be used to indicate when one of four pre-set speeds have been exceeded or when the engine speed exceeds a pre-set rev limit – much the same as a red line on a tacho, but this unit gives an indication you can't ignore!

When used as a speed limit alarm the four pre-sets can be set to different speed limits, say 60 km/h, 100 km/h, 110 km/h and 120 km/h. Of course these speeds will only be accurate in top gear, so the unit should be provided with a switch to turn it off when driving around town. Its main use will be on country trips and on expressways.

When used as an over-rev alarm only one range will be necessary so the switch and three unused trim pots can be left out. The unit can be set to any rev limit, say 6000 revs, to indicate when you're coming close to over-revving the engine. The actual limit depends on the particular engine in your vehicle.

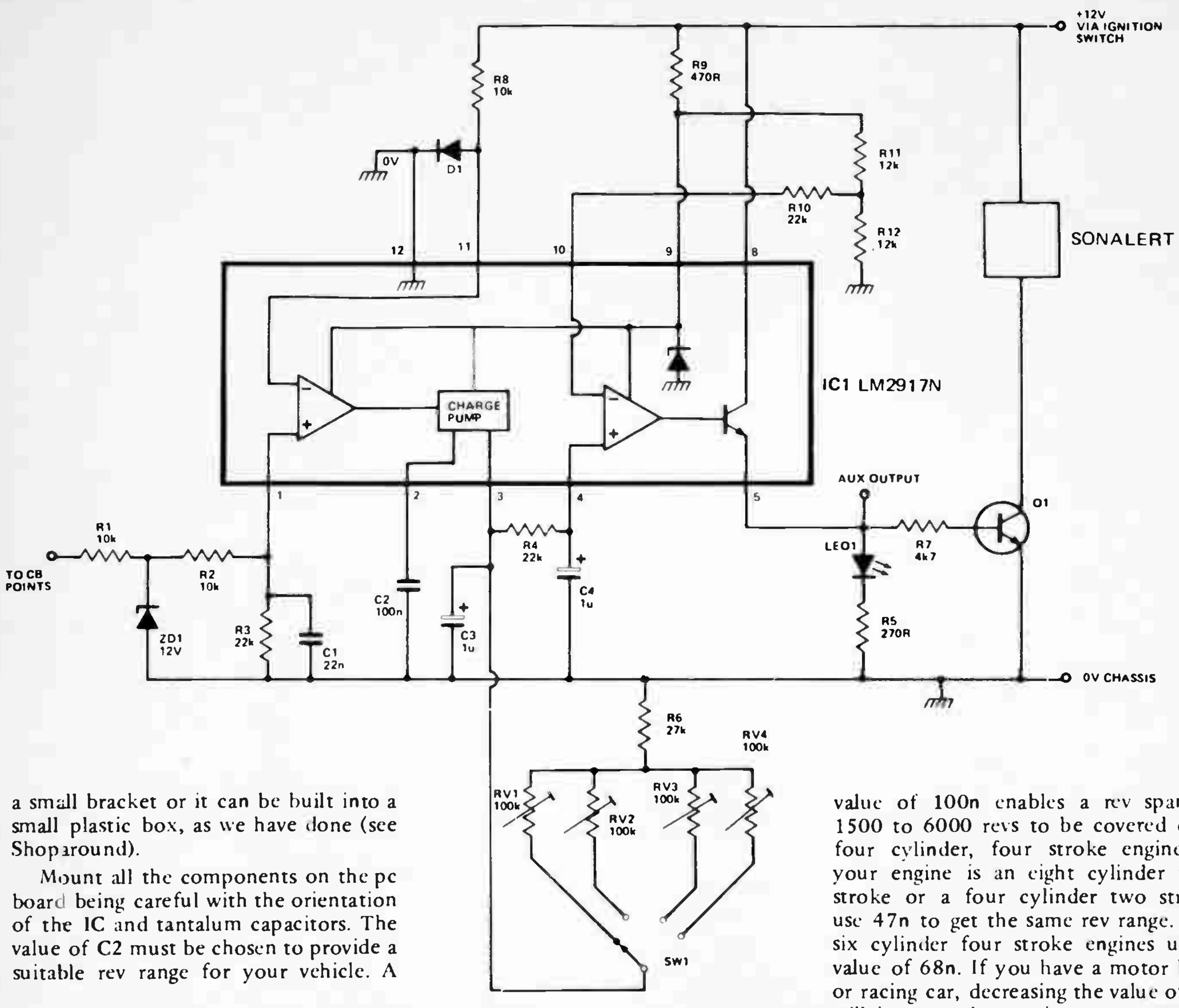
The unit could be used as both an over-rev alarm and a speed alarm by using one switch position as a rev alarm and the other three set to speed limits in top gear. For city driving it would be left in the over-rev position and switched over in the country.

When the engine speed reaches the pre-set limit the LED lights, (we used a flashing LED) and the Sonalert alarm sounds. The Sonalert is very loud and can be left off or reduced in level with a series resistor. A relay can be used in place of the Sonalert, to control an external circuit, but never use it to turn off the ignition. You are likely to need the full power of the engine to avoid a collision!

The circuit employs an LM2917 frequency-to-voltage converter recently released by National. The input waveform from the points switches a comparator and charges a capacitor, C3, from a charge pump. The charge on the capacitor is proportional to the frequency and is set by the values of C3 and the trim pots. When the voltage rises to a pre-set limit the second comparator switches and an output from the chip, on pin 5, lights the LED and drives Q1.

Construction

The over-rev alarm can either be incorporated into the car under the dash, with the switches and LED mounted on



a small bracket or it can be built into a small plastic box, as we have done (see Shoparound).

Mount all the components on the pc board being careful with the orientation of the IC and tantalum capacitors. The value of C2 must be chosen to provide a suitable rev range for your vehicle. A value of 100n enables a rev span of 1500 to 6000 revs to be covered on a four cylinder, four stroke engine. If your engine is an eight cylinder four stroke or a four cylinder two stroke use 47n to get the same rev range. For six cylinder four stroke engines use a value of 68n. If you have a motor bike or racing car, decreasing the value of C2 will increase the maximum rev setting.

Once the unit is constructed, mount it in a convenient position in the car within easy reach of the driver. Connect the unit's 0 V line to the chassis and the positive supply to the vehicle's battery supply after the ignition switch. Try the fuse box on the accessories fuse wiring for a suitable supply point.

The input signal comes from the breaker points and can be tapped off the wire between the coil and the distributor.

HOW IT WORKS — ETI 322

The alarm detects the engine RPM by looking at the pulses from the contact breaker points. These pulses are used to charge a capacitor, so the voltage on that capacitor is linear with respect to pulse frequency. When the voltage across the capacitor reaches a pre-set value a comparator switches over, lights the LED and turns on the Sonalert alarm.

When in top gear, the engine speed is proportional to road speed. The frequency of the pulses from the points is therefore also proportional to road speed. The pulses are fed through a current limit resistor, R1, and to a zener diode ZD1. This insures that no damaging high voltage spikes reach the IC. The pulses are then differentiated by C1 and fed to the non-inverting input of a comparator. The inverting input is clamped by D1 to about 0.6 V. The comparator switches when the input pulse is greater than 0.6 V. This avoids triggering of the comparator on noise.

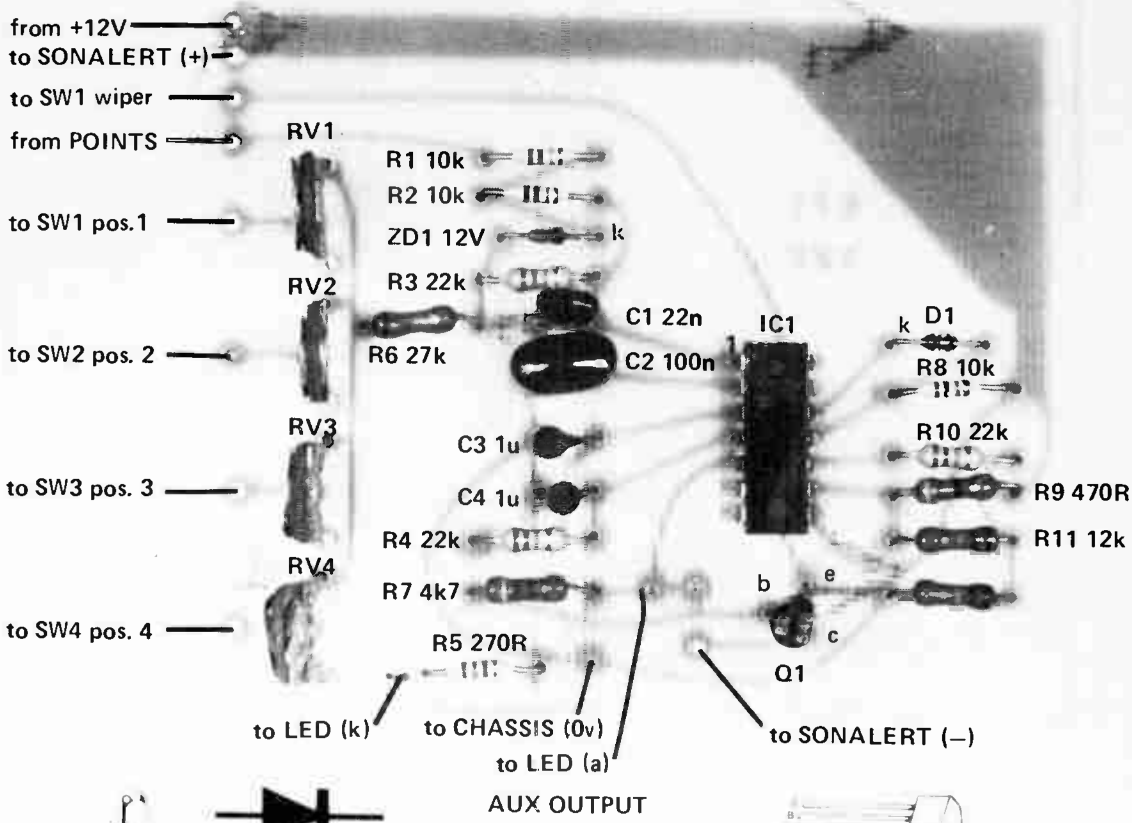
The charge pump is controlled by the output of the comparator which puts a constant current pulse into the charge capacitor C3. The length of this pulse is determined by the value of C2. The voltage across C3 then rises linearly with frequency as the pulse repetition rate increases. The range resistors vary the discharge time of the charging capacitor, thus varying the voltage across it for a given frequency.

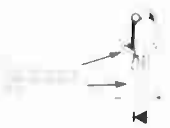
The voltage across the timing capacitor is monitored by a second comparator. The switching point for this comparator is set by the voltage divider R11 and R12 on its inverting input. When the voltage on the charging capacitor reaches this fixed voltage the comparator switches and the output on pin 5 goes high.

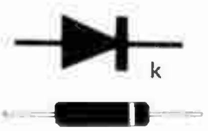
The LED lights and Q1 switches on, turning on the Sonalert alarm. The supply for the IC and the reference voltage for the second comparator come from an internal, zener-regulated supply, the output of this being connected to pin 9.

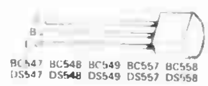
Calibration

This is a two-man job with one person driving the car to the required speed while the other adjusts one of the trim pots. This has to be done for each speed setting. Adjusting the rev limit is a little more difficult since few cars will reach their top revs in top gear. In any case, they would be doing well over 160 km/h. A little fast. If you have a friend with a tacho this is the easiest way. If not, the









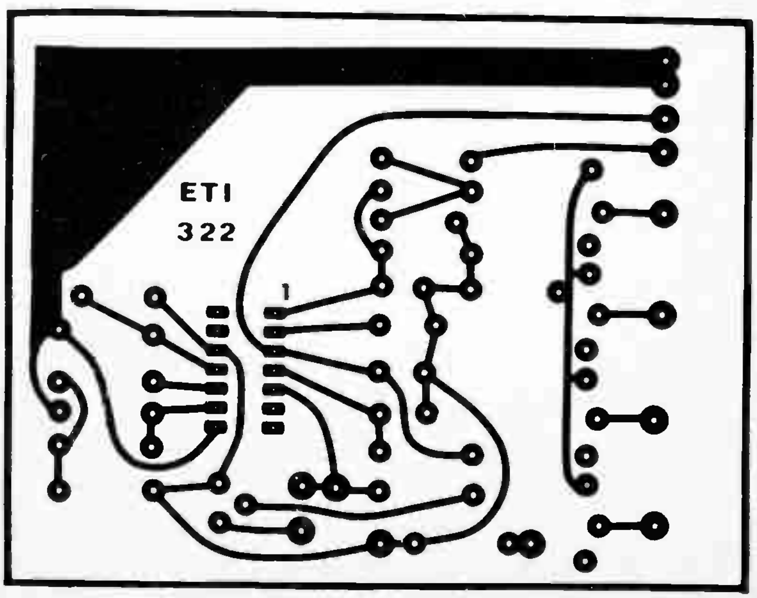
PARTS LIST - ETI 322

Resistors	all ½W, 5%
R1, R2	10k
R3, R4	22k
R5	270R
R6	27k
R7	4k7
R8	10k
R9	470R
R10	22k
R11, R12	12k
Potentiometers	
RV1–RV4	100k min vert mounting trim pots
Capacitors	
C1	22n greencap
C2	100n greencap - see text
C3, C4	1µ 33V tantalum
Semiconductors	
D1	1N914 or similar
ZD1	12V, 400 mW zener diode
LED1	TIL220R LED or similar OR flashing LED (see text)
Q1	BC558, BC108 or similar
IC1	LM2917N
Miscellaneous	
ETI 322	pc board
SW1	one pole four position rotary switch

Sonalert alarm or similar, case to suit (see Shoparound on page 97.)

unit can be set from the manufacturer's data. Information is available for each car showing the speed per thousand revs in each gear. Simply choose a suitable gear, say second, and multiply the number of thousand revs you want to set the limit to by the speed per thousand revs in that gear. Drive the car up to that speed in the gear and set the trim pot so the alarm just sounds. Once set, the unit should not require attention. ●

(See page 44 for Over-rev Safety Cutout for this project.)



Reversing alarm for your car

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

Roger Harrison
Graeme Teesdale

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

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

Getting attention

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

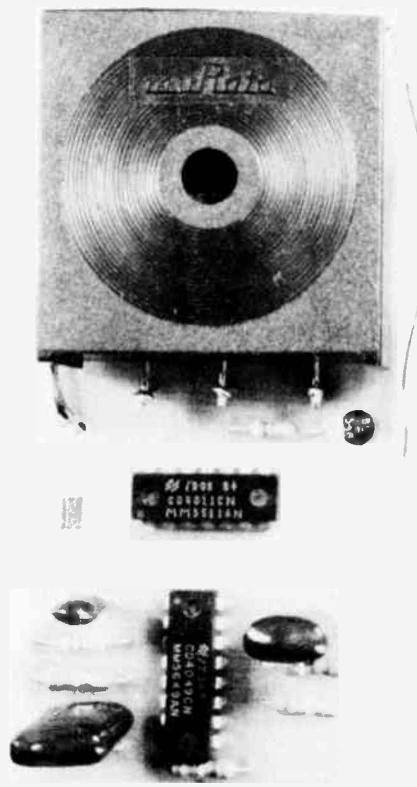
The second attention-getter we have incorporated is to *pulse* the alarm. But, to improve its attention-getting, it is a staccato pulse rate rather than an even rate. The project will work on 6 V or 12 V electrical systems, positive or negative (conventional) 'ground'.

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

Construction

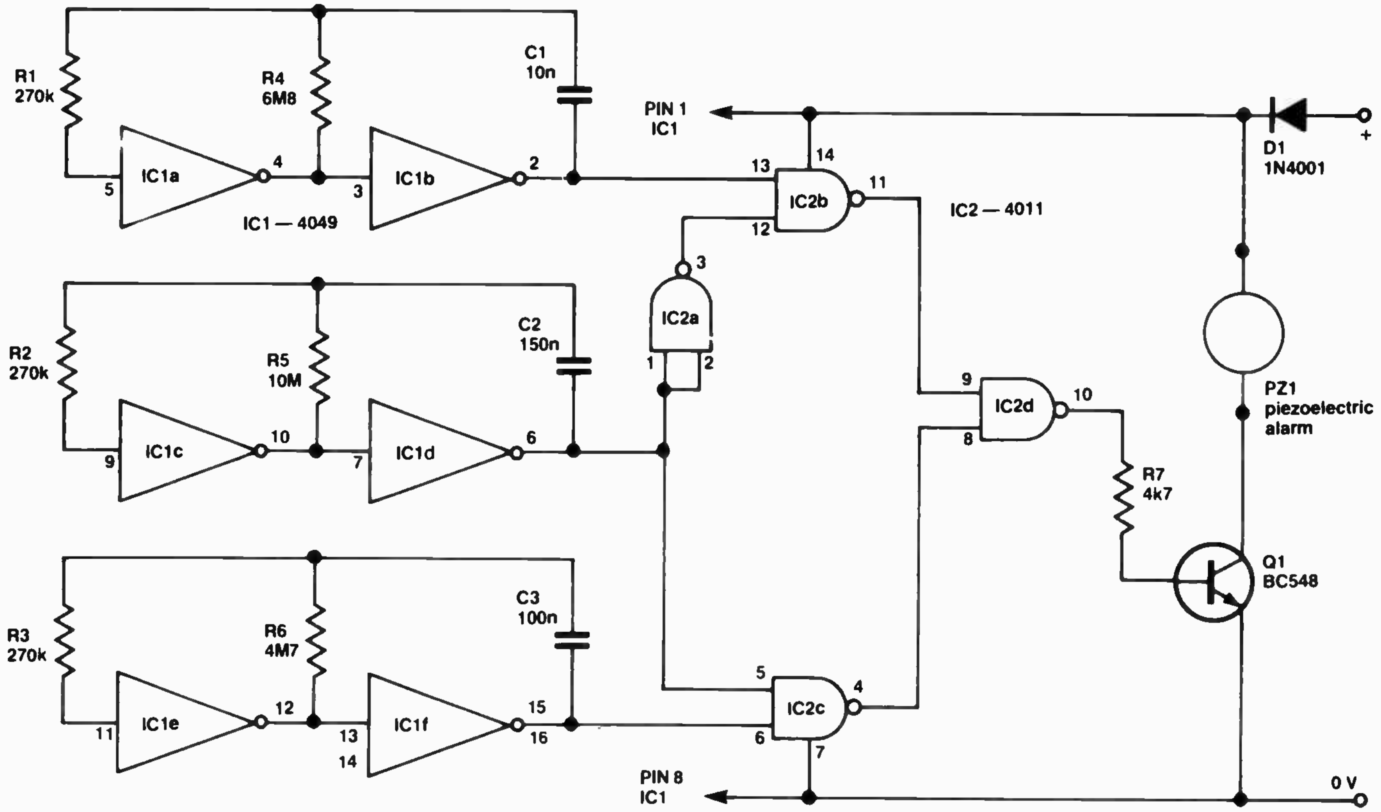
While we have designed a printed circuit board for this project it is not essential to use one and the unit could be constructed on matrix board, Uniboard or Veroboard if you wish. However, our construction description applies to the pc board we designed.

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



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

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



The printed circuit board pattern is on page 34.

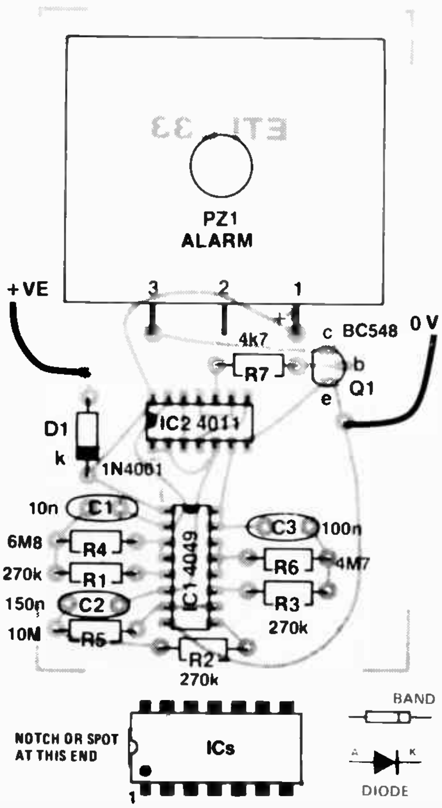
HOW IT WORKS — ETI 333

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

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

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

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



PARTS LIST — ETI 333

Resistors .... all ½W, 5%

R1,2,3	270k
R4	6M8
R5	10M
R6	4M7
R7	4k7

Capacitors

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

Semiconductors

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

Miscellaneous

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

Price estimate

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

$8 — $10

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

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

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

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

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

Testing

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

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

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

Installation

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

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

short circuits

Thermatic fan controller for a vehicle

Mike Collins

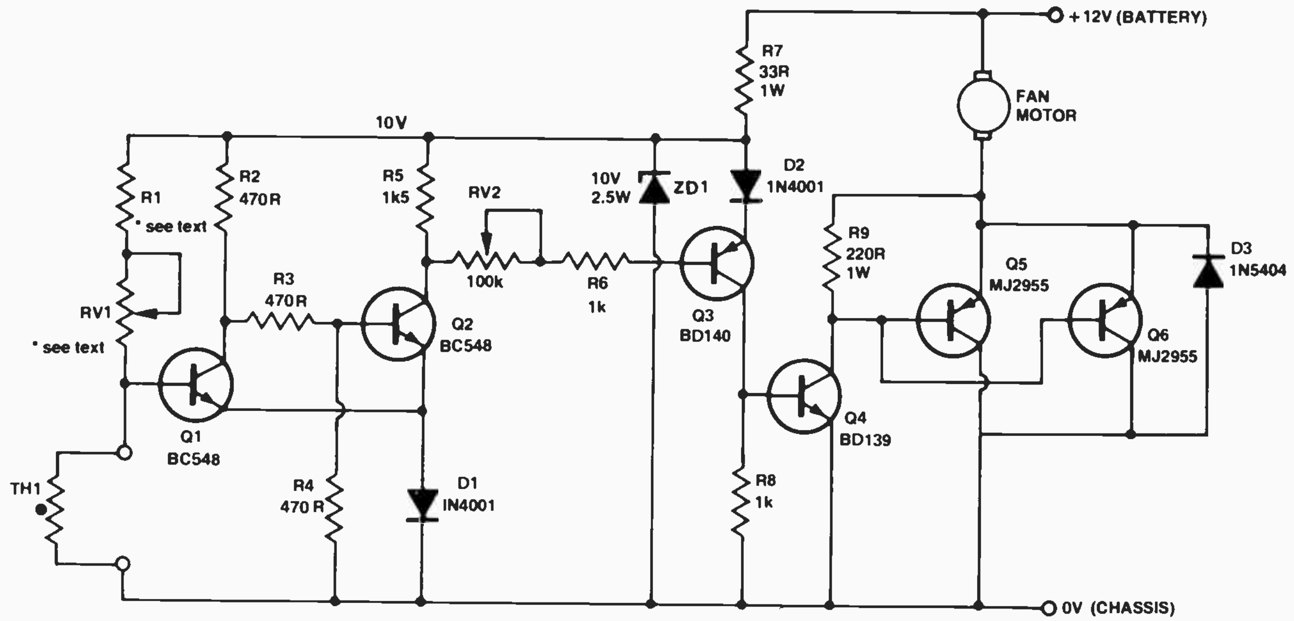
RECENTLY I decided to install a thermatic fan to my car but was dismayed to find that the price was around $80.

This discovery sent me off to the local wreckers where I was able to purchase a fan for $15. Unfortunately, the temperature control for this fan was unsuitable as it was fixed at the wrong temperature and was not adjustable.

I began putting together a few circuits to switch the fan on when the engine reached the desired temperature. Apart from turning the fan on at the right temperature, the circuit would have to turn it off once a predetermined lower temperature had been reached so that the engine would be maintained within its normal operating temperature range. A few circuits I tried had a tendency to 'hang on' past this lower temperature which was definitely an undesirable situation. I eventually solved this problem by using the circuit shown here.

Circuit operation

Engine temperature is sensed by a thermistor, TH1, mounted at a convenient point on the engine block. This



thermistor controls a Schmitt trigger (Q1 and Q2) which drives several power transistors (Q5 and Q6), connected in series with the fan motor, via two intermediate stages (Q3 and Q4).

So that the operating points of the Schmitt trigger remain stable despite supply voltage variations (as much as 30% in 12 V systems) the collector supply to Q1 and Q2 is stabilised at 10 V by zener diode ZD1. This also ensures supply line spikes do not cause spurious operation of the fan.

Potentiometer RV1 sets the switch-on temperature while RV2 sets the switch-off temperature.

When the engine is below the required temperature the voltage drop across TH1 should be above 1.2 V. Thus, Q1 will be on and Q2 will be off. As no collector current flows in Q2, Q3 and Q4 will be off and no base drive will be applied to Q5/Q6. Thus, the latter transistors do not conduct and the fan will be idle.

When the engine reaches the required temperature, the voltage drop across TH1 will fall below 1.2 V (preset using RV1) and Q1 will turn off. Q2 then turns on and base current will be supplied to Q3 via D1, Q2, RV2 and R6, turning Q3 on. This turns Q4 on which applies base drive to Q5 and Q6, turning them hard on, operating the fan.

Diode D3 prevents back-emf spikes from destroying the two MJ2955s when the unit turns them off.

There will be a certain amount of hysteresis in the operation of the Schmitt trigger. However, the collector current in Q2 will vary as Q1 will turn on gradually when the temperature drops below the preset switch-on temperature. Thus the base current to Q4 will vary. The point at which insufficient current is supplied to Q3 can be set by varying RV2.

Construction

The whole unit was constructed in a die-cast aluminium box which was bolted to the vehicle chassis inside the engine compartment. The MJ2955s were mounted directly on the case, no insulation is required as the collectors are connected to 0V in any case. General construction is non-critical. However, I used a pc board and supported it by soldering the common connection copper area to the backs of the pots which were mounted on the box.

The thermistor I used had a resistance of 34 ohms at 77°C (170°F). In general, R1 and RV1 are selected such that the voltage across the thermistor TH1 is 1.2 V when the engine is at its recommended operating temperature (or in the middle of its operating temperature range). Whatever thermistor you use, you will need to know its resistance at that temperature. Knowing this, you can calculate R1 and RV1 as follows:

$$R1 = 4 \times R_{TH1} \text{ (at operating temp.)}$$

$$RV1 = 6 \times R_{TH1} \text{ (at operating temp.)}$$

Having calculated these values, use the component nearest in value above that calculated. The correct setting of switch-on temperature should be within the range of RV1. Values used in my unit were, R1 = 150R, RV1 = 250R.

You will need an engine temperature meter of some sort to set the on and off points correctly.

All resistors should be of the rating specified. Those used around Q1 and Q2 (R1 to R5) may be ¼-watt types, but ½-watt or higher rated types may be more reliable. I did not find it necessary to use low value emitter resistors on the MJ2955s to assist current sharing (though it may be a good idea to match a pair for Vbe . . . Ed.). The current through the fan motor when connected directly across the battery was 8.6 amps. In this circuit it draws 7.7 amps but the loss did not noticeably affect the cooling.

Build a LED oil temperature meter for your vehicle

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

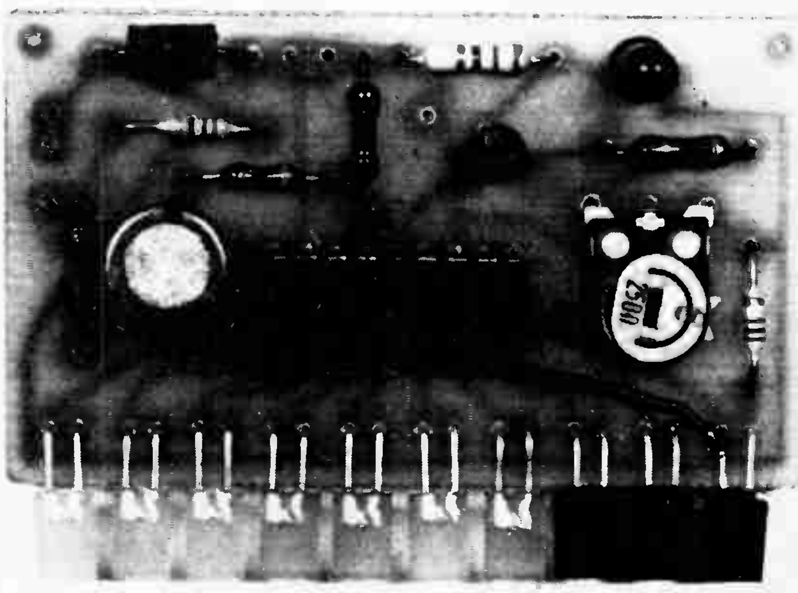
Phil Wait
Simon Campbell

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

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

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

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



How it's caused

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

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

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

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

Too hot

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

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

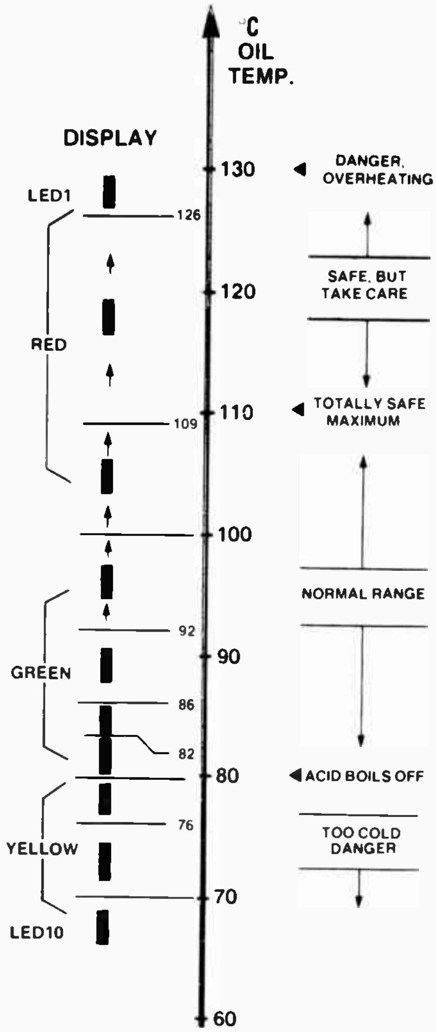
Few modern vehicles suffer from overheated engine oil (transmission fluid is something else again though!) A notable exception is some VWs (particularly Kombi versions) — few can be driven hard in an Australian summer without severe oil overheating and the risk of consequent severe engine damage.

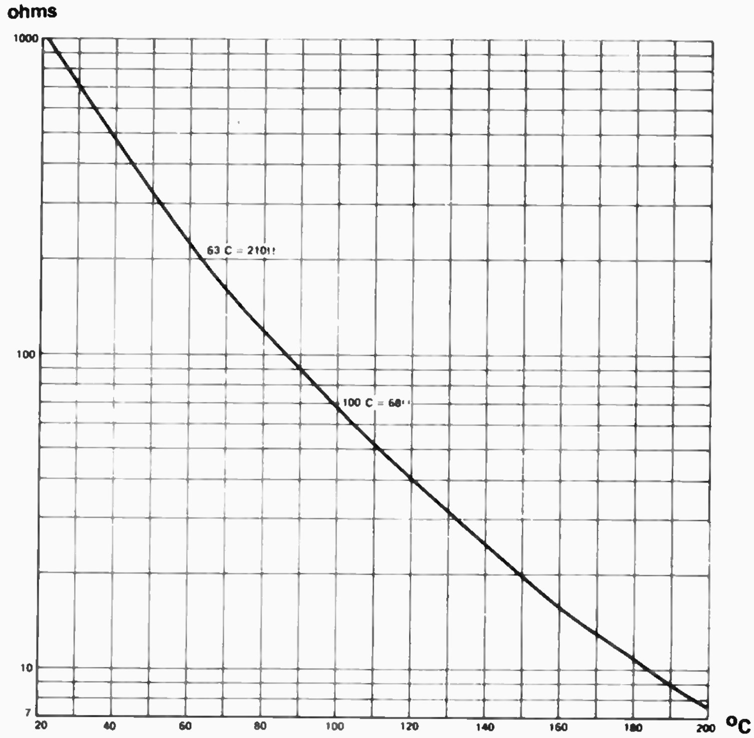
Overheating engine oil is simpler to cure than oil that's insufficiently warm. Simply add an oil-cooler; obtainable from most specialist parts suppliers.

A monitor

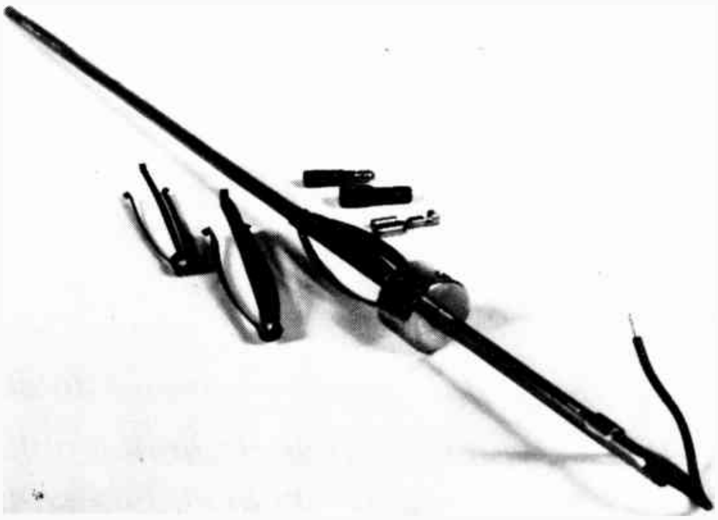
Most cars these days, with the exception of Volkswagens, are fitted with some sort of water temperature indicator. Often this is no more than a warning light which hopefully never comes on during the life of the vehicle, and if it ▶

Project 328





Calibration curve for the NTC thermistor in the dipstick probe.



The V.D.O. dipstick probe with its associated parts. Full assembly details are given on page 33.

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

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

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

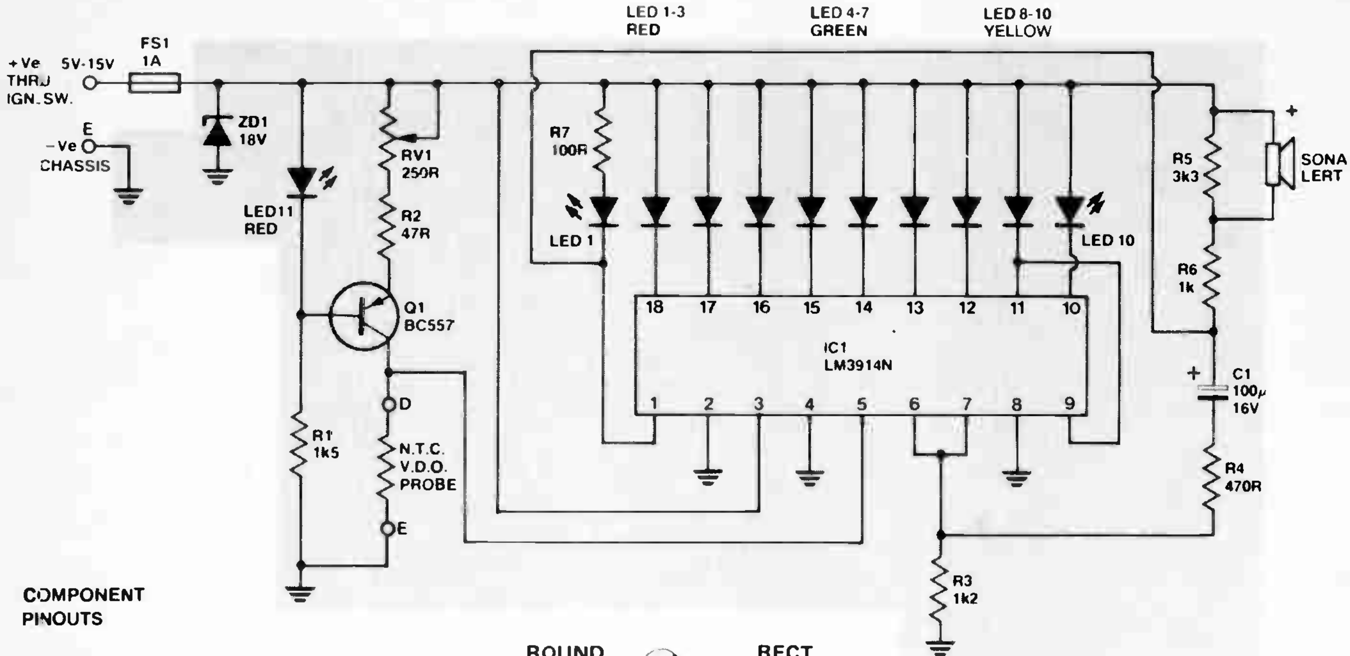
We have chosen the VDO dipstick probe for our project as it is easy to install without having to drain the sump, and the wiring to the probe is well protected in the engine compartment. The last thing you want is a heavy-fisted mechanic tampering with wires to the sump plug every time the coil is changed.

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

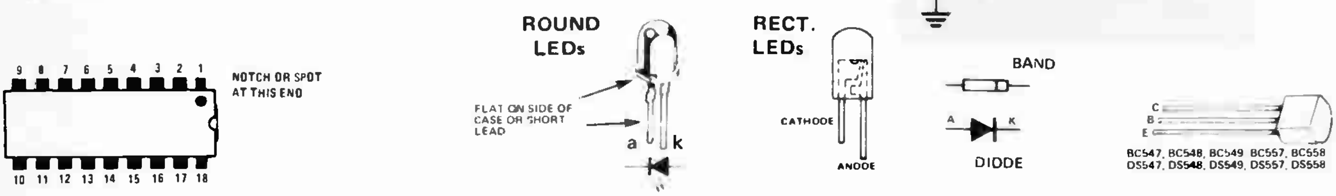
The temperature display employed in our project uses ten LEDs in a 'dot' mode (single LED lit at a time) bargraph display and is designed as a matching instrument to our LED Expanded Scale Voltmeter (ETI-326, September 1980). The display covers the range 70°C to 126°C with the first LED lit at temperatures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

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

oil temperature meter



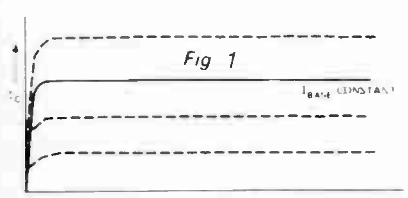
COMPONENT PINOUTS



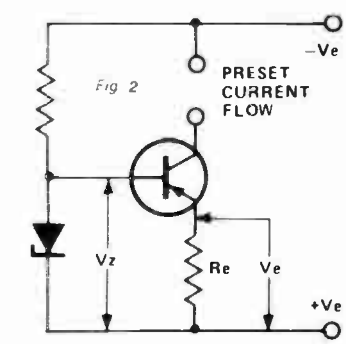
HOW IT WORKS — ETI 328

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

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



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



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

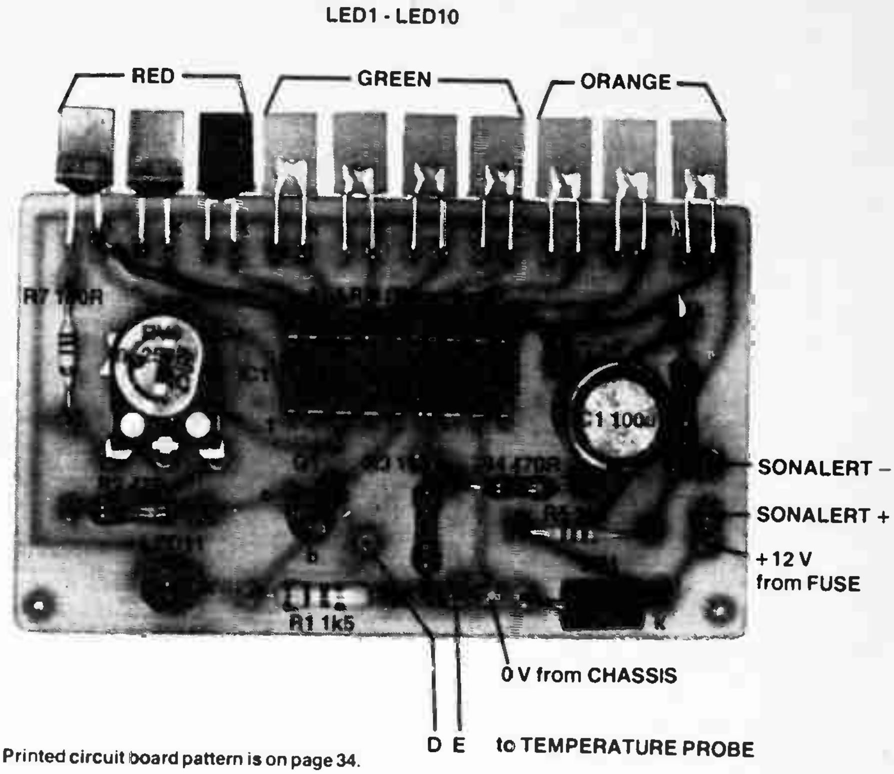
With this circuit, so long as there is about one volt between the emitter and collector, the collector current will remain constant at the chosen value until a load of too large a value robs the collector of its working voltage.

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

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

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

A complete description of the operation of the LM3914 is provided in the article on the Expanded Scale LED Voltmeter, ETI-326, on page 50.



Printed circuit board pattern is on page 34.

Construction

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

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

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

Calibration

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

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

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

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

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

PARTS LIST — ETI 328

Resistors .... all ½W, 5%

R1	1k5
R2	47R
R3	1k2
R4	470R
R5	3k3
R6	1k
R7	100R

Capacitor

C1	100u, 16 V electro.

Semiconductors

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

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

Miscellaneous

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

Price estimate

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

$18 - $22

(excluding the dipstick probe)

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

ASSEMBLING THE DIPSTICK PROBE

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

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

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

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

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

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

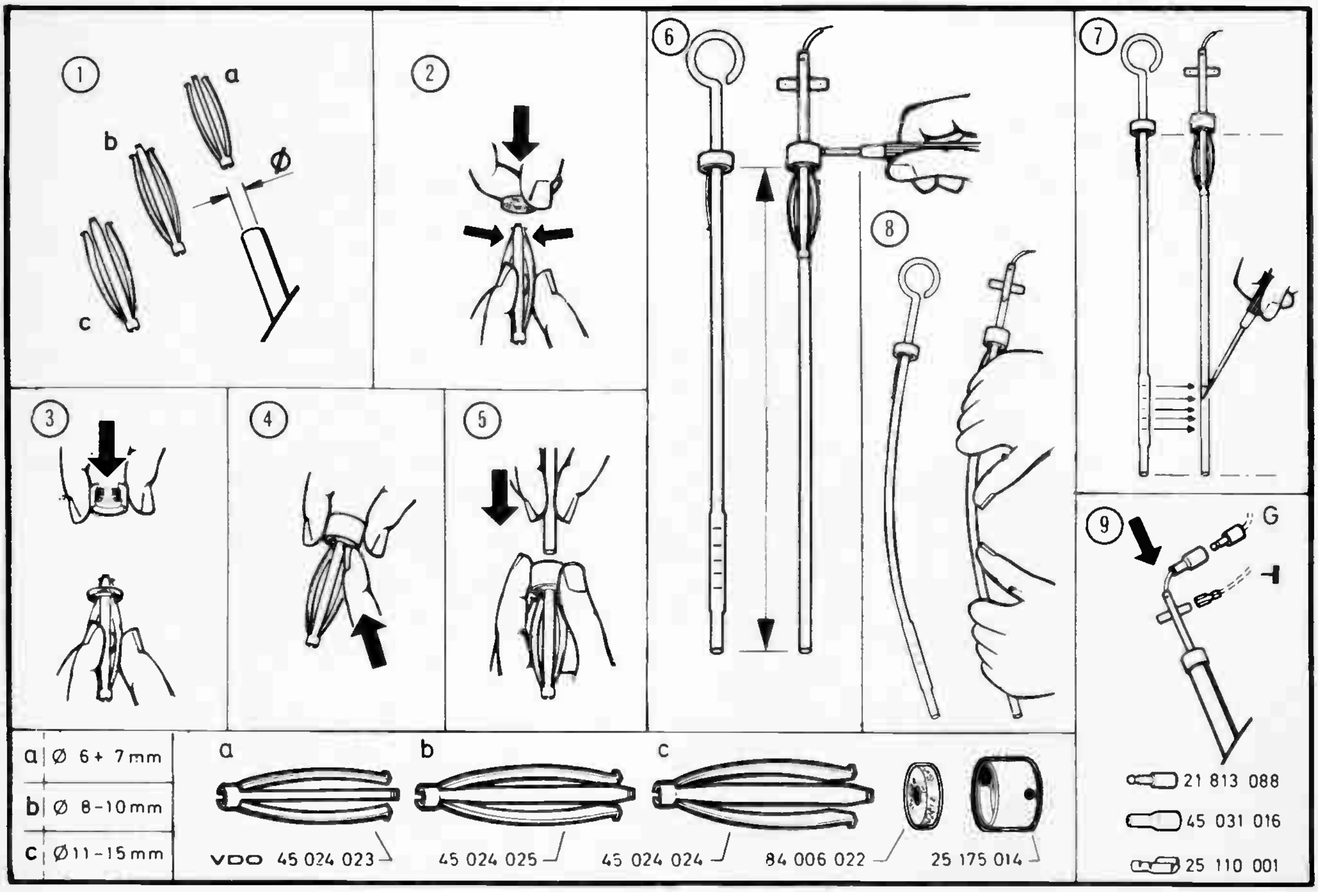
Panel 5
Slide the whole assembly over the probe. This may be a tight fit as the probe holds the ends of the spring fingers in place in the groove inside the collar so there is no danger of the springs falling out.

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

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

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

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

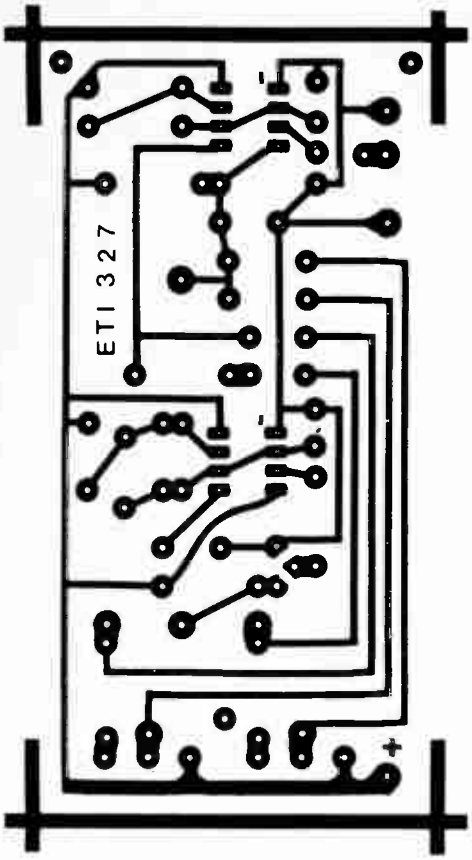


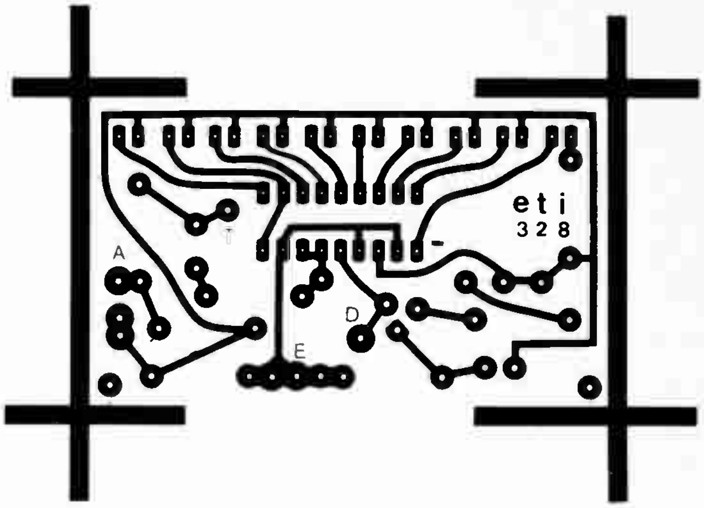
Installation

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

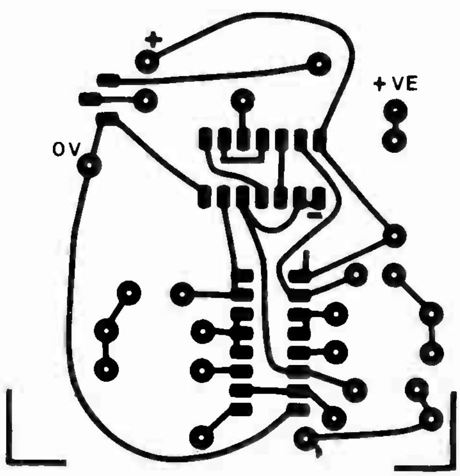
The wires from the dipstick probe should be passed through the firewall alongside existing wiring or the speedometer cable, and taped to a support to prevent them catching in the fan. The battery supply can be taken from any convenient point under the dash, such as the fuse box, but make sure the instrument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

PCB's





ETI 333

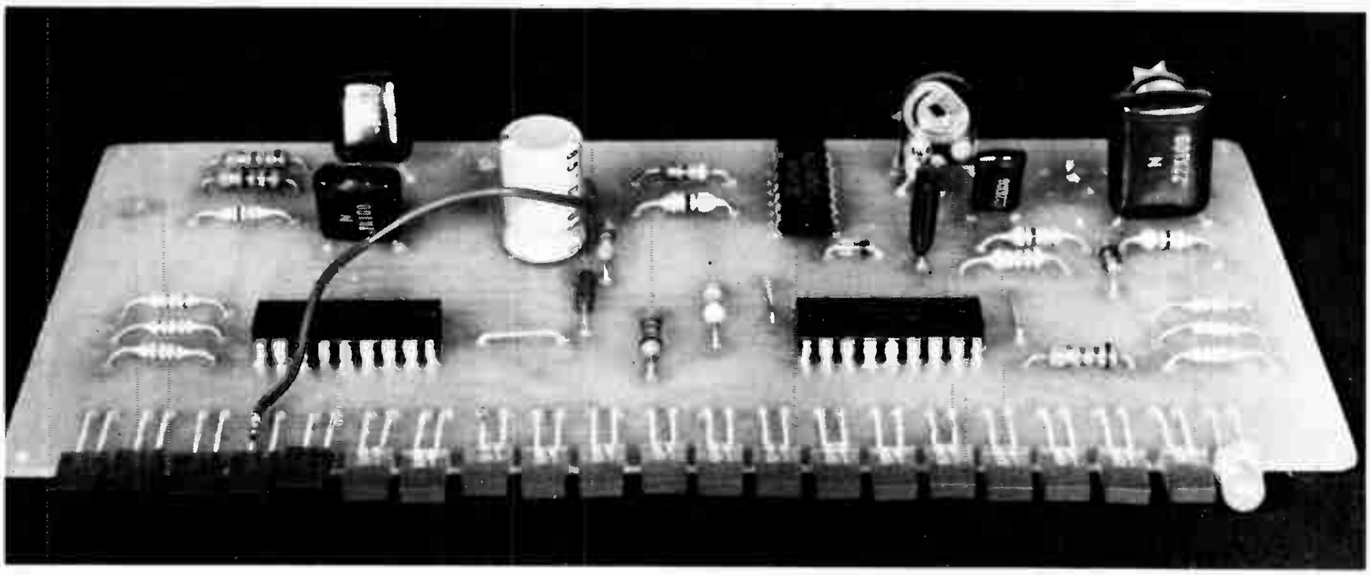


Project 324

Twin range tacho features LED bargraph display

Staff

Another in our series of projects to "update your car electronically", this tacho has many advantages over conventional types.



FEATURING a bargraph display of 20 rectangular LEDs arranged in a single line, plus one 'zero' LED, this tachometer incorporates an over-rev alarm feature and a high/low range switch. It displays engine speed in an analogue form (as with a conventional tacho) as an illuminated section of the row of LEDs, the length of the 'bar' being proportional to engine speed. This form of display indicates at a glance what your engine is doing, without the necessity of having to mentally interpret a numerical display as you would with a digital tacho — you don't have to take your eyes off the road, nor try to interpret rolling numerals during acceleration or deceleration.

This unit may be used with virtually any type of multi-cylinder petrol engine. The two speed ranges are calibrated by means of preset trimpots to give any full-scale speed range required. The lower range is of great value when setting or checking an engine's ignition and carburation for recommended tick-over speeds. The unit has been designed for use on 12 volt, positive or negative earthed electrical systems. It can be used with conventional (Kettering), capacitor-discharge (CDI) or transistor-assisted ignition systems — where a contact breaker system is used. Only three connections are required to install the unit — one to the positive supply, one to the negative supply and one to the contact breaker points. Protection circuitry has been included to prevent noise on the supply from causing problems and high voltage spikes from the points and coil circuit damaging the electronics.

Design

The tacho has been designed around a frequency-to-voltage converter IC, the LM2917, driving two LM3914 LED bargraph chips. The LM3914 is described more fully on page 53 of this book.

The LM3914s have an alarm facility which we have incorporated as a feature of the circuit. The triggering point for the alarm is arranged by taking a connection to an appropriate LED in the display. When the engine revs reach the point where this LED is turned on, the alarm will be triggered and the display will flash. An optional audible alarm can also be attached, the better to attract the driver's attention.

We chose a conventional (round) orange LED for the (zero) indicator in ▶

HOW IT WORKS ETI-324

The circuit consists of a pulse conditioning circuit, R4 - R6, C5 and ZD1, a frequency-to-voltage converter, IC1, and two LED bar display drivers, IC2 and IC3. Each display driver is capable of driving 10 LEDs, giving a total of 20, plus one 'zero' LED. The number of LEDs illuminated is proportional to the output voltage from the frequency-to-voltage converter.

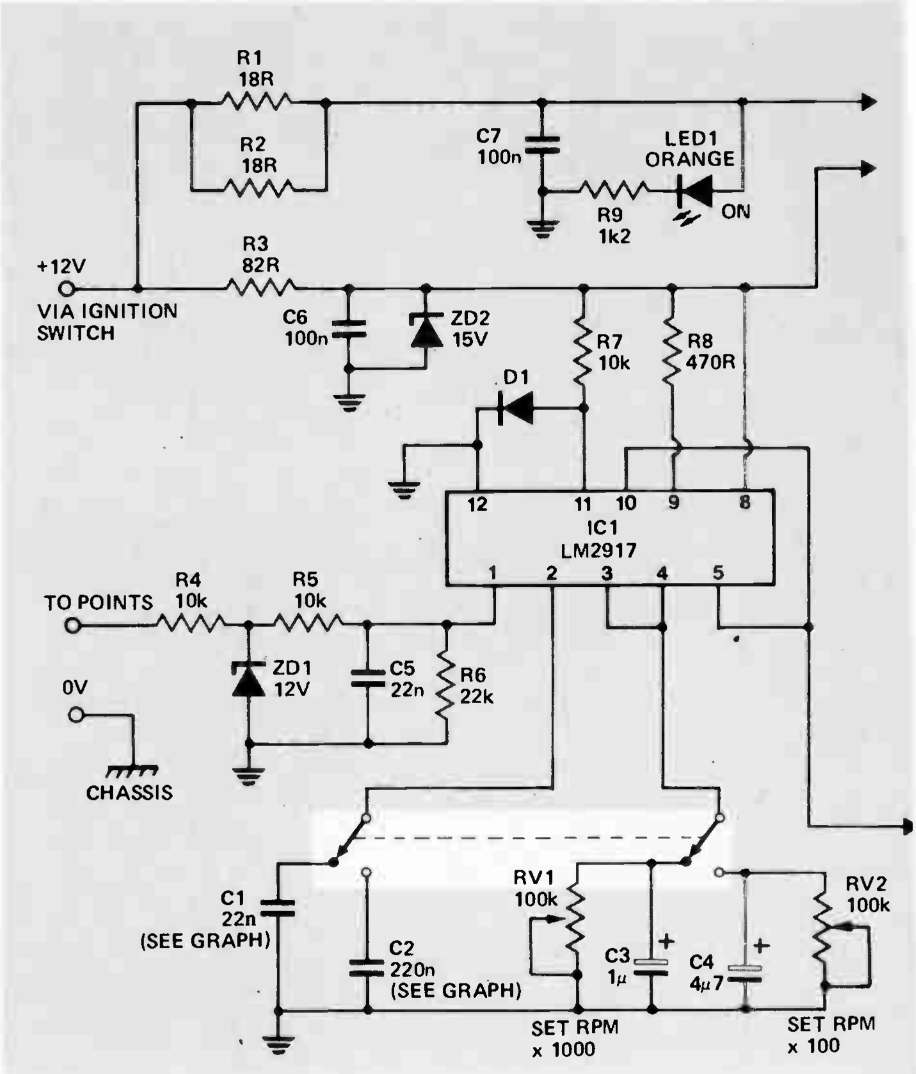
The ignition pulses from the contact breaker points in the vehicle have a repetition rate proportional to the RPM of the engine. The pulses from the points contain high voltage ringing components on the rising and falling edges of the waveform. These can be as high as 250 V at frequencies up to 10 kHz. These pulses would almost certainly damage the electronics so the input to IC1 is preceded by a pulse conditioning circuit. The 12 V zener diode, ZD1, shorts out any voltage spikes above 12 V while any remaining high frequency component is removed by R5 and C5.

The 'cleaned-up' rectangular waveform is fed to pin 1 of IC1. This is a voltage-to-frequency converter, providing an output voltage directly proportional to the frequency of the input waveform. The operating range of the IC is determined by the value of a capacitor connected to pin 2, either C1 or C2, and by a timing resistor and smoothing capacitor connected to pins 3 and 4. (RV1, C3 or RV2, C4). In our application, two preset ranges are provided by the range switch, SW1. The IC contains a constant current charging circuit for the timing capacitors (to ensure an output that is linear with frequency) and an internal voltage regulator. The network of R7 and D1 provides an input threshold level to guard against false triggering from noise.

The dc output of IC1 is fed to the inputs of the display drivers IC2 and IC3. These are LED 'bar' or 'dot' display drivers. Each IC can drive a chain of 10 LEDs and the number of LEDs illuminated is proportional to the output voltage from IC1. Put simply, the ICs act as LED voltmeters. The two ICs are 'cascaded' such that they perform as a single 20-LED voltmeter with a full-scale range of 2.4 volts. The resistors R13 to R18 are wired in series with the display LEDs to reduce the power dissipation in the two ICs. LED1 is permanently illuminated, providing a 'power on' indication and a 'zero' point for the display.

The LM3914 ICs incorporate an alarm facility. The triggering point for the alarm can be connected via a flying lead to any of the LEDs, selecting the trigger point. When the selected LED is turned on, the voltage on its cathode goes low, triggering the alarm. Capacitor C8 discharges, blanking the display. The LED is then turned off and the alarm resets. The capacitor is then re-charged, the display lights, and the alarm is triggered once again. The audible alarm will sound and display flash a few times a second. As soon as the RPM drops so the selected LED does not light, the function of the tacho returns to normal.

Supply line filtering of noise pulses is achieved by R1 - R3, C6 and C7. Reverse polarity and overvoltage protection is provided by ZD2.



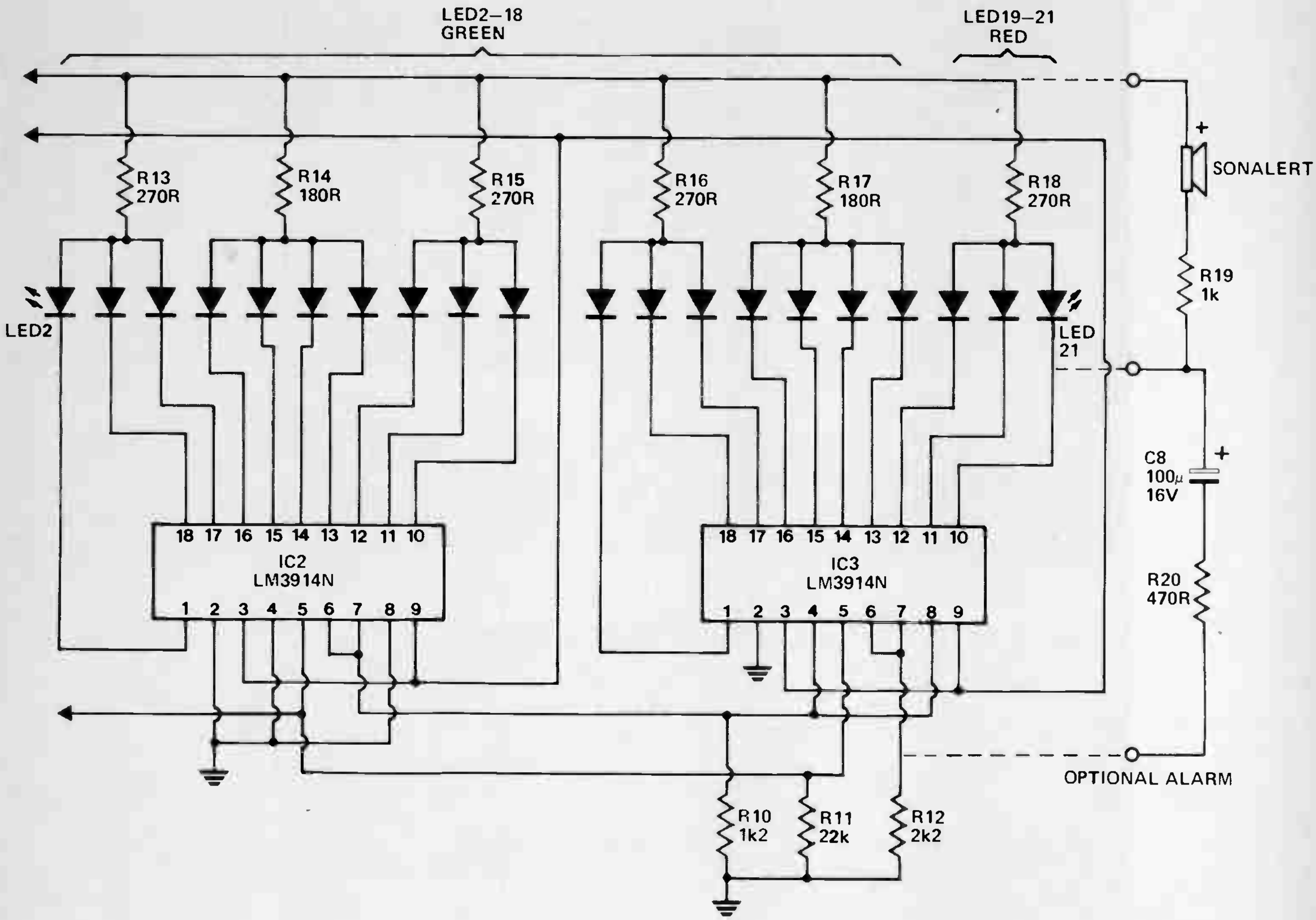
position one (it also indicates power on), rectangular green LEDs in positions 2 - 18 for the normal driving range, and rectangular red LEDs for the positions 19 - 21 giving a 'red line' area of 25% of full display. We thought this was the most convenient arrangement but you may vary it to suit your particular situation. All round LEDs may be used if you wish, but we found the rectangular LEDs provide a better looking display.

Construction

Our printed circuit board is pretty well essential for constructing this project. The LEDs for the bargraph display are all mounted in a row down the front of the board. As you can see from the accompanying photographs, all the components with the exception of the range switch and audible alarm are mounted on the pc board.

You will find construction easiest if you mount all the ICs, resistors and capacitors first, leaving the LEDs till last. Make sure you have the ICs correctly oriented, as well as the diodes and tantalum and electrolytic capacitors. Refer to the component diagrams and pc board overlay.

When mounting the LEDs it is *most important* that they be placed in the board the right way around. One of the best ways of ensuring this is to first place them on the table or workbench in a row in front of you, with their leads all correctly oriented, just as they would be when mounted on the board. To ensure the leads are the right way around, refer to the overlay and the accompanying



drawing showing LED orientation. Now comes the hard part — mounting the LEDs so that they're all level! Insert LED2 first and bend it such that it lies flat on the board with the base of the LED flush with the edge of the board — as shown in the pictures. Solder its leads. Bend it back upright and then insert LED3, carefully positioning it such that it is flush with LED2. Solder it in position. Proceed like this until all the LEDs are in place and then bend the whole row over, parallel to the board.

A flying lead is used to connect the alarm circuit to one of the LEDs. This determines when the display will flash and the audible alarm (if used) will sound. This lead should be left floating until the two speed ranges are set up. Attach flying leads for the switch connections, supply and points connection.

Mounting

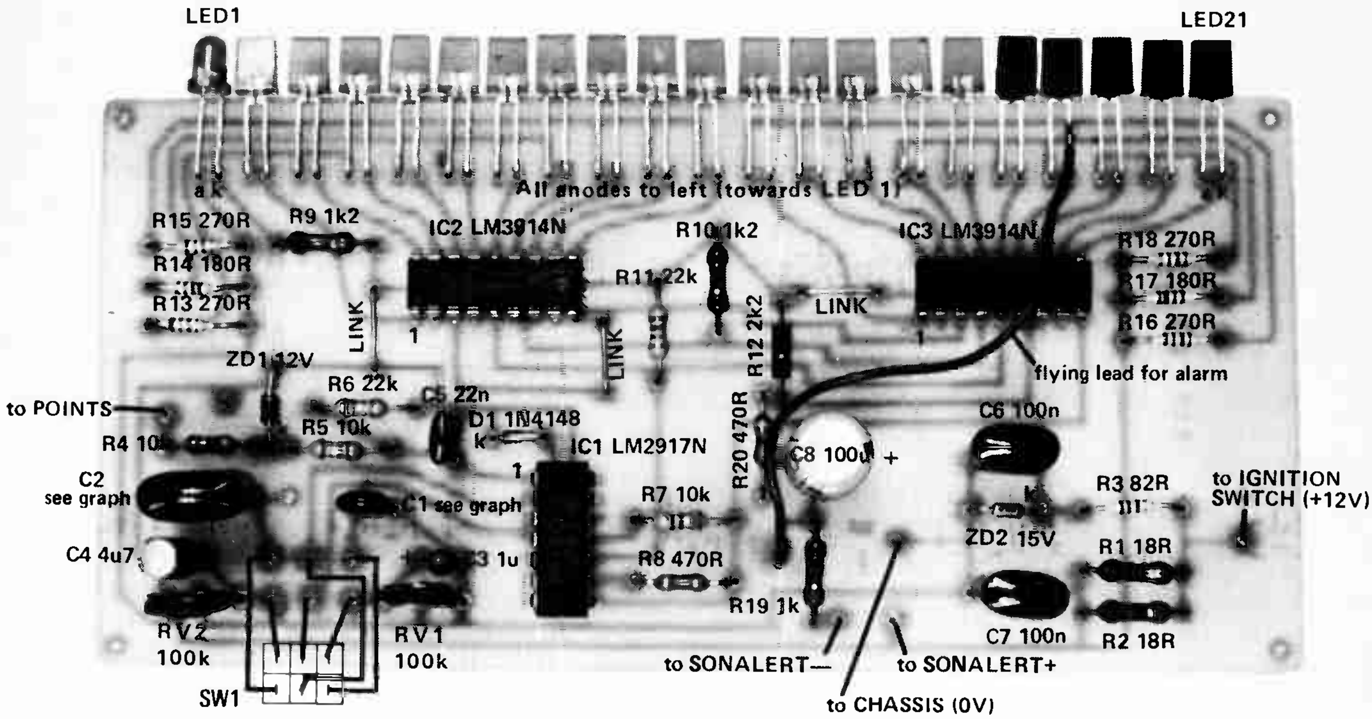
Having built the unit, you'll have to consider where it is to be mounted. In fact, it may be prudent to think about this as your very first step! The tacho can be mounted such that the display is either horizontal or vertical, depending on your preference and available space in the dashboard. It is best mounted not too far from the driver's line of view so that it can be seen without his eyes leaving the road for too long, and to the side of his normal vision.

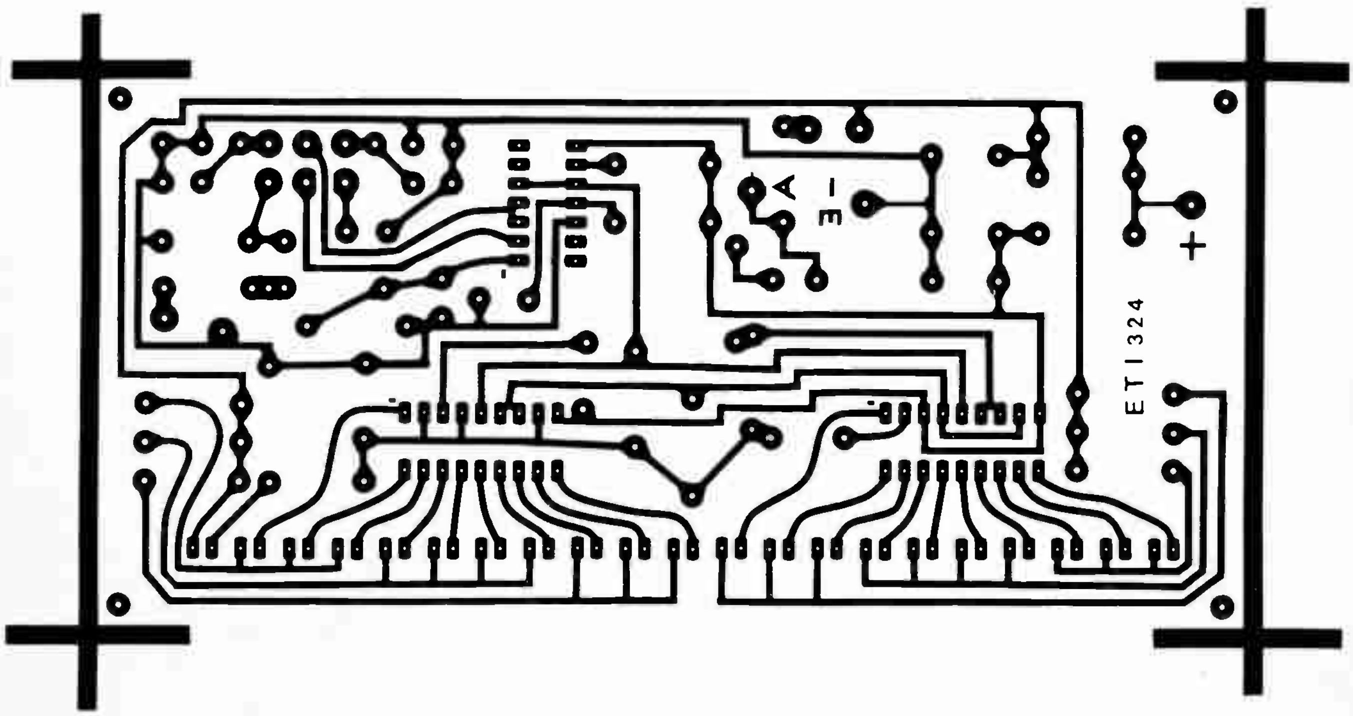
If you are brave enough, the unit can be mounted behind a slot cut in the vehicle's dash, as near to the speedometer as you can manage. Watch out that there's enough space to accommodate the unit behind the panel before you cut, though!

If that doesn't appeal to you, the unit may be housed in a slim plastic case which is then mounted in a convenient position on the dashboard.

The range switch and audible alarm may be mounted in any convenient position, no matter where or how you mount the tacho itself, as lead length to these components is not at all critical.

Only three connections are made to the vehicle's electrical system: battery +12 V, contact breaker points and chassis (0 V). The battery connection should be taken after the ignition switch so the unit is only on when the ignition is on. The wire to the points will have to be taken through the fire wall to ▶


LED1
LED21
a k
All anodes to left (towards LED 1)
R15 270R
R9 1k2
IC2 LM3914N
R10 1k2
IC3 LM3914N
R18 270R
R14 180R
R11 22k
R17 180R
R13 270R
LINK
R12 2k2
LINK
R16 270R
ZD1 12V
LINK
flying lead for alarm
R6 22k
C5 22n
to POINTS
D1 1N4148
R20 470R
C6 100n
R4 10k
R5 10k
IC1 LM2917N
C8 100u +
C2
see graph
C1 see graph
R7 10k
R3 82R
to IGNITION SWITCH (+12V)
C4 4u7
C3 1u
R8 470R
ZD2 15V
R1 18R
R19 1k
RV2 100k
RV1 100k
C7 100n
R2 18R
to SONALERT—
to SONALERT+
SW1
to CHASSIS (0V)


A
E
+
ETI 324

PARTS LIST — ETI-324

Resistors	all ¼W, 5%
R1, R2	18R
R3	82R
R4, R5, R7	10k
R6, R11	22k
R8, R20	470R
R9, R10	1k2
R12	2k2
R13,15,16,18	270R
R14, R17	180R
R19	1k
Potentiometers	
RV1, RV2	100k, miniature vert, mounting trimpots
Capacitors	
C1	22n greencap (see text)
C2	220n greencap (see text)
C3	1u, 16V electro. or tant.
C4	4u7, 16V electro
C5	22n greencap
C6, C7	100n greencap
C8	100u, 16V electro.
Semiconductors	
IC1	LM2917N
IC2, IC3	LM3914N
D1	1N914, 1N4148 or similar
ZD1	12 V, 400 mW zener
ZD2	15 V, 400 mW zener
LED1	Orange LED, round or rectangular
LEDs 2 - 18	Green LEDs, round or rectangular
LEDs 19 - 21	Red LEDs, round or rectangular

Miscellaneous
SW1 — DPDT miniature toggle switch, ETI-324 pc board, case (if required), Sonalert (if required).

the points terminal on the outside of the distributor. The easiest way, rather than drilling a hole in the firewall, is to run the wire next to a wiring loom or the speedo cable, through an existing hole. Make sure the wire is well insulated and there is no possibility of the insulation being rubbed off, causing the points to be shorted to the chassis. The chassis connection can be made to any convenient point on the car body under the dash.

Setting up

All that's left is to set the two RPM ranges by adjusting the two trimpots and to set the point when the alarm triggers.

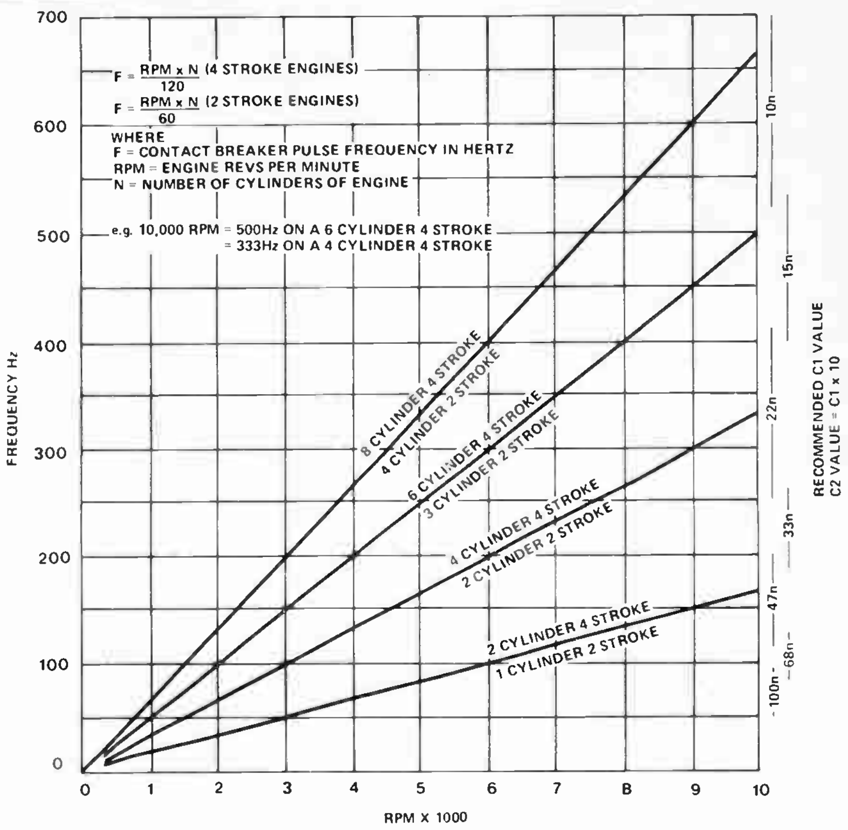
The easiest way to set the RPM ranges is to borrow a friend's tacho. All good dwell angle test meters have an RPM range so it shouldn't be too hard to find a suitable unit.

Run the engine at half the required maximum RPM range and set RV1 so that the *eleventh* LED just lights. Full scale will then be *twice* the engine speed. This technique avoids having to run the engine at full RPM with no load which can be very damaging to your engine as well as you ears!

The low speed range can be set by adjusting RV2 until the *21st* LED just lights at the desired engine RPM. As this is a low speed range there is no danger to the engine.

The alarm triggering point is set by soldering the flying lead directly onto a LED cathode lead. We set ours on the lead of the second red LED. This can be made to trigger at say 6000 RPM by adjusting RV1 for a full range of 7000 RPM. If you don't need the alarm, the flying lead can be left off or the optional components left off the board completely.

That's it — project completed, calibrated and ready to roll!



Setting C1 and C2

The values of the two timing capacitors, C1 and C2 are selected to give the desired full-scale RPM ranges.

The graph gives the value of C1 (right hand scale), for various RPM ranges (bottom scale). As the number of breaker point openings per revolution depends on the number of cylinders and whether it is a two-stroke or four-stroke engine, four lines are drawn on the graph for the eight common engine types.

Select the RPM range over which you want your tacho to operate (i.e: 10 000 RPM full scale) and draw a line upwards from the bottom scale until it intersects the line for your particular engine type. Then, draw a horizontal line across to the capacitor scale and read off the value of C1.

Since the low speed range is one-tenth the scale of the high range the value of C2 will be 10 times C1. i.e: if C1 is found to be 22n, C2 will be 220n.

If your engine is something out of the ordinary, like a five cylinder two stroke diesel (!! . . . Ed), you will have to draw your own line on the graph! This is what the left hand frequency scale and the formulae are for. The formulae give the frequency of the points openings for all engines. Work them out for two RPM values, at say 2000 and 8000 RPM, plot the points on the graph, and draw a straight line between them. You can now work out the values of C1 and C2 as before.

If you have some entirely different use for the tacho, for example: on a piece of rotating machinery, if you know the maximum frequency, or speed, in revolutions per second draw a straight line across the graph from the frequency scale to the capacitor scale and read off the value of C1.

SIMPLE TACHO

Car tachometer circuits are generally complex and expensive devices. But here's one that can be put together for only a few dollars!

UNTIL TEN OR SO YEARS AGO, car tacho's were cumbersome mechanical devices usually driven via a flexible cable from skew gearing attached to the shaft of the vehicle's dynamo – or sometimes via the distributor shaft.

The advent of transistor technology changed all this and since then almost all car tacho's are electronically operated.

The basic principle is much the same for all electronic tacho's. An electrical signal taken from the low tension side of the distributor is converted into a voltage proportionate to engine rpm and this voltage is displayed on a meter calibrated accordingly.

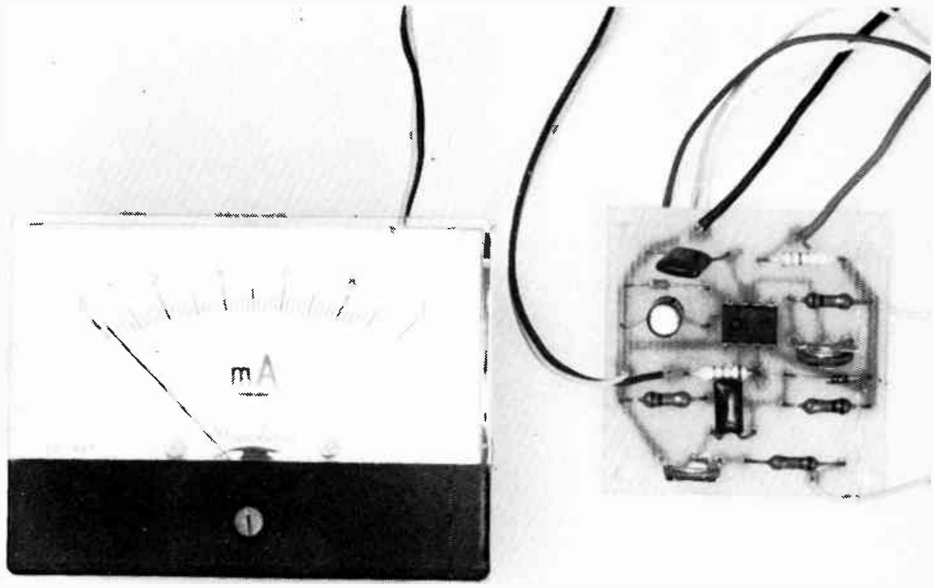
Most car tacho's are complex and expensive devices – but here's one with a difference! It is simple yet extremely effective. Its simplicity is due to our using one single integrated circuit rather than the more conventional multiplicity of individual transistors.

The unit will operate on both positive and negative earth vehicles and will also operate successfully and without modification with most types of electronic ignition systems as well as the more common electro-mechanical systems.

Construction

As there are so few components, construction is very simple and straightforward. Do make sure though that the 555 IC is soldered in the right way round – ditto the two diodes. Compare your work against our layout drawing as a final check.

Any type of meter that has one milliamp full scale deflection can be used. This is a very common type of instrument and you should be able to obtain



one new or secondhand with no difficulty. Ideally you should choose one that has 180° or 270° movement but these tend to be rather expensive. The meter size should be chosen to suit your proposed housing.

When the meter has been assembled connect it to the vehicle's battery and connect the input to the contact breaker side of the coil. The only satisfactory way to calibrate the unit is to persuade a friendly garage to connect up their own tacho at the same time and compare readings – or to check the unit on another car already fitted with a tacho. If you do it the latter way bear in mind that if yours is a four cylinder car then you must check using another four cylinder car, etc.

Another but slightly less satisfactory way of calibrating is to ascertain, from the vehicle's specification, the engine speed per thousand rpm in top gear and calibrate accordingly.

Potentiometer RV2 is used to adjust calibration -- the value specified provides a range of adjustment suitable for virtually all vehicles. The adjustment is, however, rather coarse. If the tacho is to be exclusively on one vehicle it is possible to reduce the value of RV2 to 25 k or lower. If this is done it will probably be necessary to increase the value of R4 accordingly.

Before making the final calibration adjust RV1 to eliminate any false triggering – check at all engine speeds. This unit may be used with either positive or negative earth vehicles – simply connect the battery leads as shown. Note however that this unit cannot be used with 6 volt systems – so for those owners of early model VWs and BMWs we're sorry but . . . .

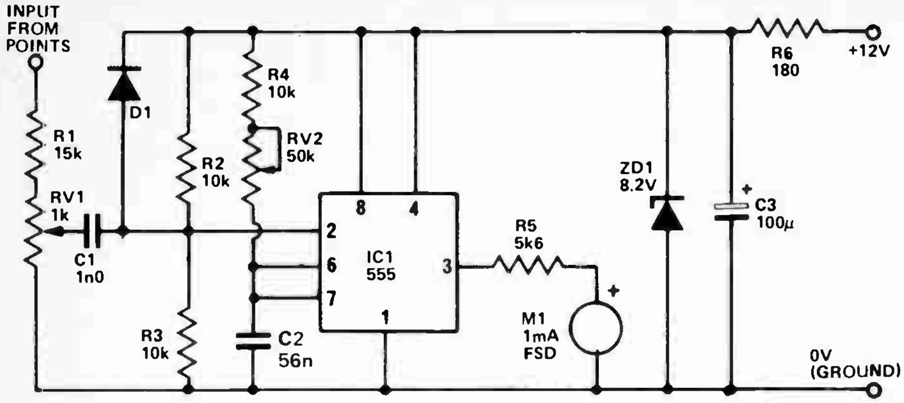


Fig. 1. Circuit diagram of the tacho.

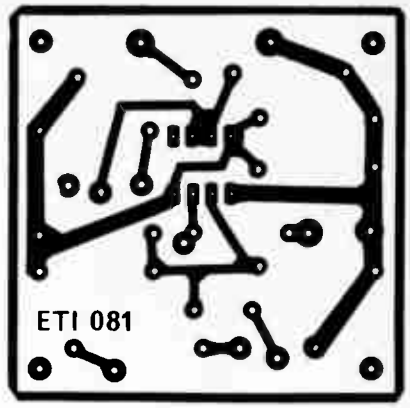


Fig. 2. Printed circuit layout. Full size 50 mm x 50 mm.

How It Works – ETI 081

The 555 timer IC is used as a monostable which, in effect, converts the signal pulse from the breaker points to a single positive pulse the width of which is determined by the value of R4 + RV2 and C2. The mathematical formula is T = 1.1 x R x C where R = R4 +RV2 (the section of RV2 in use) and C = 5.6 x 10^{-9} (Farads), and T = pulse length in seconds.

Resistors R2 and R3 set a voltage of about 4 volts at pin 7 of IC1. The IC is triggered if this voltage is reduced to less than approx 2.7 volts (1/3 of supply voltage) and this occurs due to the voltage swing when the breaker points open.

An adjustment potentiometer RV1 enables the input level to be set to avoid false triggering.

Zener diode ZD1 and the 180 ohm resistor stabilize the unit against voltage variations.

PARTS LIST ETI 081

R1	Resistor	15 k	½ W 5%
R2-R4	"	10 k	" "
R5	"	5k6	" "
R6	"	180 ohms	" "
RV1	Trim Potentiometer	1 k	
RV2	" "	50 k	
C1	Capacitor	1n0 polyester	
C2	"	56n polyester	
C3	"	100 μ 10 V electro	
D1	Diode	1N914	
ZD1	Zener	8.2 V 300 mW	
IC1	Timer	555	

PC Board ETI 081
Meter 1 mA FSD

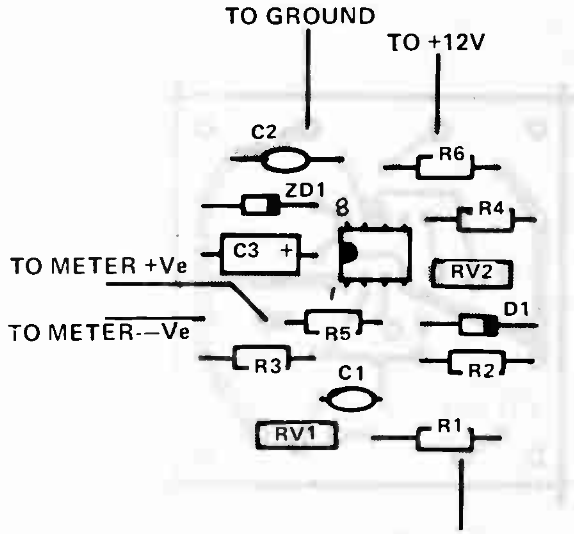
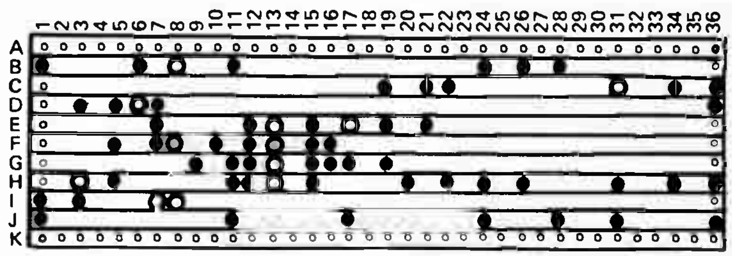


Fig. 3. Component overlay of the PCB version.

Fig. 4. The underside of the Veroboard showing the breaks in the tracks (circles) and the solder joints (dots).



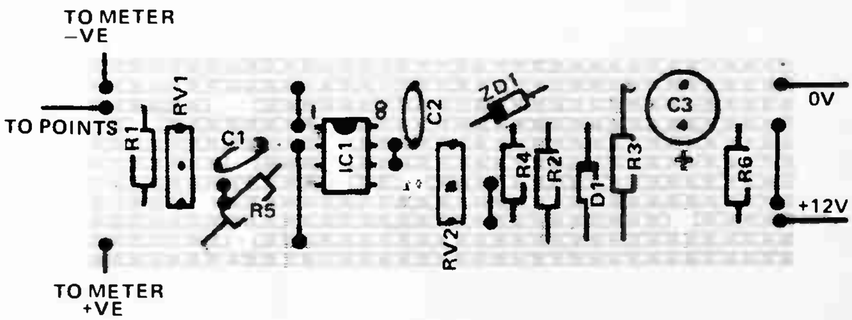


Fig. 5. Component overlay for the Veroboard version.

Project 320

BATTERY CONDITION INDICATOR

Ever been caught by a battery that went flat at an embarrassing moment — like when you've just offered a friend a lift? The conversation goes a little flat when you're both riding the bus to work, 20 minutes late. Jonathan Scott found a solution . . .

THE OLD, RELIABLE lead-acid battery may be way ahead of what ever is in second place for vehicle electrical systems, but they do need a 'weather eye' kept on them. Particularly if they're out of warranty. The same applies to 'reconditioned' batteries, so often found in secondhand vehicles of some age.

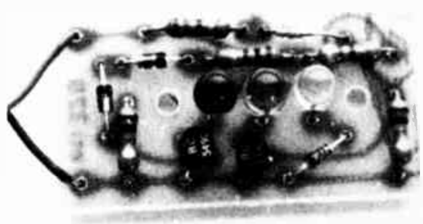
That's the problem with cars — running out of petrol and running out of battery produces the same heart-rending result. Immobility.

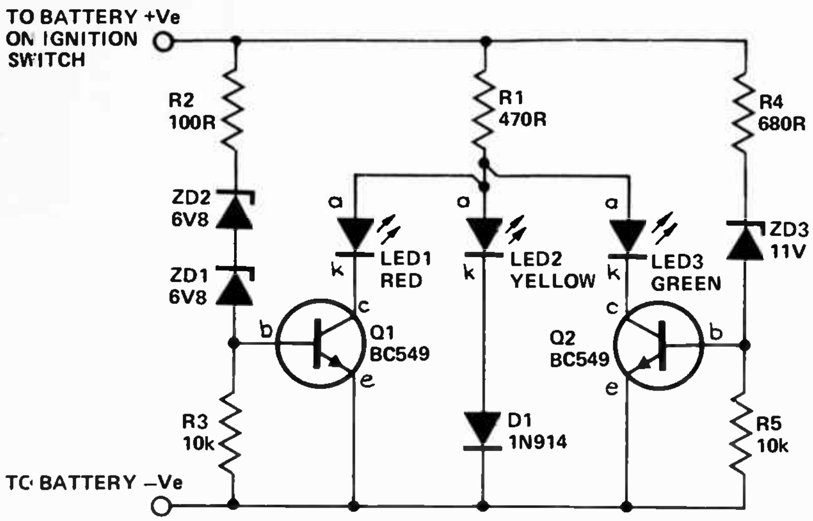
Most vehicles have a petrol gauge. Few have an equivalent for the battery. Many 'older' cars included a 'charging current' meter. This told you something about the car's generator-regulator and required some interpretation to figure out whether the battery was in good health.

Probably the best way to check on the state of your battery is to use a hydrometer. However, hydrometers have a number of drawbacks. Being made of glass, they're fragile and can't be used while a car is in motion. The small amount of battery acid that remains on them presents a storage problem — the drips and fumes attack most metals and materials. They're okay for the corner garage but justifying their cost,for the occasional use they get in home workshops, is not always possible.

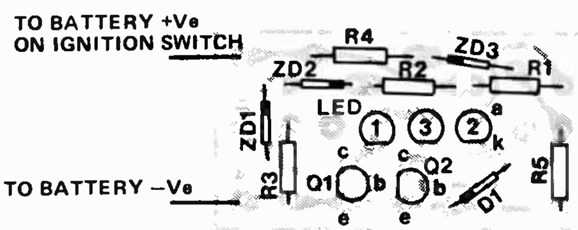
Another method of testing battery condition is by checking the voltage 'on load'. A lead-acid vehicle battery in a reasonable state of charge will have a terminal voltage under normal working load somewhere between 11.6 and 14.2 volts. When a battery shows a terminal voltage below 11.6 volts its capacity is markedly decreased and it will discharge fairly quickly. Like as not, it won't turn the starter motor for very long! On the other hand, if the voltage on load is above 14.5 volts then the battery is definitely fully charged! However, if it remains that way for any length of time while the car is on the road, the vehicle's alternator-regulator system is faulty and the battery may be damaged by overcharging.

Reading the battery voltage can be done in a number of ways. You could use a digital panel meter, set up as a voltmeter. Their drawback is that they cost nearly ten times as much as a hydrometer! The next best method is to use an 'expanded-scale voltmeter'. Reading the voltage range between 11 and 15 volts on a meter face calibrated 0-16 volts is a squint-and-peer exercise. On a 0-30 volts scale, as used on many modern multimeters, it's worse. A meter which reads between 11 volts at the low end of the scale and 16 volts at the high end is ideal. Hence, the term 'expanded-scale'.





The circuit diagram and component overlay (below). During construction, make sure all of the diodes and LEDs are the right way round.



However, you don't want to be peering at a meter on the dash board when you're driving through traffic. The range of voltage over which your battery is healthy is some two volts. An indicator which simply requires the occasional glance, and needs no 'interpretation', is what is really needed.

With this project, that's exactly what we've done.

Go, caution, stop

We have devised a simple circuit that indicates as follows:

Yellow:	battery 'low'
Green:	battery okay
Red:	battery overcharging

When the battery voltage is below 11.6 volts, a yellow indicator lights. This indicates the battery is most likely undercharged or a heavy load (such as high power driving lights) is drawing excess current. When it is between 11.7 and about 14.2 volts the green indicator lights, letting you know all is sweet. If the red indicator lights, as it will if the voltage rises above 14.2 volts, maybe the vehicle's voltage regulator needs adjusting or there is some other problem.

The circuit

The circuit is ingeniously simple, having barely a handful of parts. Reliability should be excellent.

We actually started out with a somewhat complex circuit. It used only two indicators and required you to 'interpret' what was happening. In trying to convert that to a yellow-green-red style of indication it sort of grew like topsy. This circuit had four transistors, a dozen resistors etc and didn't look at all attractive as a simple project that the average hobbyist or even handyman could build one Saturday afternoon and get going immediately. A rival circuit was devised by another staff member using a common IC. This sparked a controversy as to which was the better! Certainly, both did the job required . . . but maybe there was a simpler method.

It was discovered that different coloured light emitting diodes (LEDs), which we had decided to use for the indicators in the project, had different voltage drops when run at the same current. Seizing on this idea, the original circuit (four transistors, a dozen resistors . . .) was modified to exploit this characteristic and the simple circuit you see here was the result.

Construction

Construction is straightforward. If you haven't soldered electronic components

HOW IT WORKS – ETI 320

This circuit depends for its operation upon the different voltage drops across different colour LEDs.

At 20 mA the voltage drops across red, yellow and green LEDs are typically 1.7, 3.0 and 2.3 volts respectively. When the vehicle battery voltage is too low to cause either ZD1/ZD2 or ZD3 to conduct, Q1 and Q2 are held off by R3 and R5. Under these conditions the yellow LED is forward biased and conducts via D1 producing a potential of about 3.7 volts at point A (see circuit diagram). When the supply rises above about 11.6 volts ZD3 conducts, biasing Q2 on. By virtue of its lower voltage requirements the green LED conducts, reducing the voltage at point A to approximately 2.6 volts. This is not enough to bias D1/LED3 on, so the yellow LED goes off. The green LED 'steals' the bias from the yellow LED. When the supply rises above about 14.2 volts, Q1 is biased on and the red LED 'steals' the bias from the green. The potential at point A falls to two volts and only the red LED conducts.

R1 limits the current through the LEDs. R2 and R4 limit the base currents into Q1 and Q2.

PARTS LIST – ETI 320

Resistors all ¼W, 5%

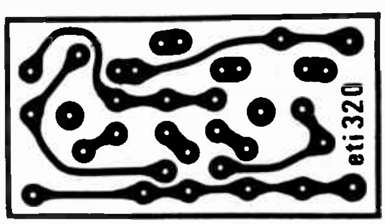
R1	470R
R2	100R
R3, R5	10k
R4	680R

Semiconductors

D1	1N914
ZD1, ZD2 . .	6V8 400 mW zener
ZD3.	11V 400 mW zener
Q1, Q2	BC547,8,9 or BC107, 8, 9 or common silicon NPN type

Miscellaneous

pcb ETI 320
Aluminium angle bracket for under-dash mounting.



The printed circuit board pattern

before – and this project was designed for the motorist/handyman as well as electronics enthusiasts – then we suggest you practice on something before tackling this project. Soldering is one of those things like swimming or riding a bicycle, or sex – it's okay once you've done it once or twice but you don't practice out on the street!

We recommend you use the printed circuit board designed for this project. The actual layout of the components themselves is not critical but a printed circuit board reduces the possibility of errors.

It is best to mount and solder the resistors first. Follow this by soldering in the diodes D1 and the zener diodes ZD1, ZD2 and ZD3. Carefully follow the accompanying component overlay making sure the diodes are all inserted the correct way around. Next, mount the transistors, again referring to the overlay, checking to see they are inserted correctly before soldering.

Finally, mount the light emitting diodes. These too may only be inserted one way. Check with the component overlay and connection diagrams. Make sure they are in the correct sequence. On the component overlay, LED 1 is the red LED, located at the left. The yellow LED is on the right, marked with a '2'. The green LED, marked '3' is between them.

The circuit could be tested at this stage if you have a variable power supply, or access to one. Simply vary the voltage across the range between 11 and 16 volts and note whether the LEDs light up in the correct sequence and close to the voltages indicated.

Mounting

As vehicles vary so much in dash panel layout, we can only make general suggestions.

Clearly, the indicator should be mounted such that the three LEDs are not in direct sunlight. A low part of the dash, but make sure it's readily visible from your normal driving position, will pretty well ensure the display may be easily read during the daytime. Alternatively, if you have an 'overhung' dash, or a portion which overhangs (usually where the instruments are mounted anyway), then a suitable position will generally suggest itself.

Exact mechanical details will have to be determined according to your particular situation. Two holes are provided in the pc board for mounting bolts. Alternatively, the whole assembly may be mounted from the LEDs. Three LED holders inserted through part of the dash panel, or an escutcheon plate mounted on the dash, will hold the LEDs quite securely. Providing the leads on the LEDs are fairly short, the pc board will place little strain on them and the assembly should be mechanically secure.

Connection

The indicator may be installed in vehicles having positive or negative earth electrical systems.

The component overlay shows the connection for a negative earth vehicle. The 'battery +ve' lead goes to the ignition switch – the indicator only operates when the vehicle is being used – the battery negative lead should be taken to a good 'earth' point on the vehicle frame.

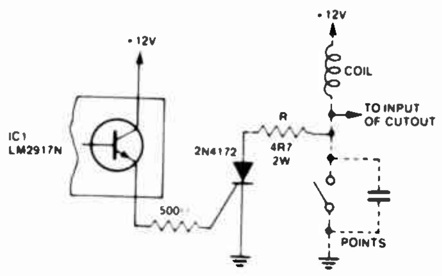
For a positive earth vehicle, the lead marked 'battery –ve' goes to the ignition switch connection, while the 'battery +ve' lead goes to the vehicle frame.

Ideas for Experimenters

Over-rev safety cutout

When the ETI-322 Over-rev Alarm project (page 22) was first published, it was pointed out that for road use, the alarm should never be used to cut the ignition. However, **N. Pollock of Sandringham, Vic**, points out that many high-performance engines used in racing cars and boats have a very small speed margin between maximum power and physical destruction! For such engines, used in competition, it may be desired to have an over-rev ignition cutout to prevent the otherwise very expensive consequences of a missed gear change or a broken propellor shaft.

An ignition cutout cannot simply turn off the low tension supply to the ignition system, since this would deprive the cutout of its engine speed information. This problem is easily overcome for a capacitor discharge ignition system, but



requires somewhat more work for a conventional system. The following suggestions should assist those wishing to convert the ETI-322 project to a cutout.

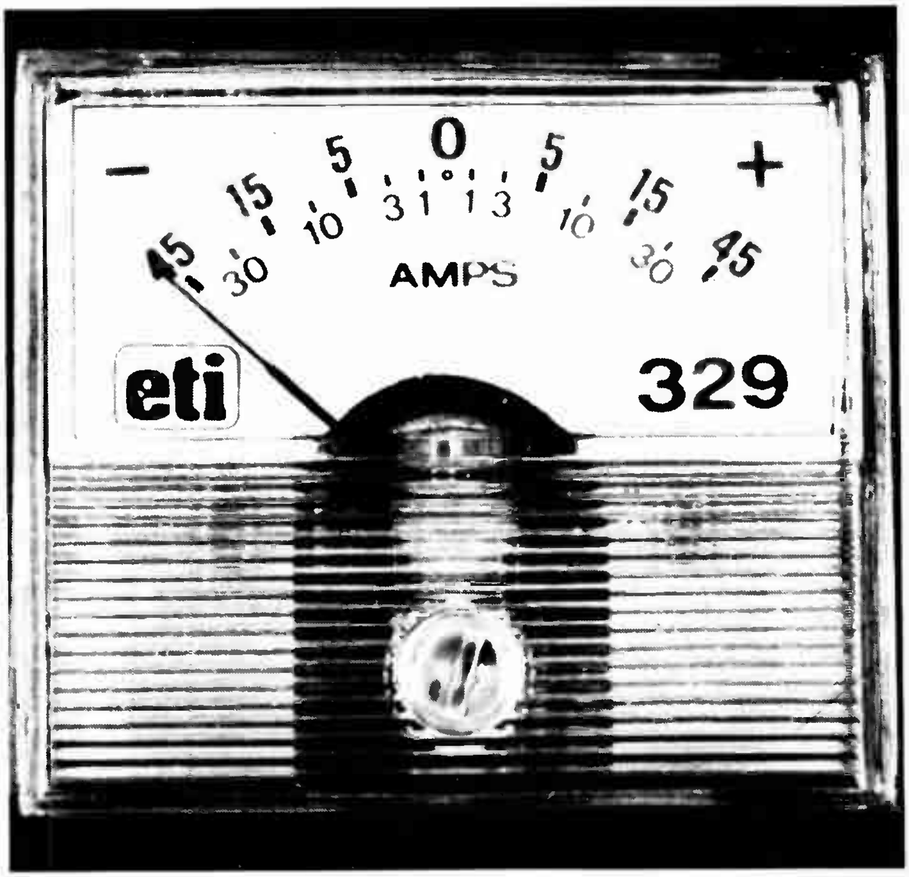
For a CDI system (referring to the original article) Q1 can be used to pull the gate of the CDI's SCR to ground, but a germanium transistor (i.e: AC127) should be used so that its c-e voltage hard-on is lower than 0.6 V, else the SCR may still trigger. Alternatively, Q1 could drive a relay, the contacts of which short the SCR gate to ground in the CDI. Mount the relay close to the SCR. It is suggested that R7 be reduced to 1k.

For a conventional ignition system, the circuitry shown here should do the trick. The output stage of IC1 in the ETI-322 alarm is taken via a 500 ohm resistor to the gate of a 2N4172 SCR, shunting the points. The resistor R (4R7, 2 W) effectively shunts the points when the engine exceeds the rev limits, and its value must be low enough to prevent spark production, but high enough to leave sufficient signal for the input comparator on the LM2917 in the ETI-322 alarm. It should be noted that a cutout of this type will have some small delay in operation when the engine speed is increasing rapidly. To reduce this delay it is suggested that C4 be removed and C3 reduced in value.

Expanded scale vehicle ammeter

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

Jonathan Scott



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

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

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

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

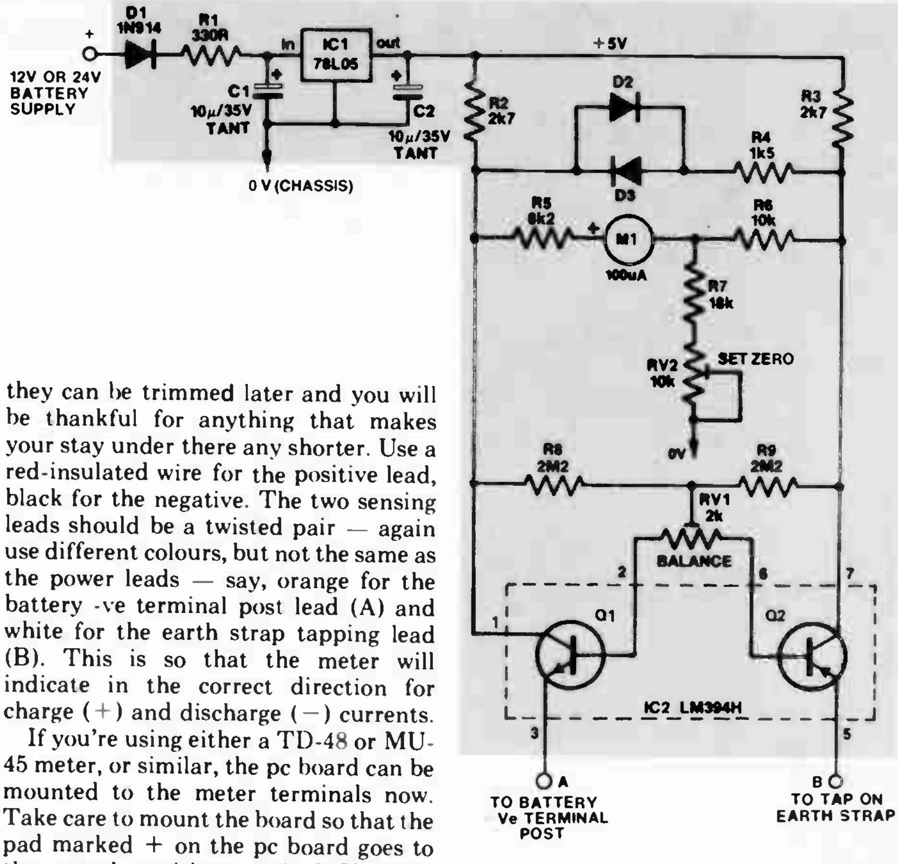
Meters and scales

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

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

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

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



Construction

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

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

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

Setting up

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

HOW IT WORKS - ETI 329

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

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

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

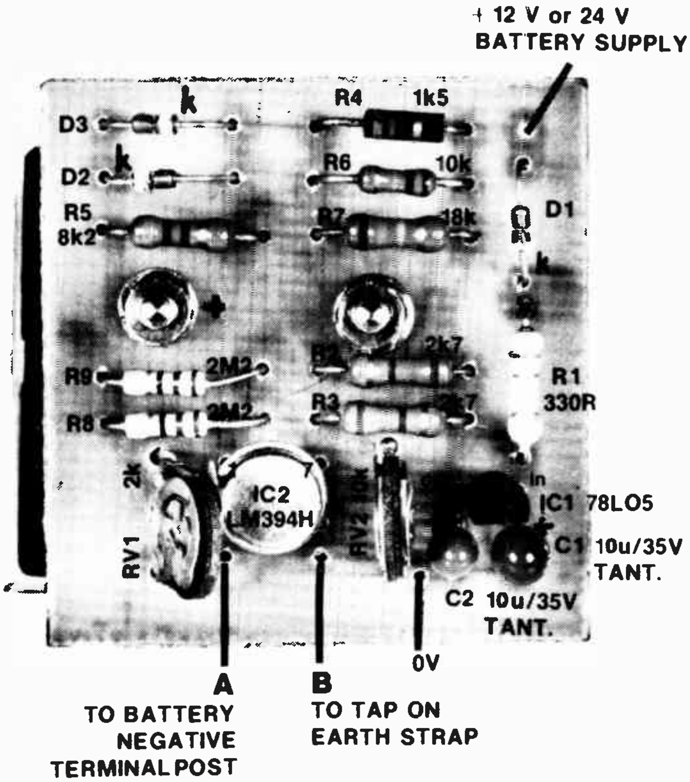
The meter is connected between the collectors of Q1 and Q2 from IC2. The centre-zero function (regardless of which type meter you use) is obtained by shunting some current to the common (0 V) rail via R7 and RV2. The latter provides a zero-point adjustment. Scale-linearity is achieved by the addition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

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

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

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

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



Component overlay for the pc board (pc board pattern is on page 74). Trimpot RV1 is for BALANCE while RV2 is for ZERO SET. The latter, along with R7, is left out if you use a centre-zero meter.

PARTS LIST - ETI 329

Resistors .... all ½W, 5%

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

Capacitors

C1,C2	10u/35 V tantalum

Semiconductors

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

Miscellaneous

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

Price estimate

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

$15 - $17

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

the unit connected in the vehicle, but not mounted.

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

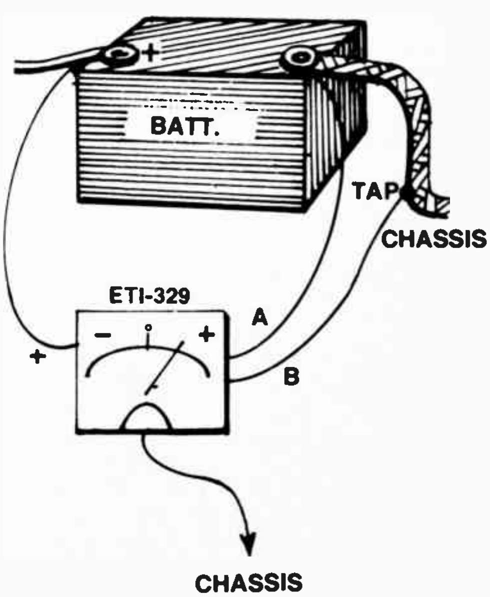
With a multimeter, measure the voltage on the collector of each transistor in the differential pair IC (pins 1 and 7). Adjust RV1 so that these voltages are equal. If you do not have a multimeter, remove R7 and short out R5 and R6. Then adjust RV1 for zero meter reading (i.e: centre scale). This last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

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

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

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

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



Calibration

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

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

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

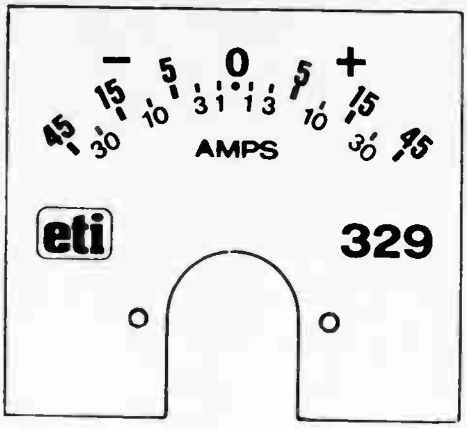
Once the unit is calibrated, permanently connect sensor lead B to the position determined. The length of strap between this point and the battery negative terminal has a resistance of around 1½ milliohms!

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

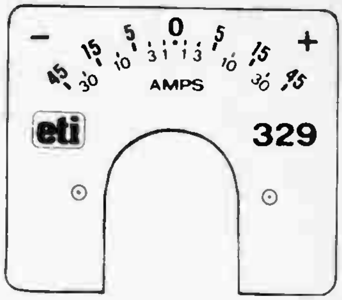
Finished? — that's it!

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

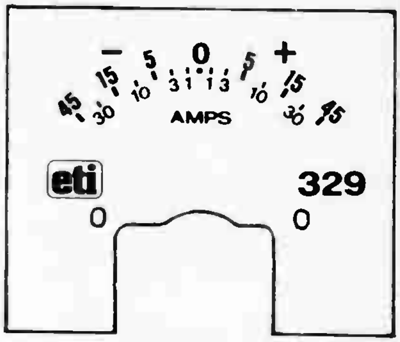
Illumination of the meter scale is useful, although we haven't included details. This will depend on the individual situation and the particular meter used. A hole may be drilled in the rear of the meter case and through the scale panel so that a small 'pea' or bayonet type globe can be fitted. (Be careful!)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



Scale for the University TD-66



Scale for the University TD-48



Scale for the Minipa MU-45

METERS, SCALES AND SHUNTS

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

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

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

LM394

general description

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

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

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

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

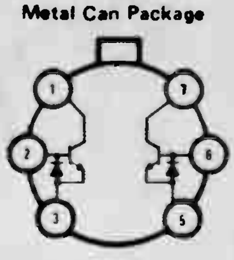
The LM194 and LM394/LM394B are available in an isolated header 6-lead TO-5 metal can package. The LM194 is identical to the LM394 except for tighter electrical specifications and wider temperature range.

features

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

connection diagram

Metal Can Package



TOP VIEW

Ideas for Experimenters

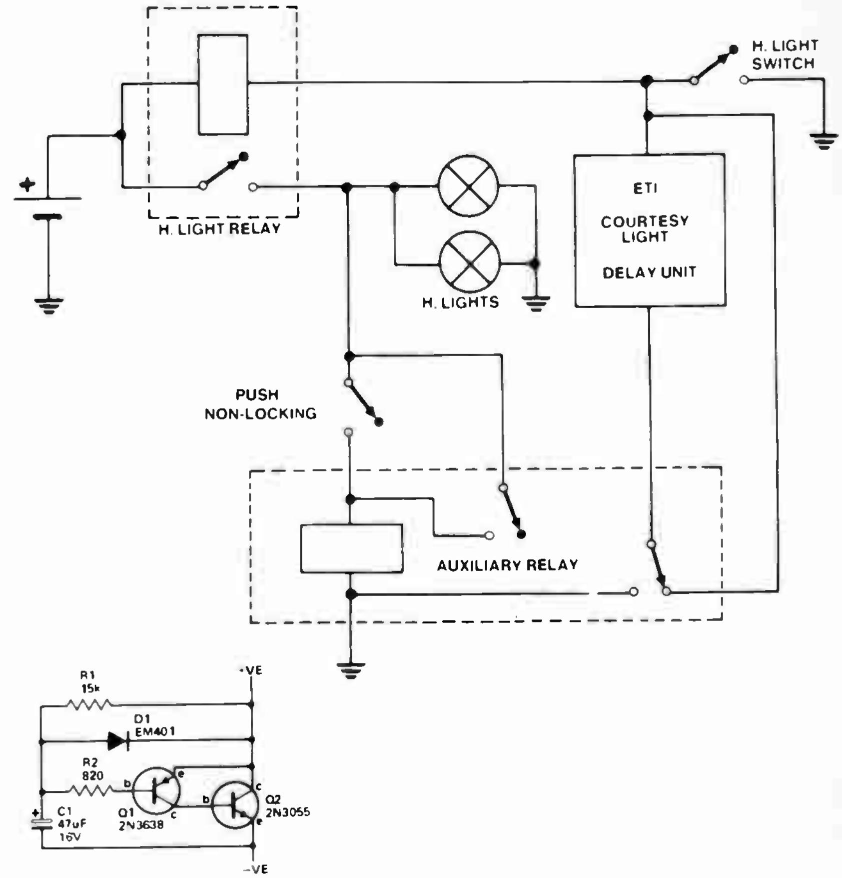
Headlight delay

Ever driven home late at night and had to risk life and limb walking in the dark from the car to the house? Well, the problem is easily and cheaply solved by adding this circuit to your car, says **Stephen Mann of Forrestfield, W.A.**

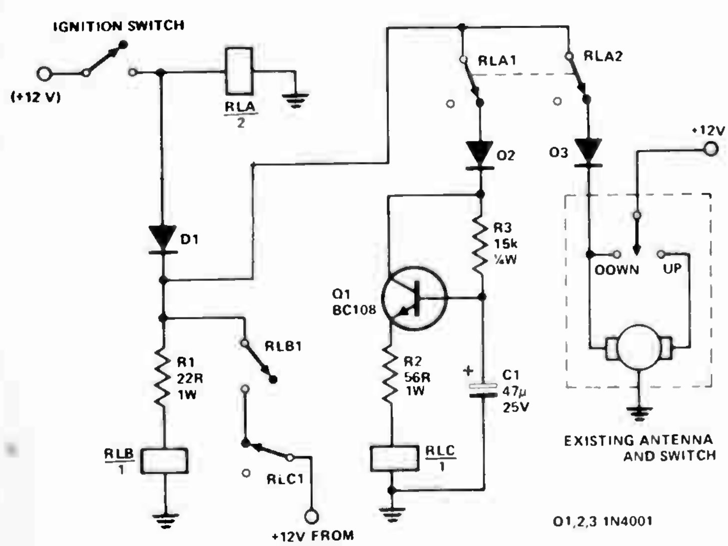
The system is built around the ETI-232 courtesy light delay unit (see page 8 of this book).

Coupling this to the headlight relay as shown provides a particularly good turn-off delay for the headlights. Operation is simple. Whilst the headlights are still on, operate the pushswitch. The headlight switch may now be turned off and the delay unit and auxiliary relay will keep the headlights on. The length of time the headlights remain on is dependent on the value of C1 and the headlight relay dropout voltage.

The unit was installed on a Toyota Corolla and a value for C1 of about 300 uF gives a delay of about 60 seconds. The auxiliary relay is simply a 12 V type with double changeover contacts.



Automatic antenna retract



This circuit was designed to automatically retract a motorised car antenna every time the ignition is turned off. With ignition on, relays A and B are energised (total current drain about 100 mA). When the ignition is turned off, relay A is turned off and 12 V from the battery drives the antenna down and charges C1 via R3. After about a three-second delay, relay C is energised and interrupts power to relay B, removing supply voltage from the circuit. This circuit suits the two-wire control motorised antennas commonly available, and comes from **Ian Hawke of North Richmond, NSW.** The values of R2 and R3 may need to be adjusted to suit different motors, as the retraction time varies.

Expanded-scale LED voltmeter has wide application

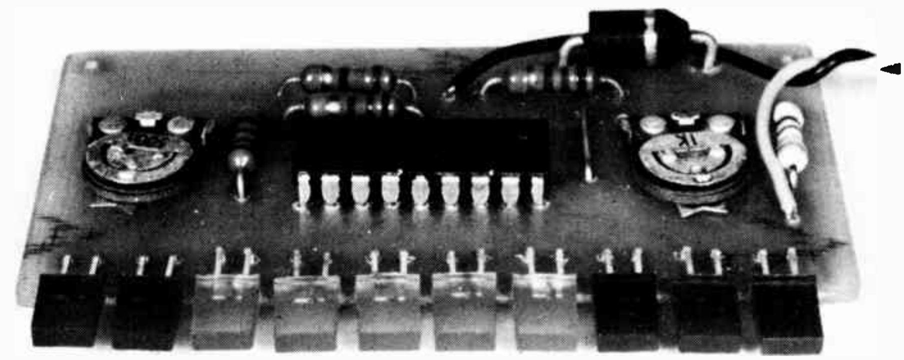
Phil Wait
Simon Campbell

One of the most useful monitors of battery 'condition' is an expanded scale voltmeter. This novel, but nonetheless useful, project should find applications in vehicles, battery chargers etc.

THE 12 V 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.

Fortunately, the terminal voltage is also 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 and rise to a defined maximum when fully charged. Under load, the terminal voltage will vary between these limits, depending on the battery's condition.



The completed voltmeter. LED1 (10.5 V) is on the right and LED10 (15.0 V) is at far left.

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!

Let's look at battery characteristics, before we get into the project's circuitry, to get an understanding of what the project can do.

Lead-acid batteries

The fully-charged, no-load terminal voltage of a lead-acid cell is between 2.3-2.4 volts. This drops under load to about 2.0-2.2 volts. When discharged, the cell voltage is typically 1.85 volts. The amp-hour capacity is determined from a 10 hour discharge rate. The current required to discharge the battery to its end-point voltage of 1.85 V/cell is multiplied by this time; e.g: a 40 AH battery will provide four amps for 10 hours before requiring recharge. Note however that the amp-hour capacity varies with the discharge current. The same battery discharged at a rate of 10 amps will not last four hours, on the other hand if it is discharged at 1 amp it will last somewhat longer than 40 hours. The typical discharge characteristics of a (nominal) 12 V battery are shown in Figure 1.

The initial charging current for the fully discharged battery (cell voltage under 2.0 V), should be about 20 amps per 100 amp-hours of capacity (i.e: 8 amps for a 40 AH battery). Once the electrolyte begins to gas rapidly, the terminal voltage will be around 13.8 volts and rising rapidly. At this point, the charging current should be reduced to somewhere between 4-8 amps per 100 AH until charging is complete.

At the end of charging, terminal voltage may rise to about 15.6 volts or more but this decreases slowly after the charger is removed, the terminal voltage then usually reading around 14.4 volts per cell (see Figure 2.).

NiCad batteries

The no-load terminal voltage of a nickel-cadmium cell is typically 1.3-1.4 volts. This drops to about 1.2 volts under load, and to about 1.1 volts when discharged. As the electrolyte does not change during discharge (as it does in lead-acid batteries), the number of amp-hours obtained from a Nicad battery is much less affected by the discharge rate than are lead-acid batteries (see Figure 3.). Ten individual cells are generally used to obtain 12 V.

A number of charging systems can be used to replenish the charge in NiCad batteries. Constant current chargers are well known and quite common (such as the ETI-578 in the June 1980 issue). Fast charging at a high rate, as illustrated in the ETI-563 Fast Charger, is another method while some commercial manufacturers (Christie Electric Asia, for example) employ the "reflex" technique — the battery is alternately charged and discharged at a high rate over a short period. Increased battery life and extremely rapid charging are the claimed features of this method.

The typical charging characteristics of a single cell are illustrated in Figure 4.

For more details on lead-acid and nickel-cadmium batteries, see "Batteries" in ETI, November 1977.

The voltmeter

This voltmeter uses ten LEDs to provide an 'expanded' voltage scale over the range 10.5 V to 15 V to suit applications with 12 V (nominal) batteries. Heart of the device is an LM3914 LED bargraph driver chip. In this application, we are using it in the 'dot' mode to provide an unambiguous display. The IC has been connected in this circuit such that the first LED (LED1) lights at 10.5 V, the second at 11.0 V and so on at 0.5 V intervals up to 15 V at LED10. Red LEDs have been employed at the extremes of the range to indicate 'problem' conditions. The first three LEDs, covering 10.5 - 11.0 - 11.5 volts, are red to show the discharge condition, while the last two LEDs, covering 14.5 and 15.0 volts, are also red to indicate the overcharge condition. The LEDs covering the 12.0 to 14.0 volts range are all green showing that the battery's within its normal operating voltage range.

An 'idiot' diode (ZD1) and a line fuse protect the instrument in the event of reverse connection or an over-voltage condition. Should the unit be inadvertently wired in reverse polarity, ZD1 will conduct in the forward direction and the line fuse will blow. If a voltage greater than 18 V is applied, which may happen if the unit is installed in a car and a battery terminal comes loose allowing the alternator voltage to rise, then the zener action of ZD1 will cause the line fuse to blow, preventing too high a supply voltage from destroying the unit. ▶

VEHICLE BATTERY FAULTS

Symptom	Probable cause
☆ Voltage falls rapidly to low end of green after engine is switched off.	Battery in poor condition or possibly faulty. Check terminals for good connection.
☆ Battery voltage falls considerably overnight	ditto
☆ Voltage falls rapidly from high end of green to low end if lights switched on with engine off.	ditto
☆ Voltage falls more than about one volt when lights are switched on with engine running at moderate speed	Charging system may be supplying low current. Check alternator slip rings, diodes and regulator adjustment. Check battery terminals.
☆ Voltage rises over 14.5 V (LED9) when engine running	Charging system may be overcharging. Check regulator voltage adjustment.
☆ Voltage never rises to top end of green (LED8).	Charging voltage too low. Adjust regulator voltage.

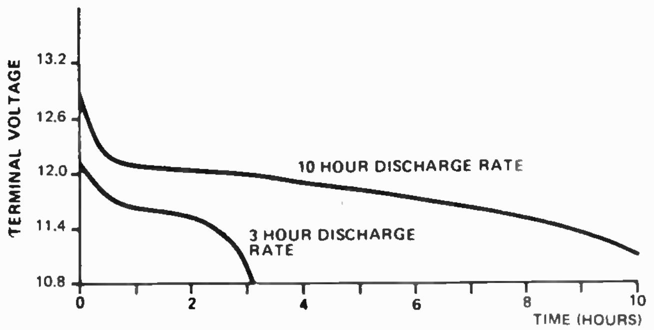


Figure 1. **Typical discharge characteristics of a 12 V (nominal) lead-acid battery.**

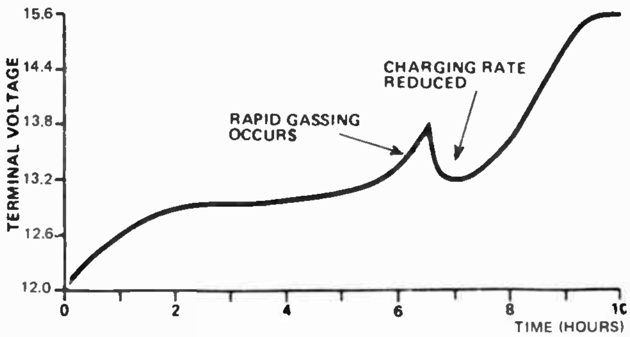


Figure 2. **Charging characteristics of a 12 V (nom.) lead-acid battery. The 'kink' in the curve near 6 hrs is explained in the text.**

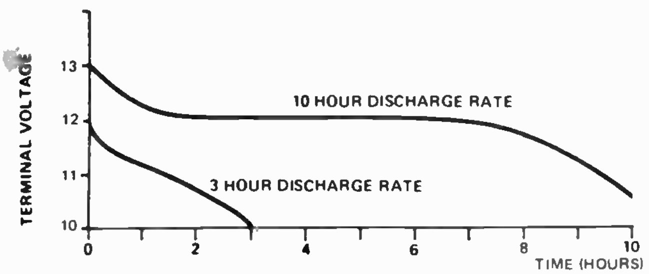


Figure 3. **Typical discharge characteristics of a 12 V (nom.) nickel-cadmium battery (usually consisting of 10 cells in series).**

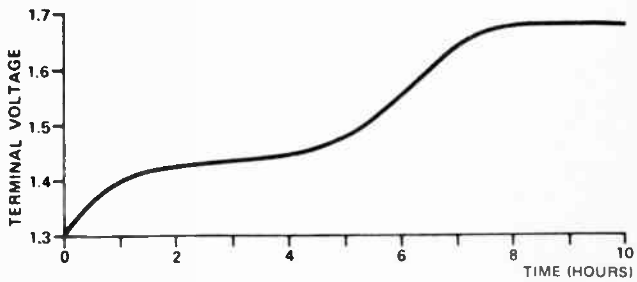


Figure 4. **Typical charging characteristics of a single nickel-cadmium cell charged at 1.4 times the discharge rate.**

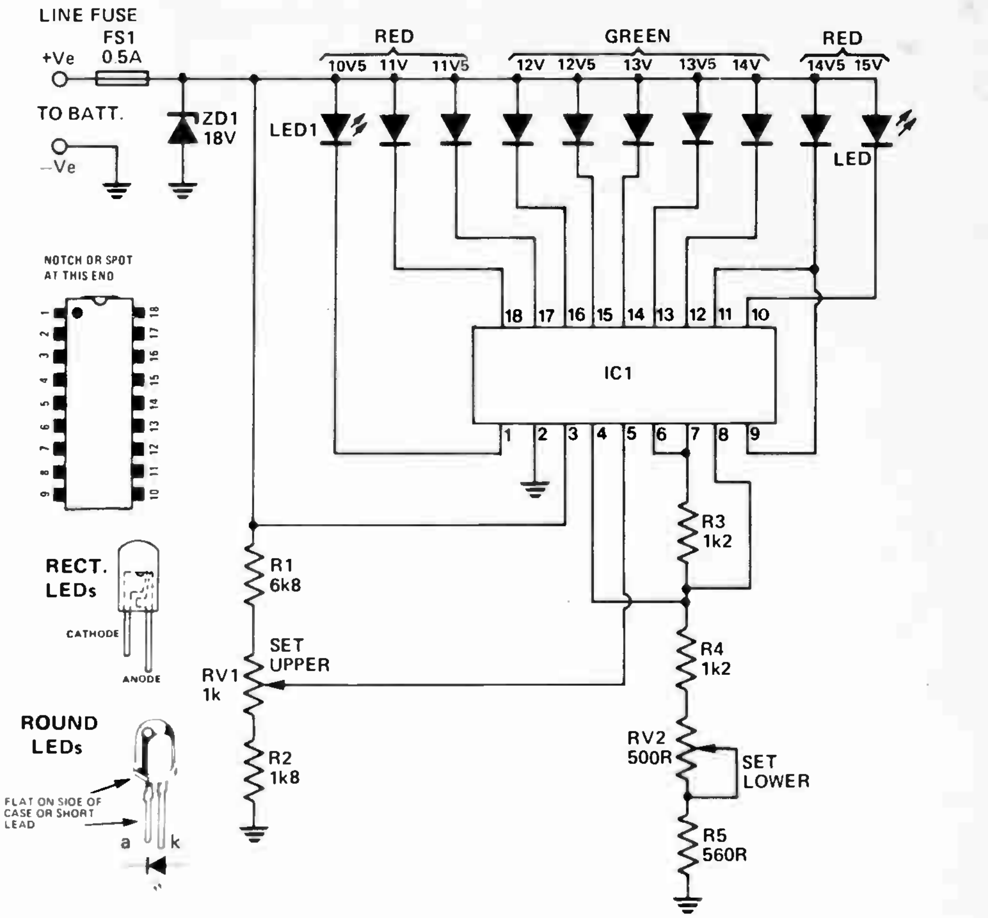
Construction

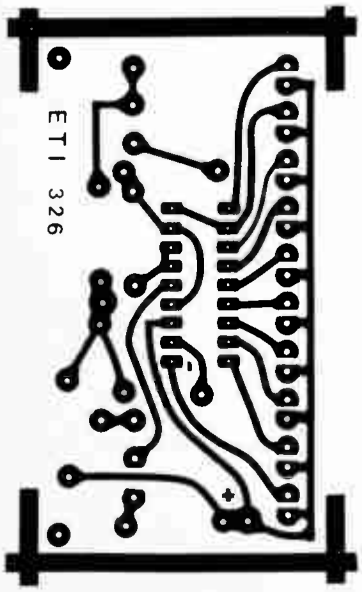
Assembling the project is extraordinarily simple! We recommend you use the printed circuit board — it does make things easier and helps avoid mistakes, although it is not essential.

As with our LED Tacho (ETI-324) we have used rectangular LEDs and mounted them in a row down the front of the pc board. The components may be mounted in any order, but you might find it easier with this project to mount the LEDs first. It is *most important* that they be placed in the board the right way round. About the best way to ensure this is to place them on the table or workbench in front of you with all their leads correctly oriented, just as they would be when mounted in the board. Refer to the overlay and you can't go far wrong. The hard part is getting them all level! Starting at LED1 or LED10 — it doesn't matter which, insert its leads in the board and then bend it over such that it lies flat on the board with the base of the LED flush with the edge of the board. This is clear from the overlay picture. Solder the leads and bend the LED back upright. Insert the next LED carefully positioning it so that it is flush with the first LED and solder its leads. Proceed like this until all the LEDs are in place and then bend the whole row over, parallel to the board.

Note that, although we have used rectangular LEDs, conventional types may also be employed.

If you haven't already done so, the rest of the components may now be mounted. Take care with the orientation of the LM3914 and the zener diode.





Setting the scale limits

To set the scale limits, you will need a variable power supply capable of delivering 15 volts and perhaps a good multimeter or digital voltmeter — the latter is preferable. Whatever you use, you should be able to read it reasonably well to 0.5 V.

Connect the instrument to the power supply (watch polarity), set the supply to 15 V and switch on. Any of the LEDs may light. Adjust RV1 until LED9 just extinguishes and LED10 lights. Next, set the supply to 10.5 V and adjust RV2 until LED1 just lights. Run the power supply up to 11.0 V and check that LED2 lights and LED1 goes out.

As there is some interaction between the two controls, repeat the process until the unit performs properly. The LEDs should light in turn at each 0.5 V interval from 10.5 V to 15.0 V.

Your LED voltmeter is ready for use!

Installation

We'll have to leave this pretty much to you as installation details will depend on the individual application. However, if you plan to mount the unit in a vehicle, here are some general hints.

HOW IT WORKS — ETI 326

The circuit uses an LM3914 LED bargraph driver arranged as an expanded scale voltmeter with a dot display, in which only one of the ten LEDs is lit at any time. If the voltage is below 10 volts none of the LEDs light, if it is above 15 volts the last LED remains lit.

The trimpots RV1 and RV2 set the upper and lower voltages respectively to give a range of 10 to 15 volts in ten steps. Over-voltage and reverse voltage protection is provided by ZD1, an 18 volt zener, and the fuse FS1. If the voltage exceeds 18 volts the zener conducts and blows the fuse, and if the voltage is reversed, the zener acts as a forward-biased diode with the same result.

The instrument can be mounted in any convenient position in or under the dash, provided the display is shielded from direct light. Seeing as the driver only need glance at it occasionally, it may be mounted away from his normal view, but not such that it's an effort to see the display.

The positive supply lead to the instrument should be taken directly to the battery terminal, or the starter motor connection. This is to avoid any voltage drop in the vehicle's wiring from affect-

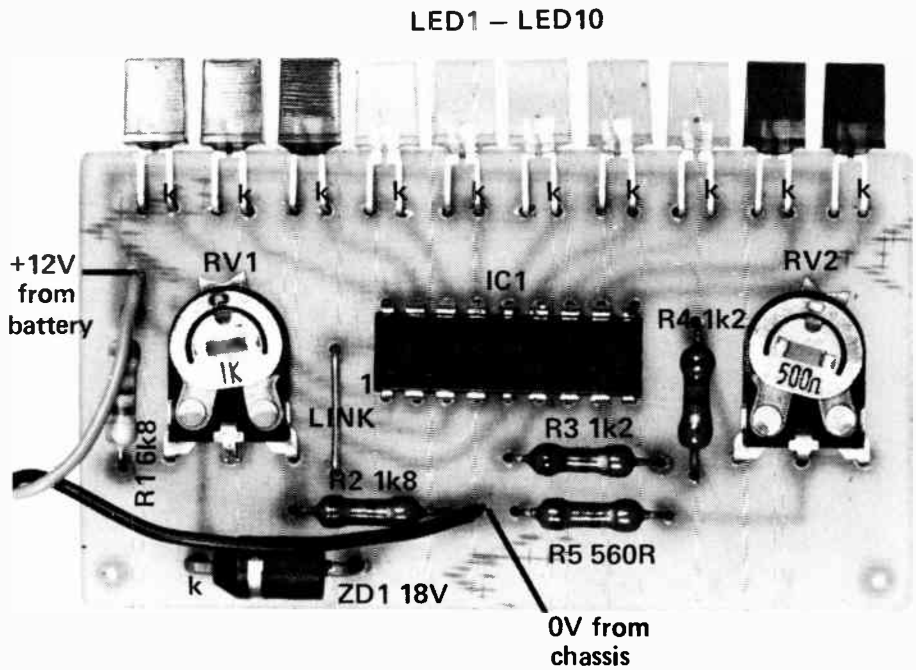
PARTS LIST — ETI 326

Resistors all ¼W, 5%
- R1 .... 6k8
- R2 .... 1k8
- R3,R4 .... 1k2
- R5 .... 560R

Trimpots
- RV1 .... 1k min. vert. mounting trimpot.
- RV2 .... 500 R min. vert. mounting trimpot.

Semiconductors
- ZD1 .... 18V, 1W zener diode
- LED1-LED3 .... red LEDs round or rect.
- LED4-LED8 .... green LEDs round or rect.
- LED9-LED10 ...... red LEDs round or sq.
- IC1 .... LM3914N

Miscellaneous
ETI-326 pc board; in-line fuse holder with 0.5 A fuse.



ing the reading (such as in the headlight wiring). The chassis connection can be made to the car body under the dash, wherever convenient, or taken to a chassis connection point in the engine bay.

Use in a vehicle

Say you get into your car in the morning. Before you start the engine, the unit will probably register in the upper range of the green portion of the scale. If you left the lights on overnight the battery voltage will most likely be low. If below 11 volts, you'll probably have to push start the car.

Let's assume you've got the car going. As you drive off, the voltage should rise until it reaches the maximum charging voltage — about 14.0 to 14.5 volts. When you reach your destination and switch off the engine the voltage should fall slightly — maybe 0.5 V - 1.0 V, to about 13.0 or 13.5 volts (LED6 or LED7 should light). The accompanying table may be used as a general guide to battery faults. ●

THE LM3914 — HOW IT WORKS

The LM3914 is a highly versatile device designed to sense an analogue input voltage and drive a row of ten outputs, usually LEDs or other indicators, in either a 'dot' or 'bar' graph mode.

The IC contains a ten resistor potential divider. Ten voltage comparators in the chip each have their non-inverting (+) input connected to successive taps on the ten-resistor divider. All the inverting inputs of the comparators are tied together and are driven by the output of a buffer from the input. The buffer has unity overall gain, so that for all intents and purposes the voltage on the inverting inputs of the ten comparators is the same as that on the input pin (pin 5). The outputs of the comparators each go to an individual pin on the IC and are capable of driving an LED or other circuitry.

An internal reference voltage source provides a highly stable 1.2 volts between pins 7 and 8. Since this reference is 'floating', the voltage between pins 7 and 8 always remains at 1.2 volts, irrespective of whether pin 8 is tied to ground or held at some voltage above ground.

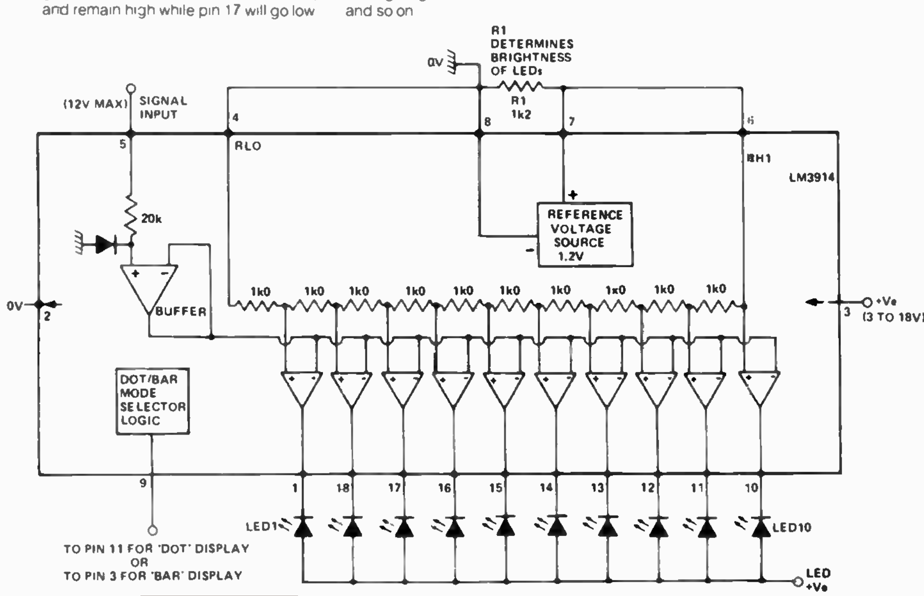
Finally, the IC also contains an internal logic network that can be externally programmed to provide either a 'dot' or 'bar' display from the outputs of the ten voltage comparators. When the dot mode is selected, only one of the ten outputs will be 'active' as the input voltage varies. When the bar mode is selected, each output becomes 'active' in succession as the input voltage increases, and vice versa.

If the reference voltage (1.2 V) is connected across the internal resistive divider, by connecting pin 7 to pin 6 and pin 8 to pin 4, 0.12 volts is applied to the non-inverting input of the lowest voltage comparator, 0.24 V to the next 'up' the divider line, 0.36 V to the next, and so on.

When the input voltage on pin 5 is zero, all the comparator outputs are high. As the input voltage is increased, the buffer output will increase. When it passes 0.12 V, the first comparator in the string (output on pin 1) will switch and its output will go low and remain low. If the input continues to rise, the next comparator will switch over and pin 18 will go low and remain low when the input passes 0.24 V. Pin 17 will go low and remain low when the input passes 0.36 V etc. pin 10 (output of the tenth comparator) will go low and remain low when the input reaches or exceeds 1.2 V. This is what happens when the bar mode is selected. For the dot mode, pin 1 will go low when the input reaches 0.12 V. When the input reaches 0.24 V, pin 1 will go high and remain high and pin 18 will go low. When the input reaches 0.36 V, pin 18 will go high and remain high while pin 17 will go low ... and so on.

The output currents from the comparators may be programmed by a connecting resistor across the reference supply, between pins 7 and 8. Each comparator output current is approximately ten times the output current of the voltage reference source. This can supply about 3 mA maximum, so the maximum output current from each comparator is 30 mA.

A detailed explanation of the operation and applications of the LM3914 appeared in the March 1980 issue of ETI, page 61.



An 'intelligent' battery charger

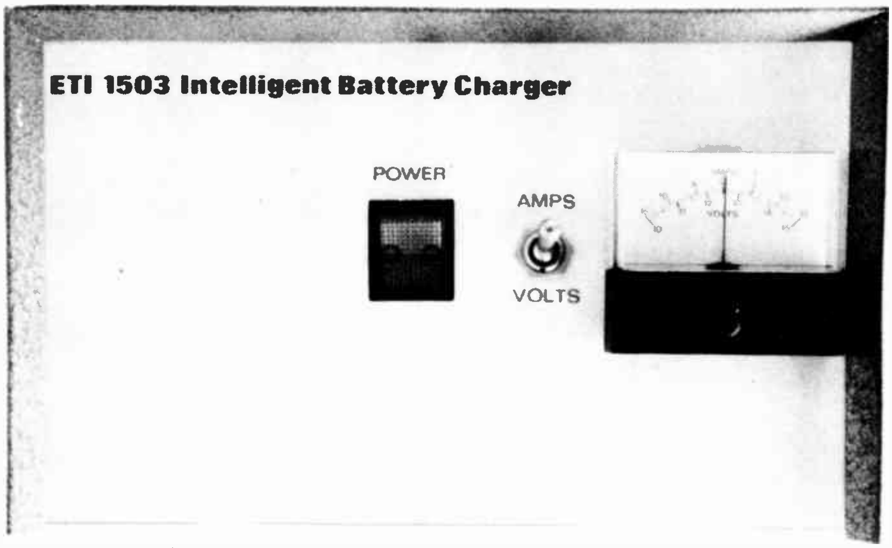
This is no ordinary battery charger. If you run a house alarm system, an amateur repeater or any electronic system with a 12 V battery 'back up' supply, this charger will keep that battery in a healthy state. It has other uses, too.

Jonathan Scott

IT IS PERHAPS too little known a fact that lead-acid batteries are not happy if left fully charged or discharged. They need to be used to stay in good condition. This is not, as a rule, a difficult situation when the battery is in a car, say, because it is called upon to run clocks or parking lights and to start the engine, and is charged when the engine is running. Some cars even arrange for the battery to be discharged to some extent when the engine is running and the lights are on (a mechanism into which we will not go just now). However, sad is the battery used as a burglar alarm power back-up system where it is continuously topped up, awaiting the moment when the mains fails. The battery fails too often before the mains supply!

As well as avoiding that situation, this charger maintains the 'spare' battery you keep in the garage for when that blighter of a P-plate driver son of yours borrows the Kingswood and leaves the lights on in the garage. Perhaps you charge it periodically at present, but the poor battery does not do any of the work that is necessary for its health and well-being.

Many amateur radio repeaters, popular on the VHF and UHF amateur bands for mobile operation with low power transceivers, employ (or should!) a battery back-up system. When a mains failure occurs the battery may be called upon to supply a pretty arduous load, cycling from a relatively low current in the listening mode to much higher currents when transmitting. To provide an operating time anywhere near the battery's rated capacity, the battery must be in 'good' condition. 'Float' or trickle charging will not ensure that.



The completed project was housed in an inexpensive yet attractive metal case, dressed up with a Scotchcal front panel label. A Scotchcal label could be used for the meter scale; however, University Graham Instruments will be supplying ready-made scales for these meters.

It is to overcome this sort of problem that we have designed this 'intelligent' battery charger.

This device monitors the state of charge and waits dormant until the battery is beginning to get flat. When it is low, but not in the deep discharge region, it turns itself on and charges the battery until it is full, whereupon it goes to sleep again until the battery is near exhausted, and so on. This has the disadvantage that there is an element of luck as to how charged the battery will be at any moment, but it is quite likely to be enough to start a car, for example, or to ring an alarm bell for quite a period. And it will be *just the same* in three months time.

In the burglar alarm back-up application this unit is ideal. It can also be used in conjunction with a load, such as the ETI-147 (Oct. 1980), to 'recycle' a battery to restore lost capacity, or perform tests on a battery in a simulated load situation (how long will it run parking lights?). These last two are the original applications for which it was designed.

Although we have not specifically included it in the circuit, it is a good idea to have a small load on the battery when it is connected to the charger. We have provided terminals on the unit from which to draw power, as we expect the unit will be powering an alarm system or similar. If it is used to keep a spare battery healthy we recommend that a load such as a 180 R, 1 W resistor or a one-watt light globe be connected across the terminals to give a constant but small current drain.

Before we get into the construction,

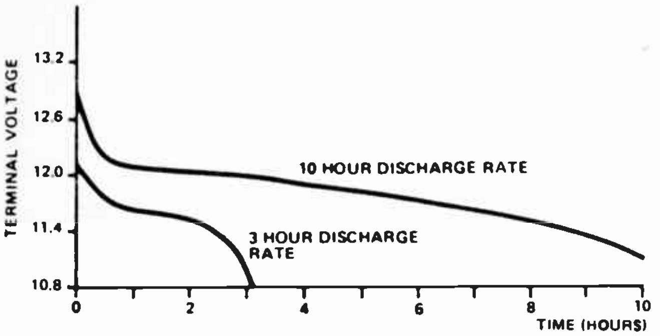


Figure 1. **Typical discharge characteristics of a 12 V (nominal) lead-acid battery.**

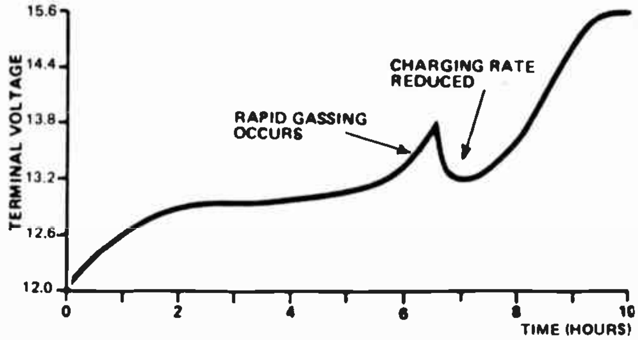


Figure 2. **Charging characteristics of a 12 V (nominal) lead-acid battery. The 'kink' in the curve near six hours is explained in the text.**

let's take a look at the characteristics of lead-acid batteries to gain an understanding of what happens when you discharge and charge them.

Lead-acid batteries

The fully-charged, no-load terminal voltage of a lead-acid cell is between 2.3-2.4 volts. This drops under load to about 2.0-2.2 volts. When discharged, the cell voltage is typically 1.85 volts. The amp-hour capacity is determined from a 10-hour discharge rate. The current required to discharge the battery to its end-point voltage of 1.85 V/cell is multiplied by this time; e.g: a 40 AH battery will provide four amps for 10 hours before requiring recharge. Note however that the amp-hour capacity varies with the discharge current. The same battery discharged at a rate of 10 amps will not last four hours; on the other hand if it is discharged at 1 amp it will last somewhat longer than 40 hours. The typical discharge characteristics of a (nominal) 12 V battery are shown in Figure 1.

The ideal initial charging current for the fully discharged battery (cell voltage under 2.0 V) should be about 20 amps per 100 amp-hours of capacity (i.e: 8 amps for a 40 AH battery). Once the electrolyte begins to gas rapidly, the terminal voltage will be around 13.8 volts and rising rapidly. At this point, the charging current should be reduced to somewhere between 4-8 amps per 100 AH until charging is complete.

At the end of charging, terminal voltage may rise to about 15.6 volts or more, but this decreases slowly after the charger is removed, the terminal voltage then usually reading around 14.0 to 14.4 volts (see Figure 2).

This project may be used with batteries having rated capacities from 4 AH to 100 AH, providing it is set up for the battery in use, according to the set-up procedure given at the end of the article.

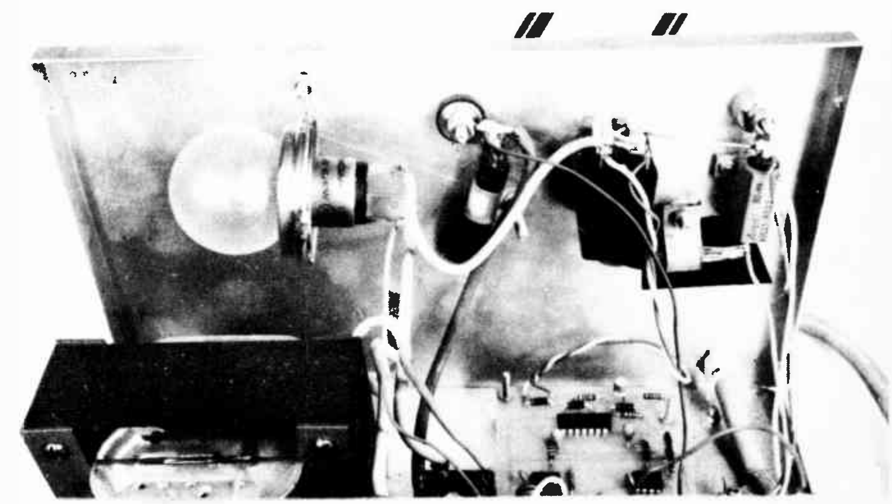
Construction

The component layout is not critical with this project, so there is no need to adhere strictly to the details which follow, provided you know roughly what you are about. The only constraint is that quite a lot of power (60-odd watts) is dissipated by the circuit as a whole and so the design needs to be fairly open and well ventilated.

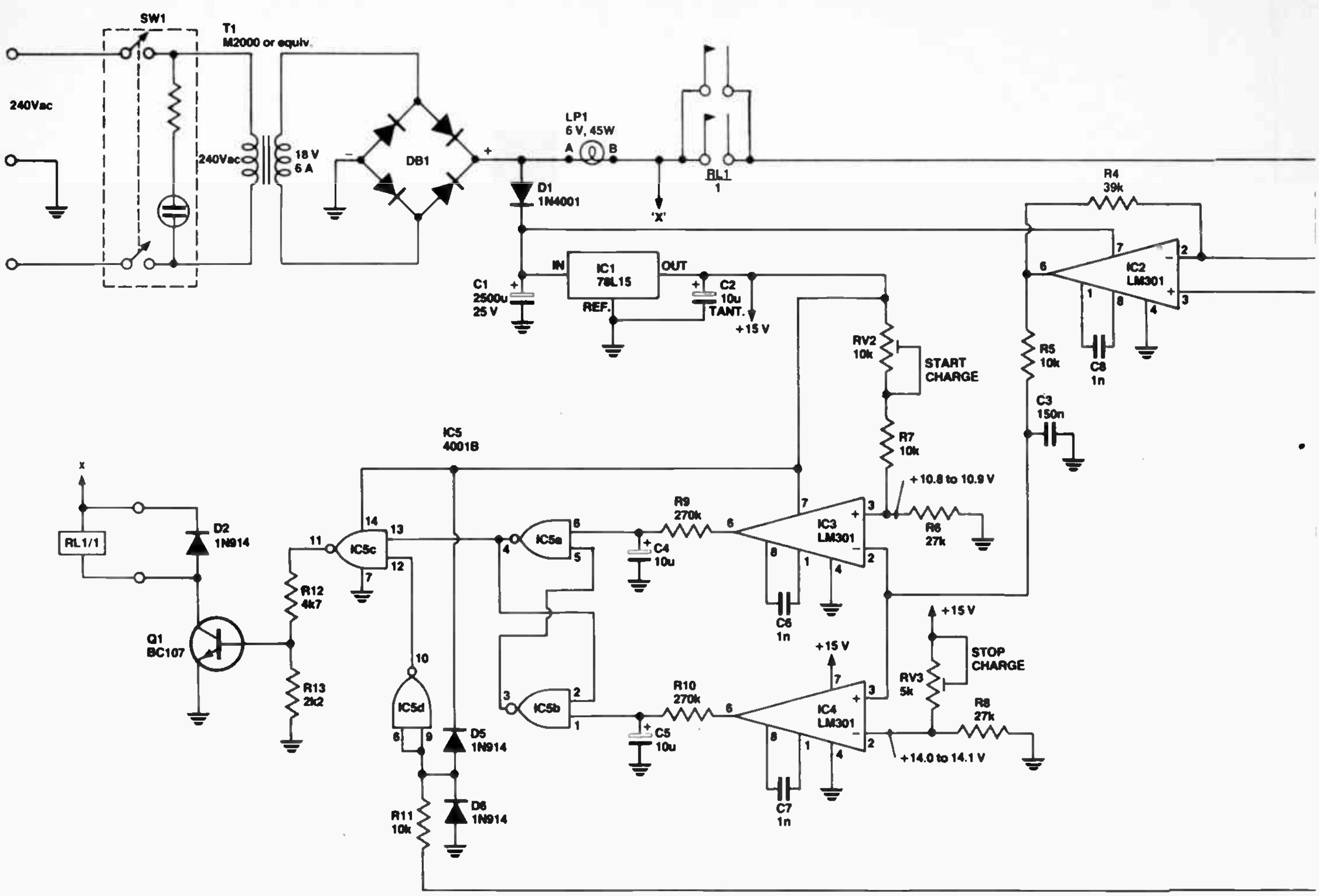
We used a 'K&W' model C1066 box which allows plenty of room and has good ventilation slots in the sides and top. The first step in the construction is to set the major components out inside the box where you will want them and check that there is enough 'room to move' and that wiring will be easy. Mark the positions for mounting holes with a soft lead pencil, then remove the bits and pieces and drill the holes. We used a 6 V headlight globe from Volkswagen for LP1, which we mounted by soldering some 18-gauge tinned copper wire to the metallic collar and forming bolt holes in the ends of the wire. This held it most satisfactorily about 10 mm from the rear panel of the case, just below a set of vent slots.

Next fit the components to the pc board as shown in the overlay, starting with the resistors and capacitors and finishing with the ICs. Take care to observe the correct polarity with the electrolytic capacitors, diodes and ICs. Attach adequate lengths of hookup wire, where applicable, to the pc board.

Next, fit and interconnect the various components in the box. The metal-clad power resistor, R1, will be carrying up to 15 A or so at maximum and thus should be connected to the battery and the output terminals by short lengths of the heaviest cable possible. We used 6 mm-thick automotive starter-type ▶



View of the rear panel showing how we mounted the various major components. Note the 45 W lamp 'ballast'. The relay was glued in place between the two output terminals. The Arcol metal-clad resistor is mounted as close as possible to the positive output terminal.



HOW IT WORKS — ETI-1503

The overall function of the device is as follows: when the open-circuit potential of the battery falls to below about 10.8 volts the charger turns on, charging the battery until the potential rises to about 14 volts, whereupon it turns off the charging current and waits dormant until the cycle repeats.

Let us start by considering the conditions when a normal, partially charged battery is connected and the unit is dormant. IC2 in conjunction with R1 and the surrounding components are connected to determine the open-circuit voltage potential of the battery even though it may have a load drawing power. IC1's output is equal to the terminal voltage of the battery minus about 4 times the voltage across R1, times the reduction fraction of RV1; mathematically it is:

$$V_{out} = V_{battery\ terminal} - \frac{39k}{10k} \times V_{across\ R1} \times K$$

where K is the fraction between 0 and 1 determined by RV1

When a load current is drawn from the battery a voltage = $I_{load} \times R1$ is dropped across R1. With respect to the voltage at the junction of R1 and the battery (the reference for IC2) this potential is negative. By choosing K to be the correct value, which is:

$$K = \text{Internal Resistance of battery} \times \frac{1}{3.9} \times \frac{1}{R1}$$

$$V_{out} = V_{battery\ terminal} + I_{load} \times IR_{battery} = V_{open\ circuit}$$

Since K cannot, of course, exceed a value of one, the circuit will handle batteries with internal resistances up to 3.9 times R1, or about 85 milliohms. This should be adequate for all car batteries, but doubling R4 to, say, 82k, will enable batteries with up to 180 milliohms internal resistance to be used, and so on.

Having ascertained the function of IC2, let us now consider the action of the rest of the circuit. IC3 and IC4 act as comparators. The output of IC3 goes high when the battery open-circuit voltage falls to below 10.8 volts. This level is set by RV2, which compensates for offsets and component tolerances. The output of IC4 goes high when the open-circuit battery voltage rises to above 14 volts. This is set by RV3. These levels correspond to a battery at the ends of its healthy charge/discharge curve.

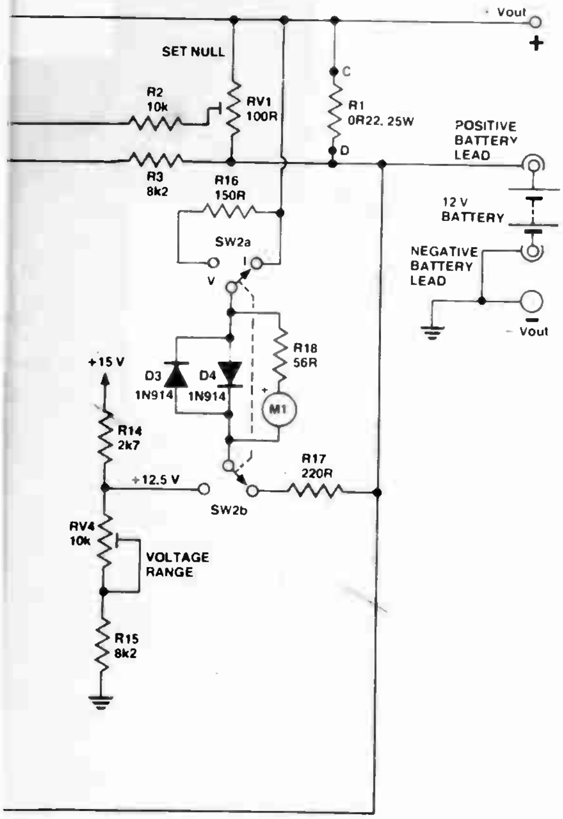
IC5 performs the logic necessary to control the relay. The first two gates (IC5a, IC5b) are coupled as a flip-flop. When the device is idle, the output of IC5a is high and the flip-flop is in the 'discharge' condition. The relay is held off by IC5c. If the battery is very flat, or if the wires are short-circuited, or the battery connected in reverse, IC5d holds the relay off irrespective of the flip-flop condition. When the battery is connected and is only normally discharged, and when the flip-flop is in the charge condition, IC5c turns Q1 on and the relay pulls in connecting the battery to the unregulated supply, again via R1 (permitting actual V_{out} to be measured) and via the light globe, which effectively regulates the current. (More on this in a moment).

IC1 simply provides a voltage reference of about 15 volts, as well as a regulated supply for IC3, IC4 and IC5. The meter and surrounding components provide a convenient 15-0-15 amp current meter and a 10-15 volt suppressed zero voltmeter, which reads the voltage delivered to the load.

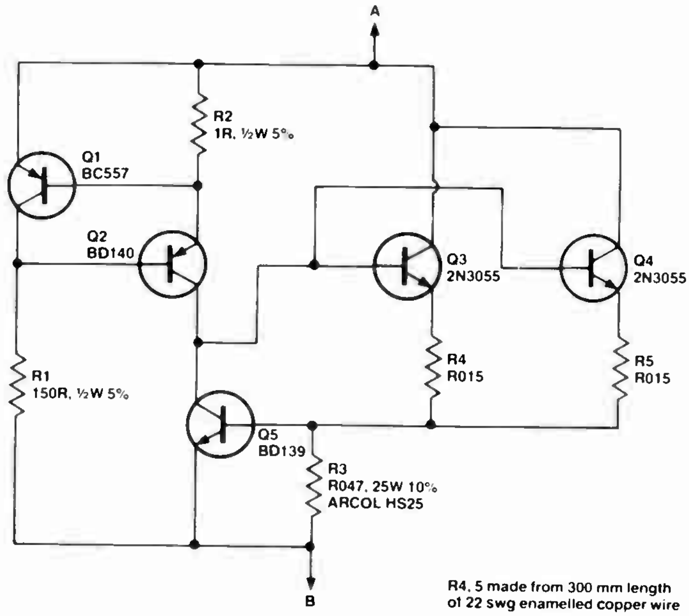
When the battery open-circuit potential falls to below the preset limit (10.8 V), IC3 toggles the flip-flop and RL1 pulls in. The charge current flows until the output of IC4 goes high, toggling the flip-flop back to the original state and turning the relay off. While charging, the current is effectively regulated by LP1 (a 6 V, 45 W light globe). The globe exhibits a characteristic of $I \alpha V^2$, which tends to hold the current at around 5-6 A after it warms up. Initial charging current will be higher. This method of current regulation is by far the cheapest, and causes no RFI, etc. In case anyone should experience trouble getting such a globe, such as might be the case if you do not have a Volkswagen parts place nearby (many old VWs have 6 V headlights), we have included a circuit which can be substituted. It is at once clear how much nicer is the globe approach!

LIGHT GLOBE SUBSTITUTE

Transistors Q1 and Q2 form a current source, feeding about 600 mA out of the collector of Q2. This turns on Q3 and Q4 until 0.6 volts is dropped across the R047 resistor, R3. At this point, Q5 turns on and removes the excess drive current from Q3/4, regulating the current in this fashion. The two R015 resistors, formed by about 300 mm of 22 swg each, ensure that Q3 and Q4 share the load roughly equally. Q3 and Q4 must be mounted on a suitable heatsink.



The circuit is fairly straightforward. The M-2000 transformer (T1) is rated to deliver 6 A at 18 V. However, it will deliver more than twice the output current for short periods, without distress, and we've taken advantage of that. The secondary voltage loads down somewhat, but that's been taken into account. Note that the relay has its contacts paralleled.



Circuit of the light globe substitute.

cables, which ran to the bolt-on battery terminals, rather than the alligator clips usually found on battery chargers and jumper leads. This minimised resistance and hence voltage drop with heavy load currents. The voltage sensing circuitry expects a low resistance path to the battery, so this arrangement is by far the best.

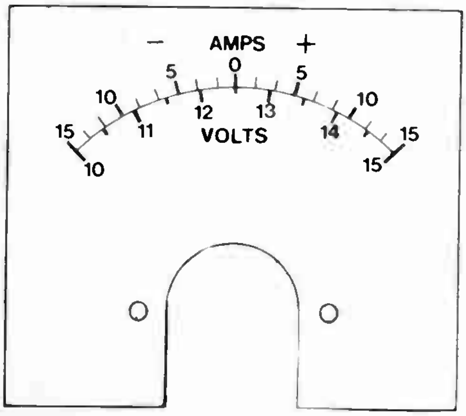
The leads connecting transformer, diode bridge, lamp and output terminals need to be fairly heavy, but not so heavy as the battery leads — ordinary automotive hookup wire (32 x 0.2 mm) or 1.5 mm tinned copper wire in spaghetti is quite adequate.

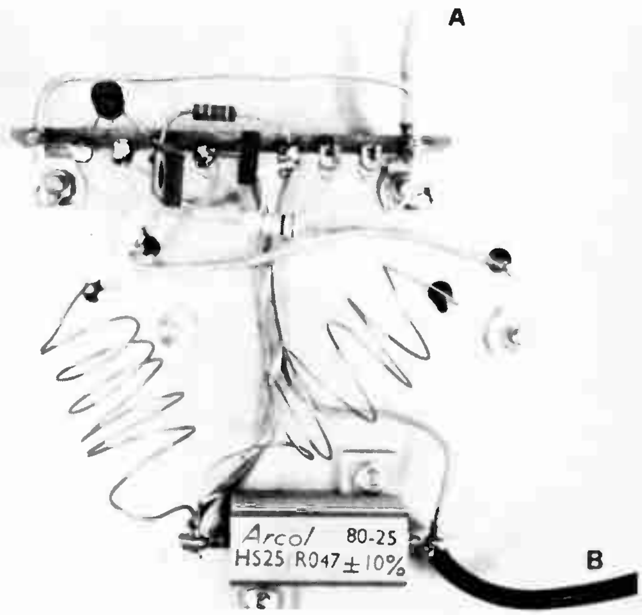
Follow the interconnection diagram to complete the circuit. If you like, a large and chunky bezel can be fitted to an appropriate part of the front panel so that it is illuminated by the globe when the unit is charging.

We felt this to be a little superfluous as light streams out of the ventilation slots!

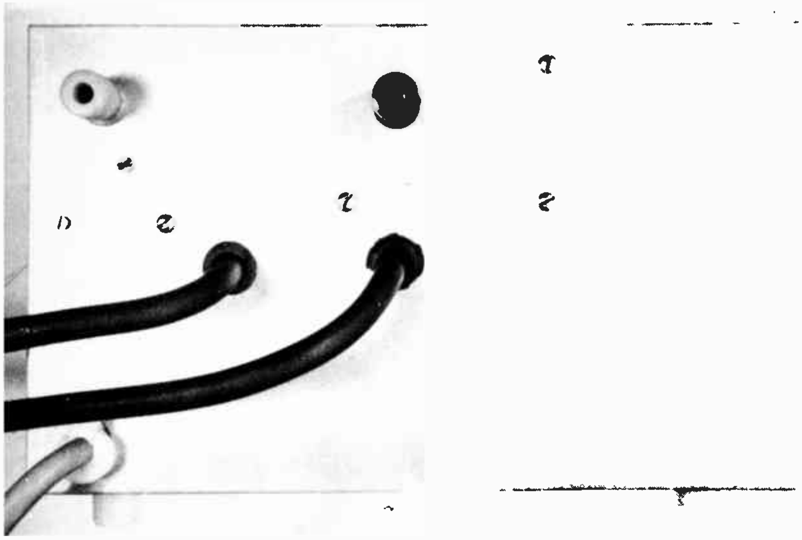
The mains wiring should be installed ▶

Full-scale artwork for the TD-66 1-0-1 mA meter. University Graham Instruments will be supplying meters for this project with this scale fitted.

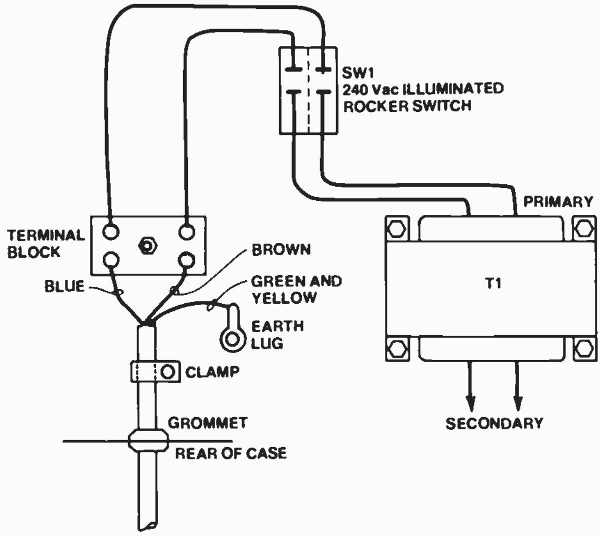




Construction of the light globe substitute circuit. Layout is not critical.



View of the rear panel (exciting, isn't it!), showing the mains cable entry and the two battery cables. The output terminals to supply equipment running off the batteries are at the top, positive on the left, negative on the right.



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

with care, the mains input lead being physically 'shielded' from the pc board by a cardboard 'screen'.

For those people with no access to a VW dealer or other source of suitable 6 V globes, we have provided a tested current regulator circuit. We constructed ours using a tag strip which bolted neatly on to the power transistor collector connections (see pic, p. 57). This is a last resort, as it is more costly and less easy to install than a simple lamp, and demands some sort of careful heatsinking. We built ours on a separate small sheet of 1 mm thick aluminium, though there is no reason why you should not use a panel of the box if physically convenient. We mounted two pre-drilled heatsinks to the transistors to dissipate most of the heat. Be sure to fit the 2N3055s carefully, removing burrs which might puncture the insulating washers and using adequate thermal compound. The value of the two R015 resistors (R4, R5) is not critical, though care should be taken to ensure that they are equal in value as their function is to make the two transistors share the load. We made them with about 300 mm of 22 swg enamelled wire each.

Setting up

Once construction is completed, the unit may be set up for correct operation after you have carried out a *thorough* wiring check.

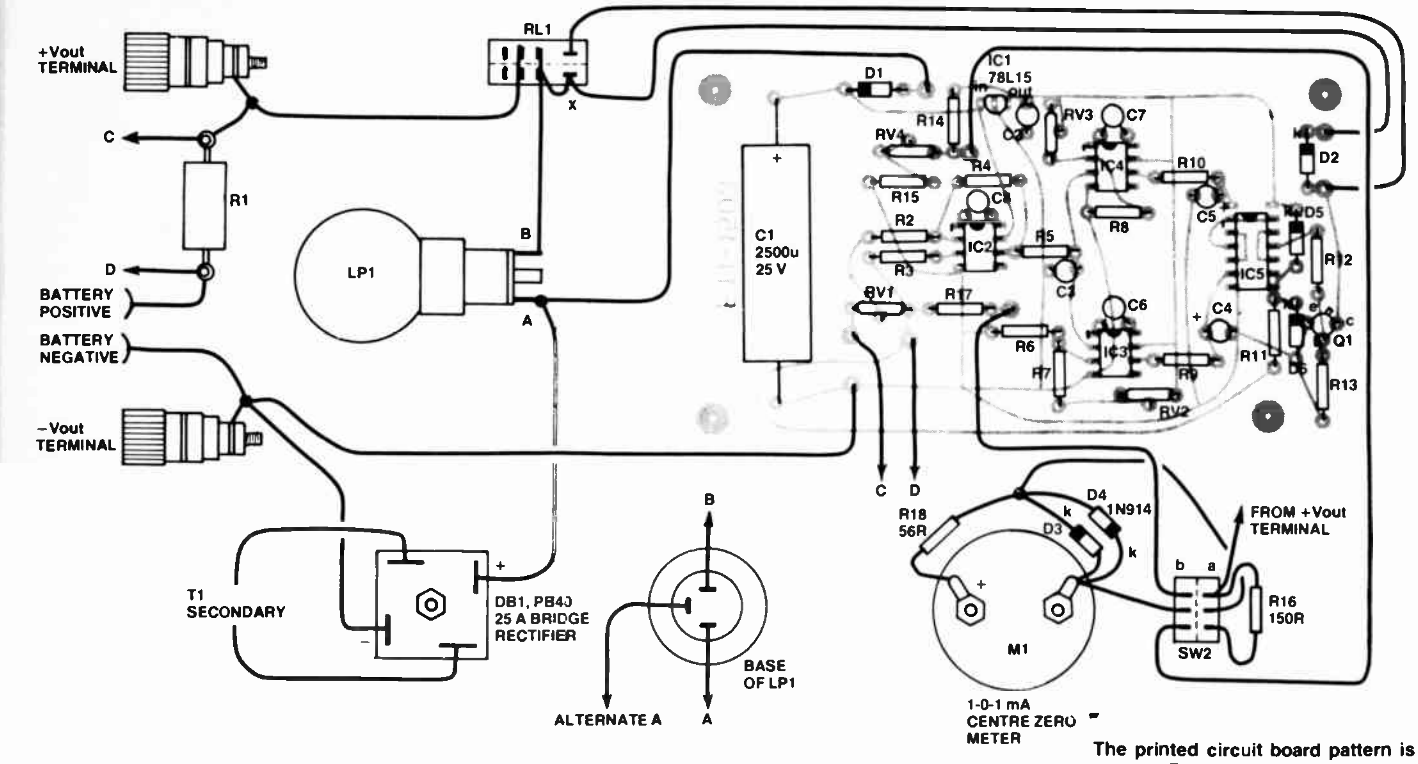
Fit a battery which is not very flat and turn the unit on. It may come on in the charge mode or it may be dormant, depending on the actual battery terminal voltage. To set the charger up you will need a multimeter with a sensitivity of at least 20k/volt.

First, operate the meter switch so that the meter reads volts (V). Connect your multimeter across the output terminals on the rear of the case, set it to read volts, and adjust RV4 so that the front panel meter reads the same voltage as the multimeter. Once RV4 has been adjusted, connect your multimeter (still on the same range) between pin 2 of IC4 (multimeter positive lead) and 0 V (black output terminal). Adjust RV3 so that your multimeter reads 14.0 to 14.1 volts here. This adjusts the point where the charger turns off ('STOP CHARGE'). Next, connect your multimeter between pin 3 of IC3 (multimeter positive lead) and 0 V, and adjust RV2 to obtain about 10.8 to 10.9 volts here. This sets the point where the charger turns on ('START CHARGE').

Finally, the unit needs to be adjusted to compensate for the internal resistance of the battery. This adjustment is simple, but will need to be done for each different battery with which the unit is used. If the unit is charging initially it may be best to toggle it off for convenience. This is most easily accomplished by momentarily connecting the positive end of C5 to the 15 V supply ('out' pin of IC1). Next, connect a load of a few amps to the charger's output terminals, either via a switch or flying leads so that you can connect and disconnect it. Then adjust RV1 so that no change in voltage occurs on the output of IC2 (pin 6) when the load is connected or disconnected. This should not be done with a flat battery — i.e: if the unit goes to charge mode at initial switch-on, let it charge for a few hours before completing the calibration.

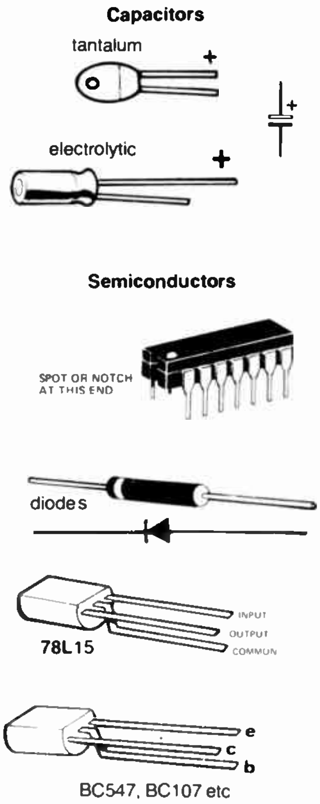
Strictly speaking, the recalibration of RV1 does not need to be redone for any new battery connected, especially if the battery is just going to be left alone and is not intended for back-up work, such as a burglar alarm battery. The internal positive lead resistance will be roughly similar for similar capacity batteries, so this can be neglected if you are only leaving the battery on for a short while, as might be the case if you transfer the car battery onto the charger for a day or a few days. However, RV1 should be recalibrated if the installation is to be considered permanent or if the batteries are very different in capacity.

The charger was designed to be used with batteries having a capacity up to 100 AH. The smallest capacity car batteries generally available are rated at around 32 AH. They will perform quite happily when used with this charger, though the charging current is greater than optimum. For batteries having a capacity lower than 40 AH, the charging current may be conveniently reduced if you wish by using the lower wattage filament in the globe specified for LP1. Connect the 'A' lead from the bridge rectifier positive terminal to the alternative filament connection as shown in the LP1 Base Lead diagram with the overlay and wiring diagram. ●



The printed circuit board pattern is on page 74.

COMPONENT PINOUTS



PARTS LIST — ETI-1503

Resistors all ½W, 5% unless noted

R1	R022, 25 W (Arcol, metal clad type)
R2,R5,R7,R11	10k
R3,R15	8k2
R4	39k
R6, R8	27k
R9,R10	270k
R12	4k7
R13	2k2
R14	2k7
R16	150R
R17	220R
R18	56R

Capacitors

C1	2500u/25 V electro.
C2,C4,C5	10u/16 V tantalum or RBLL
C3	150n
C6,C7,C8	1n ceramic

Semiconductors

D1	1N4001 or similar
D2-D6	1N914 or similar
DB1	25A bridge rectifier
IC1	78L15 3-terminal regulator
IC2,IC3,IC4	LM301
IC5	4001
Q1	BC107, BC547 etc

Miscellaneous

RV1	100R trimpot
RV2, RV4	10k trimpot
RV3	5k trimpot
M1	1-0-1 mA centre-zero panel meter
RL1	12 V SPST relay with 10 A contacts or DPST with 5 A contacts.
LP1	6V, 45 W or 50 W Volkswagen headlamp globe
T1	240 V to 17-18 V transformer, 6 A secondary (i.e: DSE M-2000)
SW1	Rocker switch, 240 Vac rated with neon illumination.
SW2	Spring-return action DPDT toggle switch

Case — 255 x 160 x 160 mm or similar (e.g: K&W Series C1066); ETI-1503 pc board; wire; mains cable clamp, mains lead and plug; battery cables and clamps; one red and one black heavy duty terminals.

Supplementary parts — substitute for LP1

Q1	BC557 etc.
Q2	BD140
Q3,Q4	2N3055
Q5	BD139
R1	1R, 1 W
R2	150R, ½W
R3	R047, 25 W (Arcol, metal clad type)
R4,R5	see text.

Transistor insulated mounting components, heatsinks, nuts, bolts, etc.

Price estimate

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

$78 - $86

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

DIGITAL DIAL FOR CAR RADIO

Most transistor radio dials are pretty hopeless these days, so we thought we'd do something about it.

WITH MODERN RADIOS which are designed to be operated anywhere in the world, the local station call signs are no longer marked on the dial. Instead the dial is marked with frequencies making it more universal. Unfortunately the scaling on many receivers leaves a little to be desired, with many car radios lucky to have 3 or 4 markings. The use of pushbutton selection helps but when a cassette is fitted or you are out of your local area there is still the problem of knowing to what station you are tuned.

This project gives a direct readout of the station being received allowing for easy identification and selection. The display is remote from the receiver allowing it to be mounted on the dashboard for easy viewing.

Design Features

This project uses the up/down counter module (ETI Project 591) which was first published in Electronics Today International, July 1978, and later reprinted in our book 'Test Gear Volume Two'.

If this module is to be used outdoors i.e. in the car, it is recommended that high brightness displays, such as the Hewlett Packard HDSP 4133, be used. As these have a different pin-out a new display board is presented in this article.

SPECIFICATION – ETI 550

Frequency range	500-1700 kHz
Accuracy	∓ 5 kHz
Sensor	pickup coil or direct connection
Power supply	7–20 V dc @ 80 mA or 240 V ac
Display	4 digit LED

The theory of operation is that we actually measure the frequency of the local oscillator in the radio and subtract the IF frequency. While we could have subtracted this using digital logic we chose to do it by resetting the display not to zero but to 9545 (10 000 - 455). The first 455 pulses in the timing period are then used getting to zero and in effect, only pulses after this are counted and displayed. This number can be loaded into the counter by selecting the appropriate diodes and using the "load counter" input instead of the reset line. The only difference is that as the data is

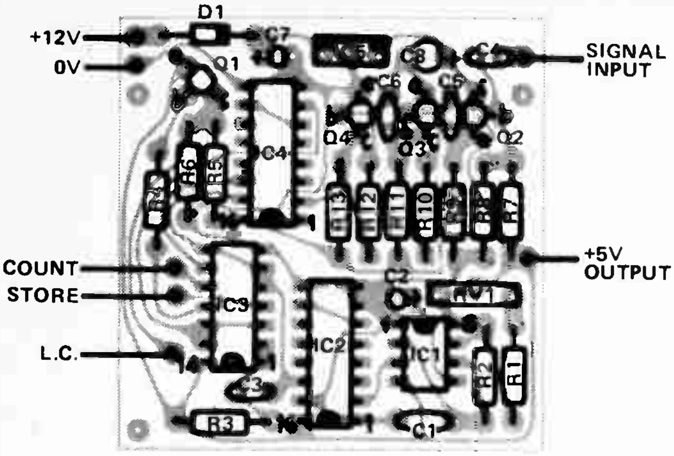


Fig. 1. The component overlay for the control card.

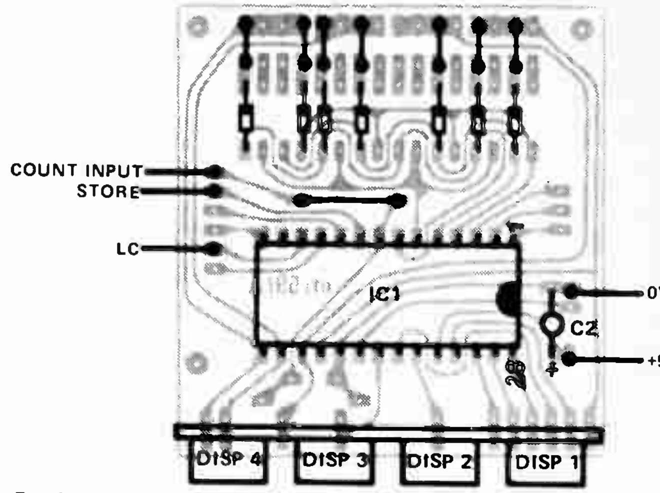


Fig. 2. The component overlay of the display module showing the diodes and links required.

PARTS LIST – ETI 550

Resistors all ½W, 5%
R1 . . . . . . 39k
R2 . . . . . . 8k2
R3 . . . . . . 1M
R4 . . . . . . 10k
R5, 6 . . . . . 1k
R7, 8 . . . . . 47k
R9 . . . . . . 1k
R10. . . . . . 2M2
R11. . . . . . 10k
R12. . . . . . 220k
R13. . . . . . 1k

Potentiometer
RV1 . . . . . 5k trim

Capacitors
C1. . . . . . . 47n polystyrene
C2. . . . . . . 1µ0 tantalum
C3. . . . . . . 2n2 polyester
*C4. . . . . . . 10p ceramic
C5, 6 . . . . . 10n polyester
*C7. . . . . . . 33µ tantalum
C8. . . . . . . 10µ 25V electro

Semiconductors
IC1 555
IC2 4520
IC3 4001
IC4 4520
IC5 7805

Q1 . . . . . . BC558
Q2–Q4. . . . BC548

D1 . . . . . . 1N4004

Miscellaneous
PC board ETI 550
Display module ETI 591
* Transformer 240V–12.6V, 150mA

* For 12V operation delete transformer. For 240V version C7 should be 220µ 25V. For use with pickup coil increase C4 to 1n0.

entered into the counter serially the pulse used must be longer than 4 times the internal oscillator period. Also as the LC input is a three state input it cannot be driven by conventional two-state.

We initially tried capacitive coupling onto the tuning capacitor of our portable radio (oscillator section!) but the loading detuned the set too much. We then tried a pickup coil and found enough signal with it in the correct place not to require any electrical connection to the set. With the car radio however the coils are shielded so well that reliable operation was not possible. However it was found that we could tap onto one side of the oscillator coil without affecting the operation.

We use a NE555 as the time base with its output being divided by 128 to improve stability. However if an accuracy of ± 5kHz is to be maintained its frequency has to be better than ¼% and a polystyrene capacitor for C1 and 2% resistors for R1 and R2 are recommended.

Construction

The display board should be built according to the overlay in Fig. 2 which shows which diodes are required. Note that R1,2 and C1 are not used in the display module and a link is used in place of R1.

The control card can now be assembled and wired to the display module. The two boards are mounted one above the other using 9.6 mm spacers. Check that these screws do not touch any tracks and insulate them if too close.

Depending on whether the unit is going to be used with a car radio or portable the values of C4 and C7 will vary. The pickup coil is made by winding about 80 turns of 0.25 mm enameled wire onto a 25 mm long piece of 10 mm ferrite rod with the end terminated onto a twisted pair of plastic covered wires long enough to go between the radio and the position of the display. Do not use coaxial cable for this as the capacitance is too high.

The case chosen has been left to the individual with our own being from a discarded digital clock. If you use the 240V powered version be careful with the high voltage wiring. For the 12V version the power can come from the radio via a twisted lead (3 wires).

When connecting into a car radio, tune the set to a local station and try the pickup wire on the terminals of the tuning coils in turn until one is found which will give a reading without moving it off station. Permanently connect to this point. With a portable radio try moving the pickup coil around the set, probably in line with the aerial coil, until the best results are obtained.

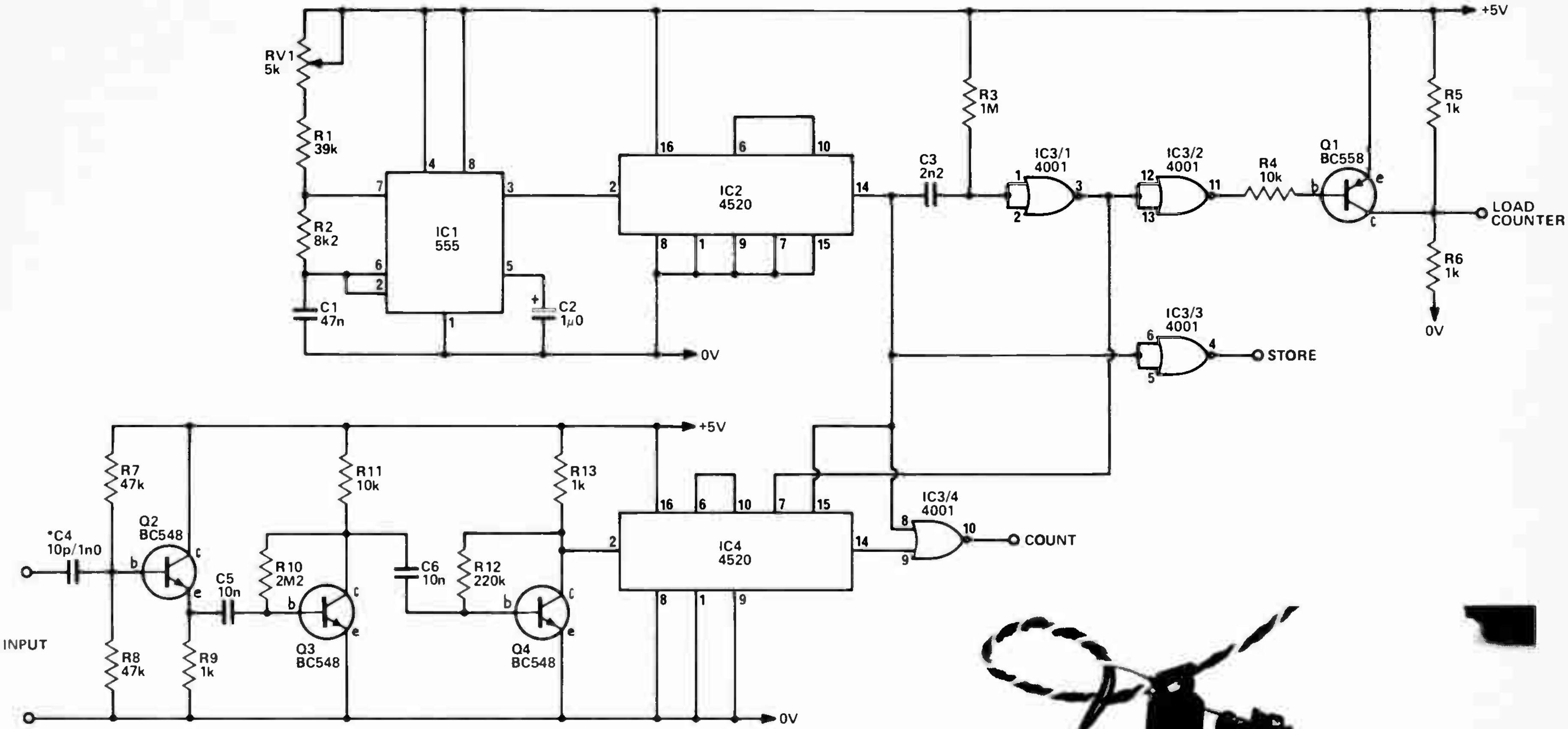
Calibration

Place the pickup coil in position such that reliable operation is obtained and tune to a know station (preferably near the top end of the dial). Now adjust RV1 until the digital dial agrees with that station. Check then with other stations.

Alternately feed a known signal of between 1 and 2MHz from an oscillator into the input and adjust RV1 until it reads 455 less than that frequency.

Power Supply

The unit can be powered by an ac or dc voltage of between 7 and 20 volts. If an ac voltage is used the capacitor C7 should be increased to 220 µF. A 240V to 12.6V, 150 mA transformer is recommended.



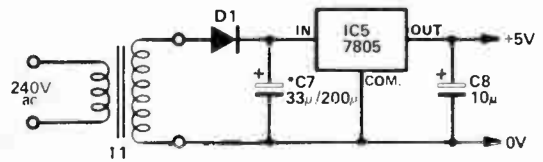
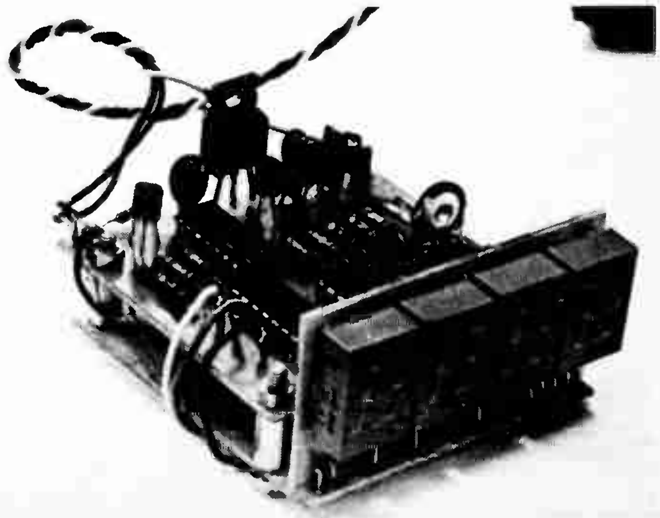


Fig. 3. The circuit diagram of the control logic.

The photo to the right shows the module with the HP 5082-7663 displays. Suitable displays and their light outputs are given below. The 10.9 mm displays need the ETI 591C pc board.

Type	Colour	Size	Light output
HDSP 4133	yellow	10.9 mm	2100µCd @ 20mA
HDSP 3733	red	10.9 mm	1800µCd @ 20mA
5082-7663	yellow	10.9 mm	1500µCd @ 20mA
5082 -7653	red	10.9 mm	1720µCd @ 20mA
DL704	red	7.6 mm	320µCd @ 25mA



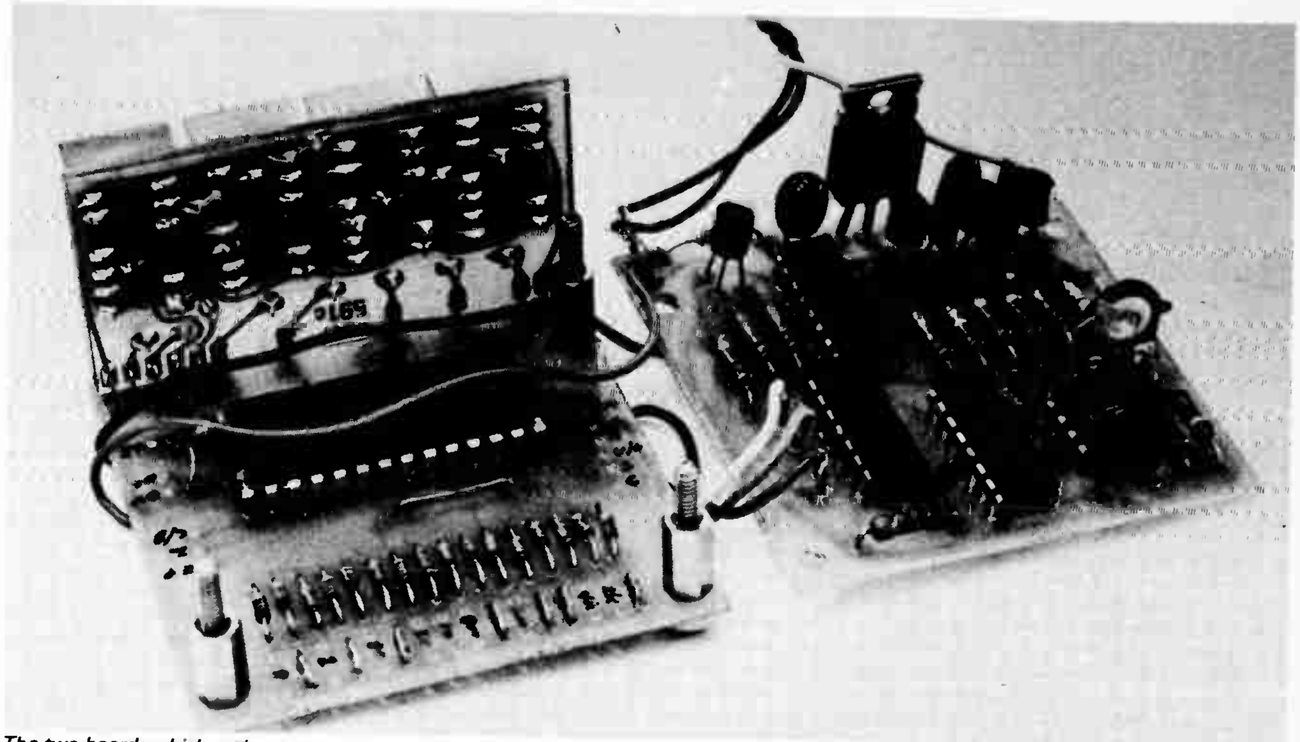
HOW IT WORKS - ETI 550

A signal from the local oscillator in the tuner is picked up either by a pickup coil or by direct connection to the set. It is then amplified by Q2-Q4 to give a square wave on the collector of Q4. The gain of this amplifier is about 250 (48 dB). The frequency of this signal will vary from around 1 MHz to about 2 MHz and this signal is then frequency divided by 256 (2^8) in IC4. This is used to clock the display module.

To measure the frequency we have to count the number of these pulses for 256/1000 seconds (256 because we divided the input by 256 and 1000 as we want a 1 kHz resolution). We used a 555 oscillator for the time base and its output is also divided by 256 (by IC2). This improves the stability of the time base by averaging out any short term variations in the 555 frequency.

The output of IC2 is a symmetrical square wave and when the output goes low a 1.5 ms wide pulse is generated by R3, C3 and IC3/1. This is then inverted by IC3/2 which turns Q1 on for the 1.5 ms period. Two resistors are used to bias the output of Q1 to 2.5V to ensure that the three level input will work.

This pulse "loads" 9545 into the counters (in the display module). Counting now starts from this number and after 455 pulses it is passing through zero. 256 ms after the load pulse ended the output of IC2 goes high. This resets IC4 back to zero, inhibits any further clocking via IC3/4 and opens the latches via the strobe line allowing the total in the counter to be displayed. 257.5 ms later when the output of IC2 goes low again, the store is closed, the counter is once again preset to 9545 with the process starting again.



The two boards which make up the complete dial. Note the links on the display board. The diodes where the links are not used may be deleted.

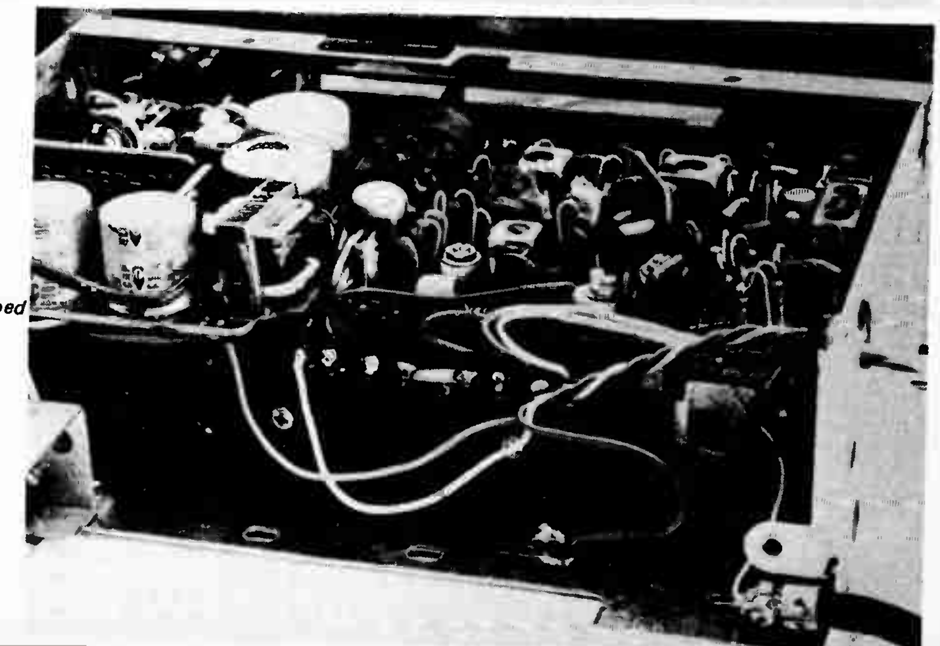


Photo showing where we tapped into the car radio.

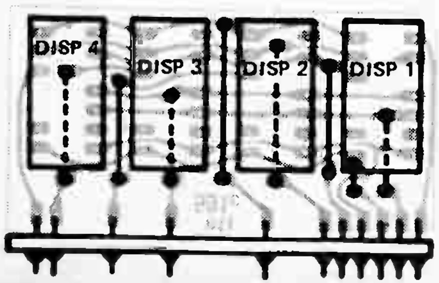


Fig. 4. The component overlay of the display when using the HP display.

Breakdown beacon

An essential device for any car owner — this project doubles as emergency flasher or trouble lamp.

THE BREAKDOWN BEACON IS A dual purpose device. It stands about 115 mm high and can be used atop a disabled motor vehicle as a flashing warning to other traffic — a highly desirable safety device. Alternatively it can be used as a non-flashing trouble light for finding and fixing faults at night. Its three rubber-sucker feet will hold it to the roof of a car, to the underside of a bonnet, or to any other convenient flat surface.

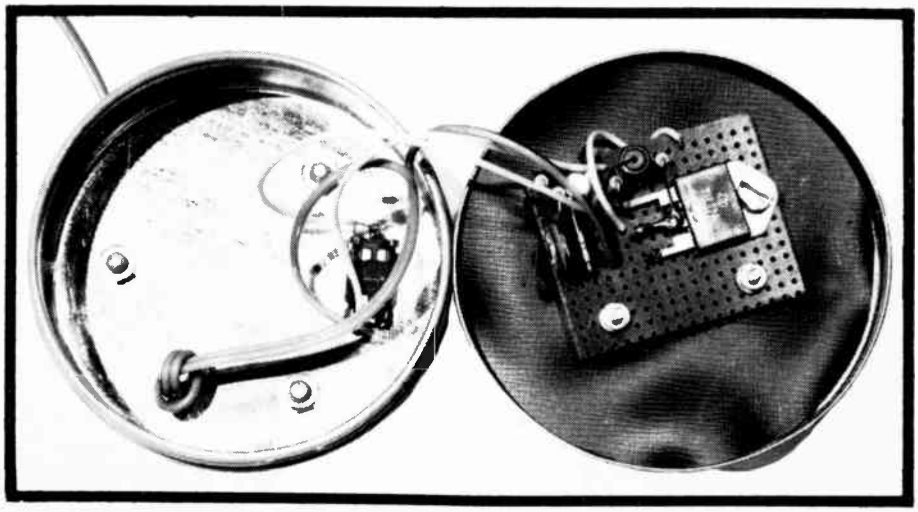
The circuit operates from the vehicle's battery and, as all electrical parts are isolated from the metal case, the same circuit can be used for cars with either negative or positive earth wiring systems. The beacon is fed from a plug pushed into the cigarette lighter socket — however as this plug is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

CONSTRUCTION

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

First solder the lids of the jar and the tin together, concentrically — outside to outside. Then before fitting the batten lamp holder fit the lamp to it and check that it will fit inside the jar when the jar is screwed into its lid. If it will, then mount the lamp holder by three bolts through both lids. Two of these bolts should be longer than the third as they will carry a piece of Veroboard. If the jar is slightly too short to accept the lamp holder and lamp — as was the case

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



PARTS LIST – ETI 239

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

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

HOW IT WORKS

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

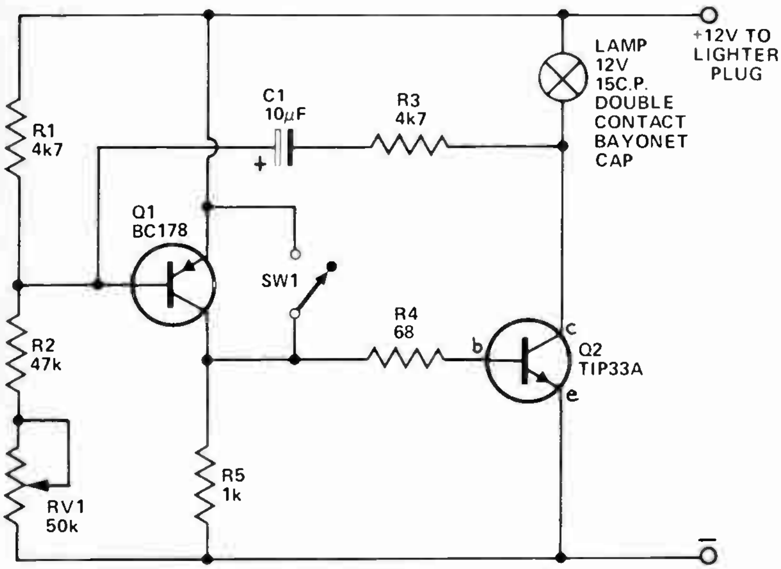
The setting of the pot RV1 is such that when power is first applied Q1 is turned on slightly. By varying RV1 the circuit can be made to 'lock' with the lamp on or off. In between these extremes the circuit oscillates. The setting of RV1 is not critical.

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

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

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

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



Circuit diagram of the Breakdown Beacon.

in the prototype – then cut a hole for the lamp holder through both lids, and fit the lamp holder so that its flange finishes up inside the tobacco tin. Spacing washers may be added if necessary. Again the lamp holder is secured to the lids with one short and two long bolts.

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

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

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

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

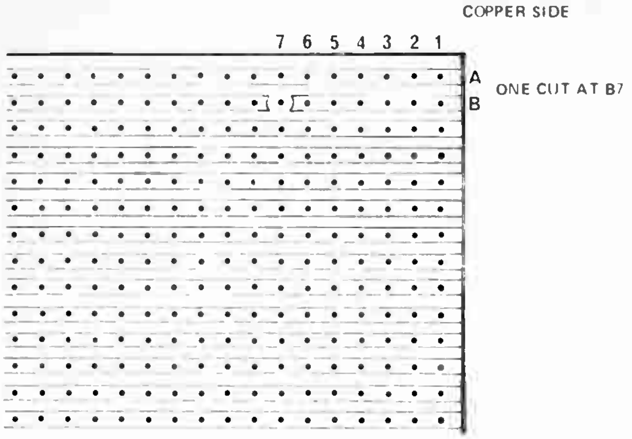
It is likely that the operation of soldering the two lids together will have destroyed the air-tight seals in the jar and tin; they should be replaced with a disc in the tin and a ring in the jar cut from fairly heavy plastic sheeting.

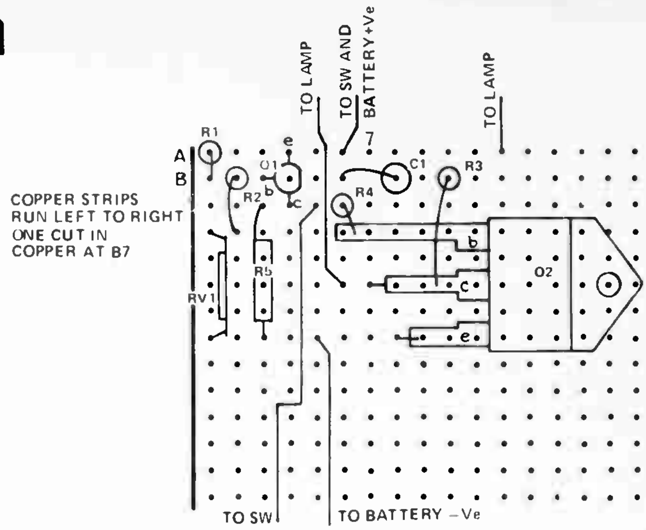
TESTING

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

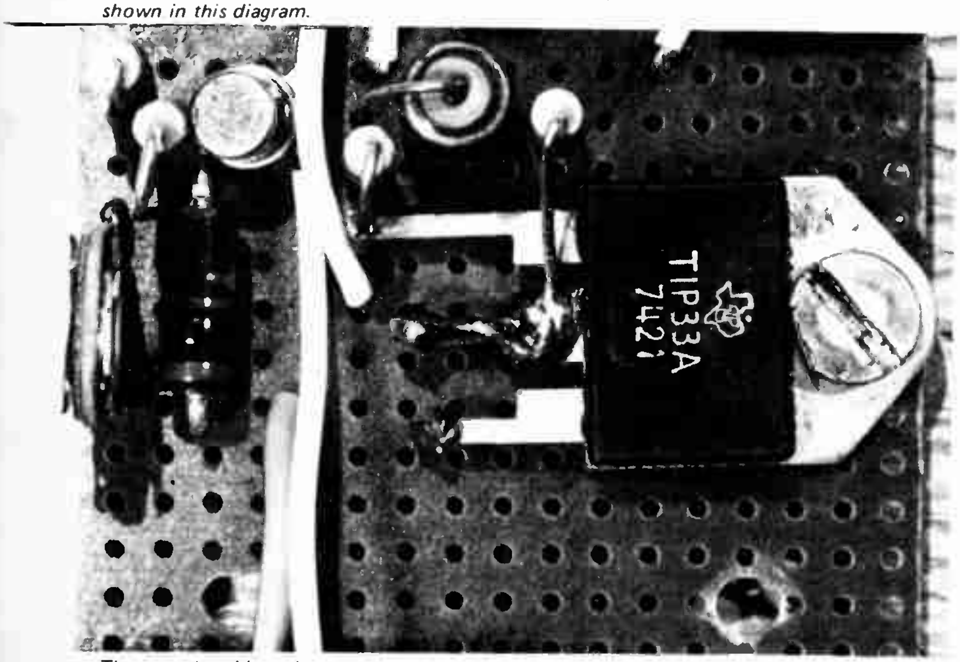
Connect the unit to the battery by inserting the plug into the cigarette lighter socket. It may now be found that RV1 needs some adjustment to make the circuit operate correctly, so don't be disappointed if the lamp does not light at first or alternatively, stays on all the time. The flashing rate may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

Breakdown beacon





Only one break in the Veroboard copper pattern is required — as shown in this diagram.



The completed board.

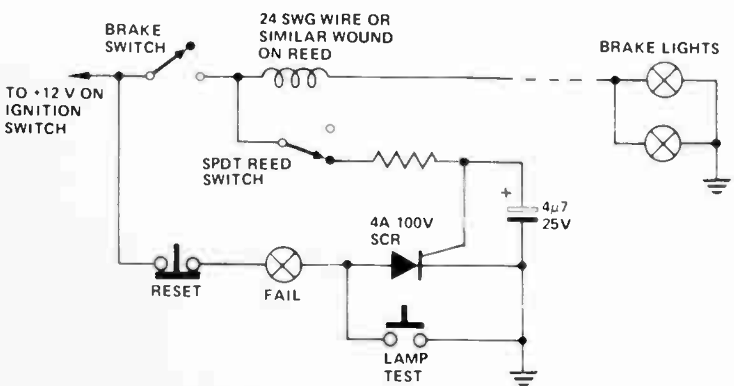
The value of R4 shown in the circuit was selected to suit the transistor Q2 used in our prototype. If the lamp lights at less than full brilliance then R4 may be reduced until Q2 saturates and the lamp is turned on fully.

USE

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

A simple inexpensive project with an intriguing circuit — and it may save you a lot of trouble! Make one. ●

Ideas for Experimenters



Car lamp failure warning

Many lamp failure warning circuits indicate only when the lamp being monitored is supposed to be on. This circuit will 'latch' to show that the brake lights are faulty — even if the fault is intermittent, as is often the case with wiring faults.

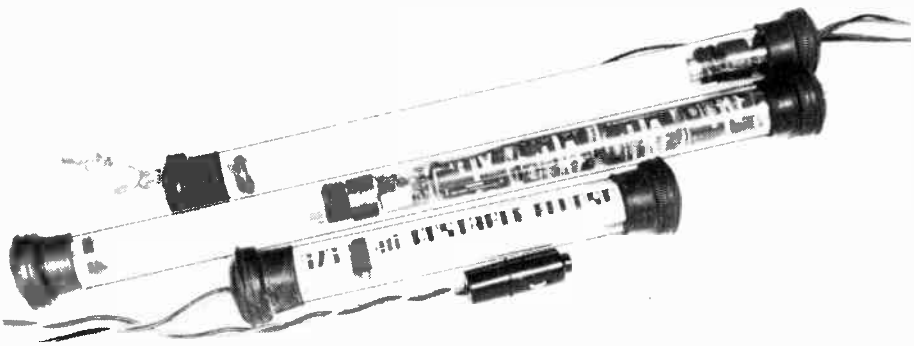
Enamelled copper wire is wound onto an SPDT reed switch until a certain number of turns is found (by experiment) that will open the contacts when both lamps are working. If either of the lamps should fail, the contacts will remain closed, triggering the thyristor.

Project 575

Portable fluorescent "light wand" for car, camping — even caving!

by Jonathan Scott and Eric Mills

A portable, battery operated light has a thousand and one uses. Torches are fine, but their narrow beam limits their application. This project describes a highly practical, battery operated fluorescent light that is highly efficient and may be built in several versions.



FLUORESCENT torches, fluorescent lights on buses and trains and battery backed-up fluorescent emergency lights have been with us for some time now. The motivation for designing this particular circuit, however, was a need to get the most light for the weight carried on a caving helmet. The design had to be compact, reliable, able to take a wide range of input voltages, but above all – efficient.

Our basic model – the 8 W one – uses parts which we readily obtained from various suppliers in Sydney, and which should be available in most major cities (see the Construction section). We also built two special variations – the caving helmet unit, with a belt pack 12 V dry battery source, and the 'Light Wand' which holds four 'C' size Nicad batteries in the same acrylic tube as the converter, thus making it self-contained. The latter required a modification to allow for the 5 V supply rail while the caving light required a custom fibre glass housing. This was supplied most kindly by Mr. Paul Hinds of Sydney University. Finally we built a 4 W version similar to the 8 W one simply by using the smaller tube directly. This is physically nicer, but inherently less efficient.

Construction

Neatness and care is important in this project, though construction is not difficult. The first step is to assemble the pc board according to the overlay. If the protection diode, D1, is in position (a), ignore position (b). If it is in position (b), link should be inserted in position (a).

The next step is the most important and the most time consuming – winding T1. Ensure that you have adequate 26 B & S (0.5 mm) and 32 B & S (0.2 mm) wire; about 2 m of the first and about 20 m of the second will be required. Have a sharp blade, some ordinary clear sticky tape and about 90 minutes on hand.

Start with the secondary winding. Leaving about 3 cm of wire projecting, close wind the 32 B & S wire onto the former. There is no need to count turns if you have exactly the same former and wire as we used because 150 turns is 4 layers almost exactly. When the first layer is complete cut a strip of sticky tape the correct width and, without letting the turns unravel, insulate the layer with the tape. Repeat this procedure, layer by layer until you have wound four layers.

Next, lead out a loop of the wire. Do not cut the wire, but twist loop and continue winding. Proceed 10½ turns, and tape these, leaving another loop projecting from the other side, but at the same end of the former. Continue winding until this layer is complete, and then tape it. Add three further layers finishing at the same end but the opposite side to where you started. This completes the secondary. Cut the wire, about 3 cm from the former.

You should now have one loop and one single wire coming out each gap at the end of the former.

Next, wind five turns of 32 B & S for the feedback winding and tape these. Start and finish in one of the gaps in the other end of the spool. They can be close wound or spread – we tried both with no perceptible difference. Leave about 4-5 cm of wire on the end of this coil as the feedback winding connections on the pc board are further away. Finally, wind 2 layers of primary similarly, starting and ending at the unused spool gap. The former will fit into the core leaving four groups of two connections each.

The core is a gapped one. It is rather fragile and should be handled with care and reverence. It is also somewhat conductive. The secondary connections will need to be insulated from the core at the point where they leave it. Use either some thin spaghetti, or insulation stripped from thin hookup wire. When this is done, fit the core around the former. It should be held there with a clip (provided). There is, however a small plastic inset tapped to take a 6 BA thread in one half of the core. Since this is plastic and not attached tightly to the core half a bolt may be used with it to secure the halves together. Under no circumstances should they be held very tightly by a screw through the centre, and at no time by a metal nut and thread.

Next it is necessary to tin the wires, scraping away the enamelling, being careful not to break the wires. Finally the correct phase of the windings needs to be determined. Temporarily connect the primary wires to the two primary connections on the pc board. ▶

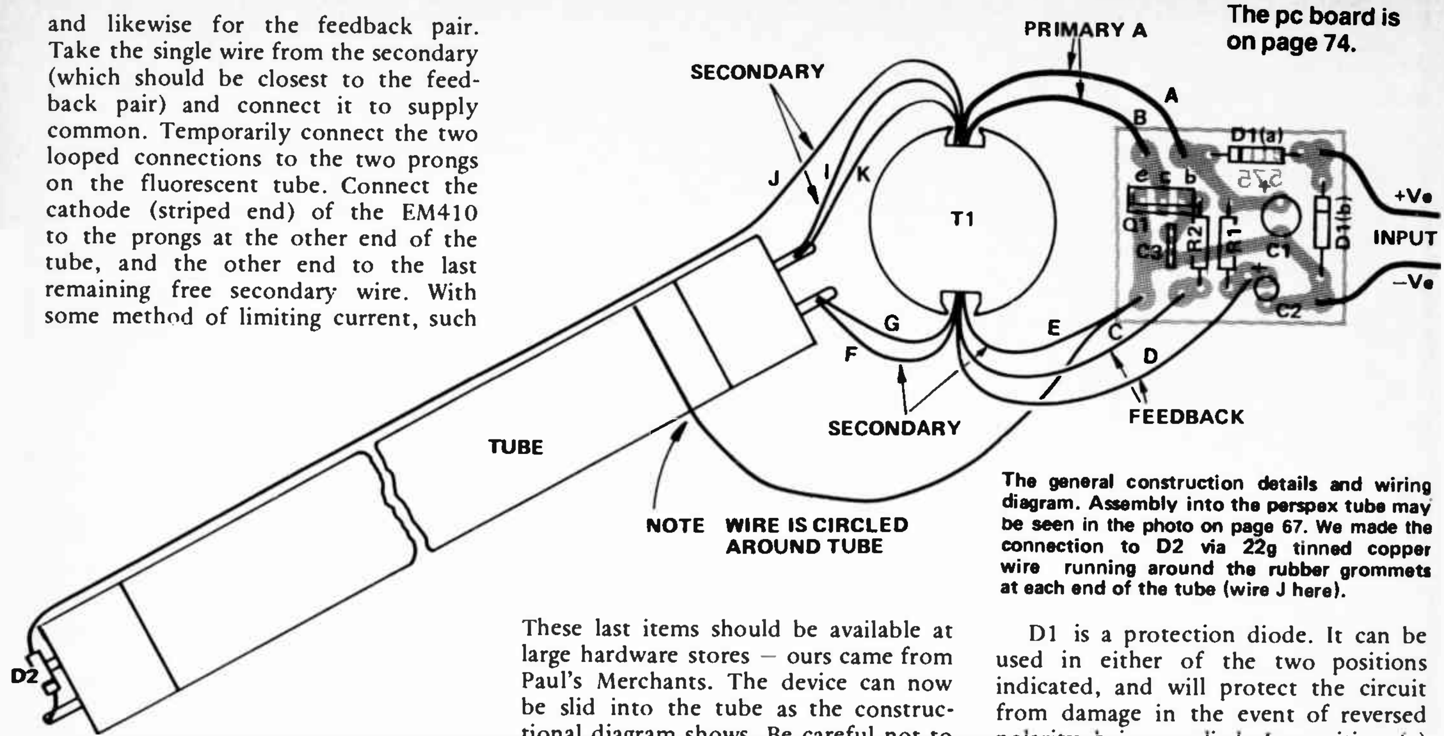
and likewise for the feedback pair. Take the single wire from the secondary (which should be closest to the feedback pair) and connect it to supply common. Temporarily connect the two looped connections to the two prongs on the fluorescent tube. Connect the cathode (striped end) of the EM410 to the prongs at the other end of the tube, and the other end to the last remaining free secondary wire. With some method of limiting current, such as a supply limiting at about 200-500 mA, or a 22 ohm resistor in series with a 12 volt supply, apply power. Now, one of three conditions will exist:

1. No oscillation. If there is ac on the secondary, the device is oscillating. If you wish to check this without a multimeter, bridge the EM410 momentarily. Any flicker indicates oscillation. If there is none, reverse the phase of the feedback winding by swapping its wires. This should get you to condition (2) or (3).
2. Oscillation, but tube glows dimly or only with the EM410 bridged out. This means that the secondary sense is wrong. Swap both the primary and feedback wire pairs. This should get you to condition (3).
3. It works.

Now connect the wires firmly, rather than temporarily as before. Check the power consumption next. If it is more than 400 mA, or the transistor gets too hot to touch, increase R1 to 1K or 1k2. If the whole draws less than 200 mA or is dim, decrease it to 680 or 560 ohms.

The remaining construction is up to you, depending upon how you have chosen to house the assembly. The description which follows pertains to the 8 W version, intended for under-car or camping uses. You will require a 380 mm length of acrylic tube, 26 mm I/D and 32 mm O/D. We purchased ours from FX Plastics, but it is available from any large perspex dealer. Also a pair of 32 mm (1¼") rubber chair feet — the type that push over the tubular legs, and a few grommets which just fit within the acrylic tube.

The pc board is on page 74.



The general construction details and wiring diagram. Assembly into the perspex tube may be seen in the photo on page 67. We made the connection to D2 via 22g tinned copper wire running around the rubber grommets at each end of the tube (wire J here).

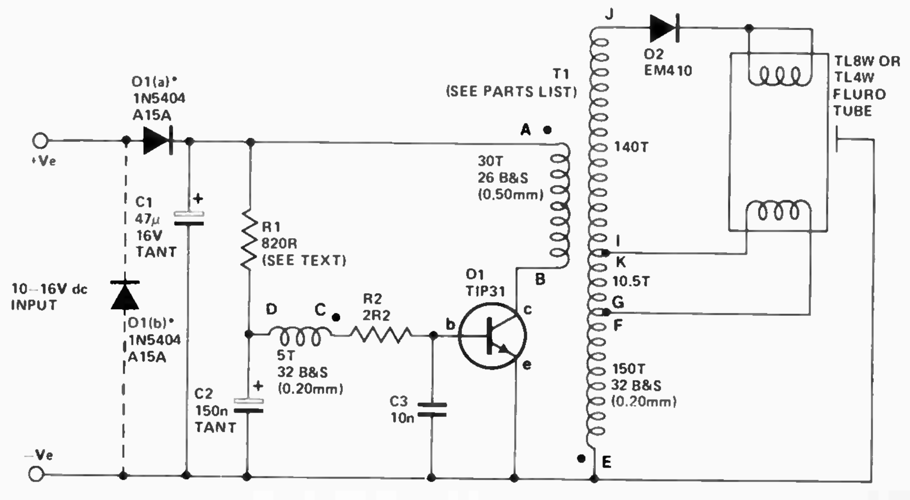
These last items should be available at large hardware stores — ours came from Paul's Merchants. The device can now be slid into the tube as the constructional diagram shows. Be careful not to strain and snap any of the 32 B & S wires — it is singularly disheartening to have to start again! Jam the parts in place with foam rubber or similar padding. You may then fit a suitable connector onto the power cable — we built one 8 W device with alligator clips and a 4 W one with a cigarette lighter plug fitted (for plugging into vehicle dashboard). A reflector may be formed by sliding some white paper behind the tube. We used a card with the project name and number on it.

Circuit notes

This converter circuit is actually much more complex in its operation than the circuit diagram appears! Hence the long 'How it works'.

D1 is a protection diode. It can be used in either of the two positions indicated, and will protect the circuit from damage in the event of reversed polarity being applied. In position (a) it blocks any flow of current in the reversed polarity condition but drops about 0.8 V from the supply in normal operation. Where a car battery or rechargeable battery pack is used and efficiency is not at a premium, this is satisfactory. When the diode is used in position (b) it shorts out the supply in the event of it being connected in reversed polarity. This protection is used when the supply is dry batteries since they cannot deliver sufficient current to destroy D1. No power is lost due to a forward voltage drop in series with the supply during correct operation. Two positions are provided on the pc board for D1; the (a) position must be linked when D1 is used in position (b).

Capacitor C1 is the supply bypass capacitor. Due to the high speed



*D1 IN POSITION (b) FOR DRY CELLS
D1 IN POSITION (a) FOR OTHER CASES

switching transients present this capacitor needs to be a tantalum type. It should be wired close to the rest of the circuit.

Actual power consumption and apparent light output can vary from unit to unit. The amount of power delivered to the tube and hence the power consumption overall can be varied by adjusting R1. The value of 820 ohms is given only a guide. In order to have a current consumption of about 250 mA, which seems to be the best compromise, as little as 560 ohms or as much as 1k2 might be required. Generally, if the supply current exceeds 400 mA R1 should be increased and if starting is unreliable it should be decreased.

One final note; Q1 appears to be very overrated being a 40 W device that can carry many amps. Much more than necessary. However, we have found that transistor dissipation goes up (and efficiency down) if a transistor of smaller rating is used. This seems to be because the beta falls if the knee current is exceeded and the transistor dissipates power during switching as a direct result. Thus, we recommend the use of a TIP31 rather than, say a BD139 or Philips BDY50. ●

PARTS LIST – ETI 575

Resistors	all ½W 5%
R1	820R
R2	2R2
Capacitors	
C1	47u 16V TANT.
C2	150n 35V TANT.
C3	10n Greencap
Semiconductors	
D1	1N5404, A15A or similar
D2	EM410 or similar 1kV PIV diode
Q1	TIP31
Miscellaneous	
T1	Philips 26/16 3H1 ue68 pot core with former, 4322-022-28250 (See 'Shop Around').
F1	Fluorescent tube; TL8W (8 watt) or TL4W (4 watt).

Wire 32 B & S (0.2 mm) and 26 B & S (0.5 mm) enamelled wire.
Perspex tube, 32 mm O.D. by 26 mm I.D., length to suit.
Rubber chair feet, 32 mm I.D. (see text).
Grommets, 26 mm O.D.
Lengths of automotive cable (one red, one black) 24/020 or similar.
Alligator clips or cigarette lighter plug.
Nicad batteries, if used.

HOW IT WORKS – ETI 575

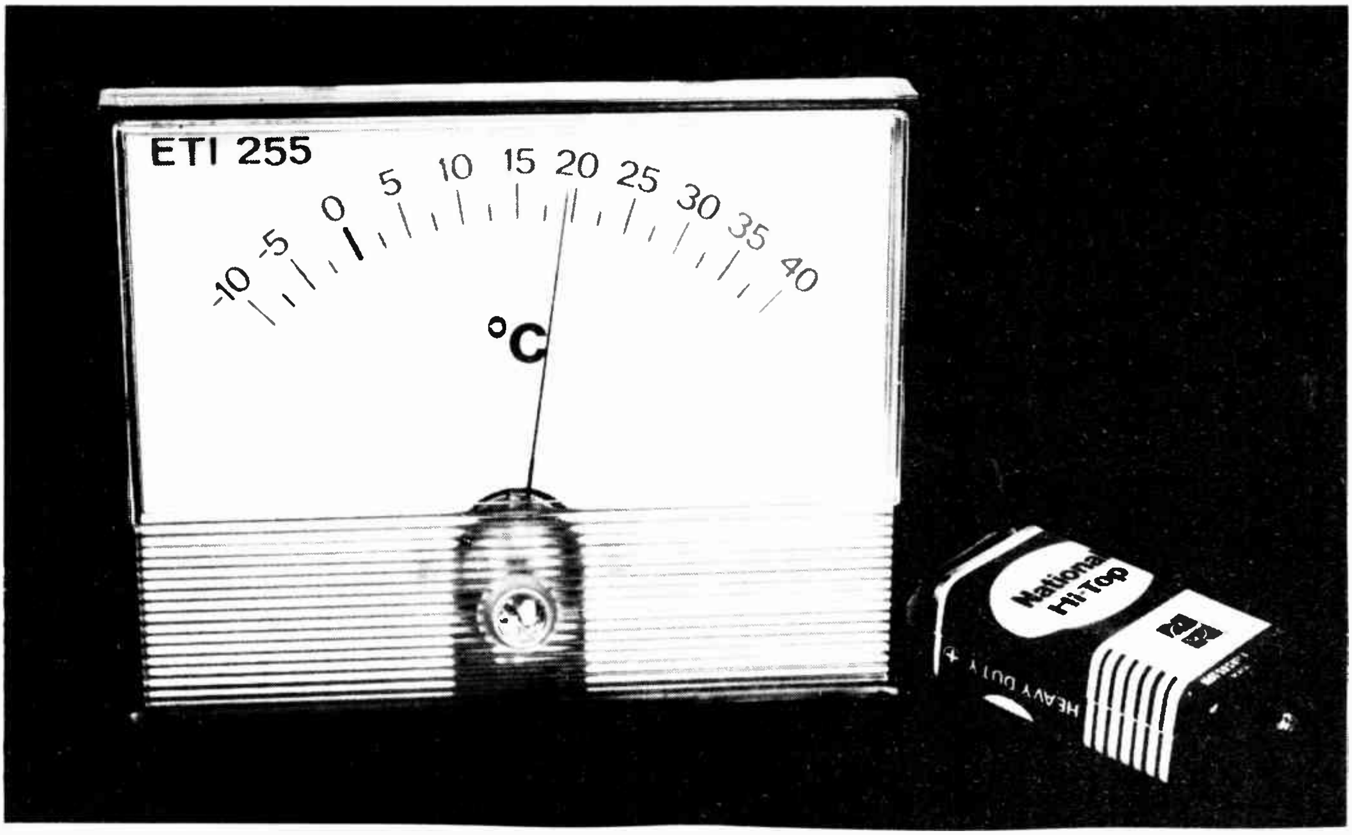
R1, R2, C2, C3, Q1 and T1 comprise a self-oscillating dc-dc converter.

Initially, Q1 is turned off. At switch-on, current flows through R1, charging C2. Subsequently C3 charges up via the five-turn feedback winding and R2. When C3 reaches about 0.55 volts, Q1 begins to conduct. The feedback winding then forces more current into C3 via R2 because of the phase of its connection. Q1 is then turned hard on. During this positive feedback cycle C2 is actually forced to discharge. R2 limits the maximum base current, and C3 removes fast spikes from the base circuit. These together serve to protect Q1's base.

Eventually, the magnetic field induced by the collector current of Q1 in the primary ceases to increase and the positive feedback ceases. Q1 then begins to turn off and the magnetic field in the core begins to collapse. This produces a negative voltage across the feedback winding which biases Q1 hard off. Then the cycle repeats, R1 and C2 defining the frequency and the power delivered to the tube, since a constant amount of energy (equal to I^2_{max} times L) is transferred to the load each cycle.

The magnetic field collapsing in the core induces a very narrow high voltage spike in the secondary. When the unit is first turned on, the fluorescent tube will appear as an open circuit and a high positive potential will be present across it as a result of the 140 turn winding. Also, the negative (cathode) end of the tube is pulled positive by the 150 turn starter winding. As these voltages add a very high potential exists from the anode to the external 'earth' contact. This is enough to force some gas to ionize and the tube breaks down or 'strikes'; This occurs for a few cycles until the 10½ turn winding heats the cathode filament and the tube conducts completely.

Once started, the increased temperature and traces of unrecombined gas permit it to conduct quickly each cycle and the tube no longer relies on the earth electrode for breakdown. Once this condition is reached the secondary voltage is held low by the tube conducting, the inductance of the core and secondary limiting the current, as in a conventional 240 V balast. Diode D2 prevents any conduction in the reverse phase which would upset the magnetic field buildup. If a high voltage is applied to the circuit and D2 is absent ac can flow in the tube and efficiency falls markedly. Hence the circuit in its correct mode acts in a magnetic pumping fashion rather than a pure transformer action. While the cathode is heated, tube life is reduced by the fact that the dc flow of current eventually strips the cathode. Theoretically, when the cathode is stripped to the point of failure the tube should be able to be physically reversed, since the anode end filament will not have been used at all. The tube does however have quite a long life.



Dashboard temperature meter

Jonathan Scott

Clear, easy to read dial makes this little thermometer a useful addition to the dashboard.

THIS TEMPERATURE meter project can stand alone or you can mount it in a desk top or even in the dash of your car if you don't mind cutting a hole for it. (If you've built all the ETI projects for motorists your dash must look like a piece of swiss cheese by now, so one more hole won't matter!)

Why an electronic thermometer, you may ask ? What's wrong with the ordinary mercury-in-glass type that's been with us for hundreds of years? It's hard to read, that's what. You have to go right up close to see the scale. And mercury thermometers are fragile, too.

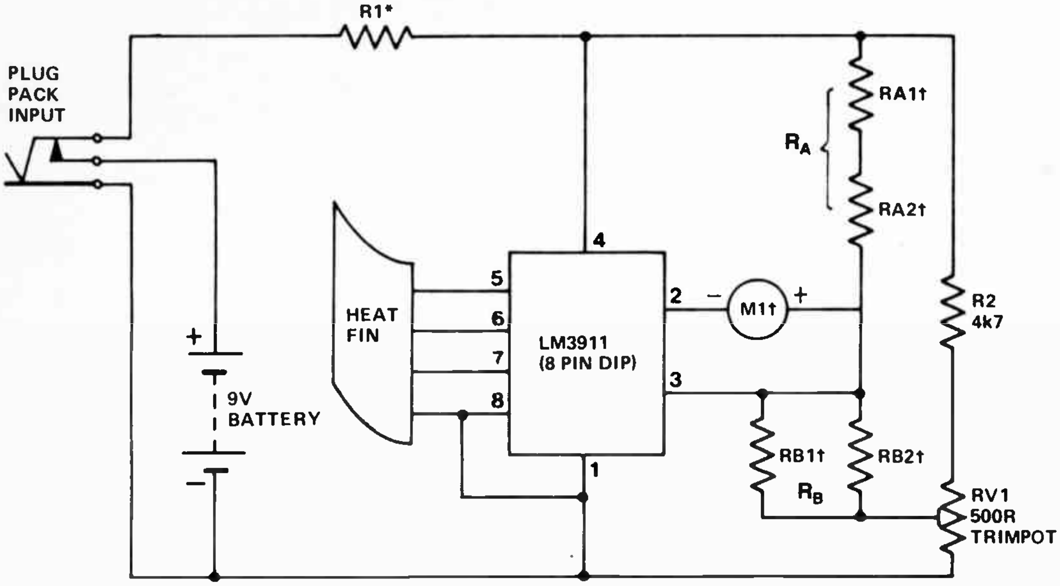
If you want to be able to read off temperature on a nice clear dial you need some kind of electric or electronic sensing element. There are several kinds of sensors you might use, including thermocouples, thermistors and diodes, all of which have their own advantages and drawbacks.

We chose to use a temperature sensing IC, the LM3911, recently introduced by National Semiconductor. There's a more detailed description of it on page 72, but basically it relies on the well-known fact that a transistor's base-emitter voltage varies with temperature — the warmer the transistor gets the greater the b-e voltage.

Because the LM3911 chip includes its own amplifer, it's very easy to use it to drive a meter. Apart from the IC and the meter, the only components in this project are five resistors and a trimpot. By choosing different values of resistors, you can build this temperature meter so that it indicates any temperature range you choose as long as it's between −25°C and +85°C.

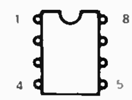
We've specified resistor values to make the meter read from −10°C to +40°C, which should be fine for most locations, but in case you live somewhere like Birdsville we've also given values for a temperature range of −10°C to +90°C. But you don't have to stick to the ranges we suggest. Opposite you'll find formulae for calculating the necessary resistance values for any temperature range.

One more useful feature of this project ▶



IC

TOP VIEW



*R1 = 470R (¼W or ½W) for 9 V operation; 1k8 for 12 V battery (11 - 15 V) operation.
†See table below for resistor values to suit different meter ratings.

The printed circuit board pattern is on page 74.

HOW IT WORKS — ETI 255

Almost all the functions take place inside the LM3911 chip. Pins 5 - 8 are thermally connected to an internal temperature sensor circuit and transmit the external temperature from a small sheet of copper. The copper fin will generally be at air temperature.

An internal voltage reference, connected between pins 1 and 4, regulates the supply rail to 6.8 volts for the chip and external circuitry. The dropping resistor R1 sets the current to about 3.5 mA, maintaining about 1.2 mA to the IC and about 2.5 mA to the external circuit. It is desirable to keep the current into the IC as low as possible to prevent excessive temperature rise in the chip giving rise to inaccurate readings.

An internal op-amp sinks current from pin 2 in order to hold the voltage on pin 3 at a level which is linearly proportional to the temperature on the sensing pins. The meter, M1, monitors the current into pin 2 giving a reading which is directly proportional to temperature. The resistors R_A and R_B are calculated to give the required zero reading and full-scale temperatures. We have included a table with suitable values as well as formulae so you can roll your own.

The meter reading is linear with temperature and is calibrated to cover the desired range.

The trimpot RV1, compensates for variations between different ICs as well as compensating for temperature rise within the chip.

SUGGESTED VALUES

Range (°C)	Meter F.S.D.	R_{A1}	R_{A2}	R_{B1}	R_{B2}
0 to +100 (note: 85 max.)	100 μA	10k	6k8	27k	270k
0 to +50	50 μA	10k	6k8	27k	270k
−10 to +90	100 μA	8k2	8k2	27k	480k
−10 to +40	50 μA	8k2	8k2	27k	480k
−10 to +40	100 μA	8k2	zero	82k	15k

NOTE: maximum rated temperature is 85°C; minimum is −25°C.

Other temperature ranges can be covered, within the specified limitations of the LM3911, the required range resistor values being calculated from these formulae:

$$R1 = \frac{V_s - 6.9}{0.0035} \quad \ldots\ldots (1)$$

V_s = supply voltage

$$R_A = R_{A1} + R_{A2} \quad \ldots\ldots (2)$$

$$R_B = \frac{1}{1/R_{B1} + 1/R_{B2}} \quad \ldots\ldots (3)$$

$$\text{Let } T_1 = T_0 + 5 \quad \ldots\ldots (4)$$

using equation (4), calculate 'M'

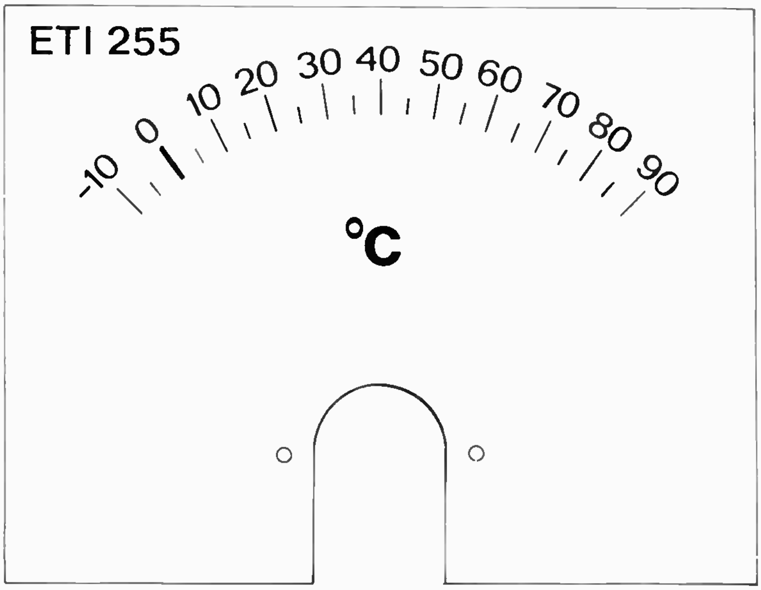
$$M = \frac{T_1}{685} \quad \ldots\ldots (5)$$

where T_0 = zero scale reading in °K
and T (°C) = T(°K) − 273 ...... (6)

$$\text{then } R_B = \frac{10^4}{M.s} \quad \ldots\ldots (7)$$

$$\text{and } R_A = \frac{10^4}{s(1-M)} \quad \ldots\ldots (8)$$

where s = meter sensitivity in μA/°C
(For example: if you choose a 100 μA meter and wish to cover a range of 50°C, then s = 2 μA/°C)



Full size artwork for meter scale covering −10°C to +90°C. Note that the limit for the LM3911 is +85°C.

THE LM3911 — HOW IT WORKS

The LM3911 is a highly accurate temperature measurement IC for use over a —25 C to +85 C temperature range. Fabricated on a single chip it includes a temperature sensor (pins 5 — 8), stable voltage reference (pins 1 and 4) and an operational amplifier.

The output voltage on pin 2 is directly proportional to temperature in degrees Kelvin having a sensitivity of 10mV/°K. By using the appropriate external resistors with the internal op-amp, any temperature range can be selected.

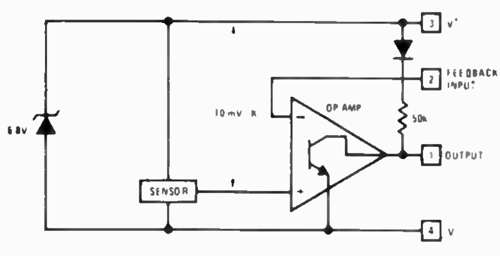
An active shunt regulator across the supply pins provides a stable 6.8 volt reference for the sensing circuitry, and allows the use of any supply voltage with the correct dropping resistor.

The input bias current is low and relatively constant with temperature to ensure high accuracy when a high source impedance is used. The output pin can be returned to a supply up to 35 volts to allow the circuit to drive lamps or relays.

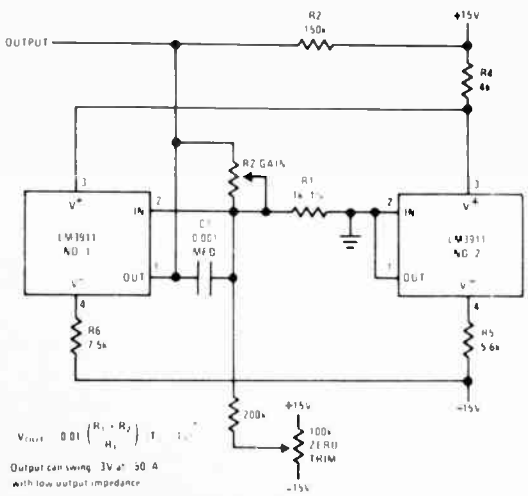
The temperature sensing element uses the difference in base-emitter voltages of two transistors operating at different current densities. Since this output depends only on transistor matching, very good stability and reliability can be obtained.

The op-amp can either be connected as an amplifier to give a linear temperature/voltage output or as a comparator to switch the output at a preset temperature. Therefore, the device can be used either as a measuring instrument or as a temperature controller.

The output can be calibrated for degrees Celsius, Fahrenheit or Kelvin.



Internal block diagram of the LM3911.



*The 0.01 in the above equation is in units of V/°K or V/°C and is a result of the basic 0.01 V/°K sensitivity of the transducer

Two LM3911s can be configured as a differential thermometer.

is that the meter doesn't need to be closely connected to the IC and the rest of the circuitry. You could, for example, have the electronics outside the house and the meter inside, so you could find out how cold it is outside without having to open the door and get chilled. Or less frivolously, suppose you're trying to grow exotic plants in a controlled temperature hothouse, you could use our project as a remote indicating thermometer to keep a check on their environment.

Construction

The entire circuit, including the heat fin, is assembled on a small pc board which is then mounted onto the rear of a moving coil meter. Connection to the meter is made by large copper pads on the pc board which can accommodate a variety of meters with different terminal sizes and spacings.

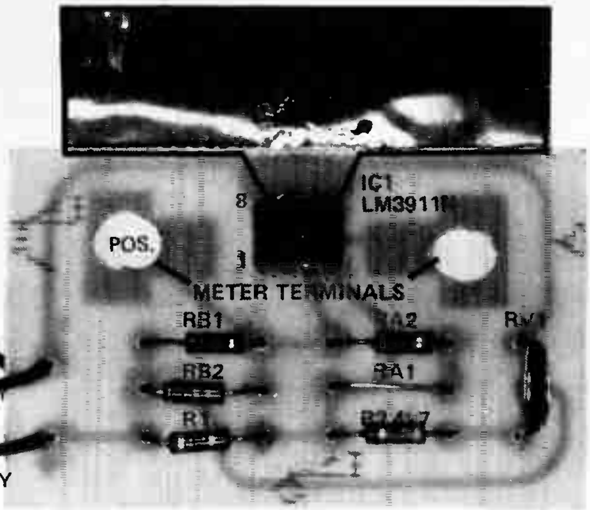
The thermometer can be mounted in a small plastic box, fitted into a car dash or perhaps built into a neat, desk-top unit for the 'shack'. Whichever you choose, be sure to leave a large enough hole in the box to allow free air flow across the heat fin so the meter reads the room air temperature and not that inside the box. If a remote reading unit is required the pc board can be mounted away from the meter.

The first job is to drill the holes into the pc board to suit the type of meter you have. Next fit all the components as shown in the overlay, taking care with the orientation of the IC and the polarity of the battery or power supply connections. The value of R1 is different depending on whether the unit is operated from a 9 V supply (battery or plugpack) or a 12 V supply (vehicle battery or plugpack). Values are beneath the circuit. The values of R_A and R_B are selected from the table for the required temperature range and meter used. Note that R_A consists of two resistors in series (R_{A1} and R_{A2}), while R_B consists of two resistors in parallel (R_{B1} and R_{B2}). Either 2% tolerance or selected 5% tolerance metal film resistors should be used for the sake of accuracy.

Power from a plugpack is applied through a shorting type socket so the unit can be battery operated when the plugpack lead is removed.

The 50 mm by 20 mm heat fin is cut from a small piece of 0.25 mm thick copper shim. Solder it to the pc board track connected to pins 5 - 8 of the IC (see overlay photo). A larger size fin may be used, but we found this one works nicely. In fact, the circuit will work well without any heat fin, but has a longer response time. Make sure the

Copper sheet connected to pins 5 – 8 of IC1



0V from PLUGPACK SOCKET AND BAT

+9V from PLUG PA SOCKET AND BATTERY

Rear view of the instrument showing general assembly. You may prefer to use a rechargeable NiCad type, rather than the dry battery shown, for battery operation of the unit.

fin is not touching any other part of the circuit.

Finally, fit the meter after cleaning the meter pads on the pc board. The spring washer supplied with the meter should be assembled on the copper side of the board so it digs into the surface of the copper for good contact. If this is not done the meter connections may become a high resistance when the copper tarnishes after use.

PARTS LIST — ETI 255

IC1	LM3911N
R1	470R or 1k8
RA1	See table
RB1	"
RA2	"
RB2	"
R2	4k7

All resistors should be 2% or selected 5%, ¼W or ½W metal film types.

RV1	500R miniature vertical mounting trimpot
M1	50 or 100 microamp meter (to suit range). University TD 106 or similar

ETI-255 pc board; case (if required); plug pack adaptor socket and 9V Plug Pack (Ferguson PPA-9/500 or similar); 9V battery (No. 216) and battery clip if required; small piece of 0.25 mm shim copper.

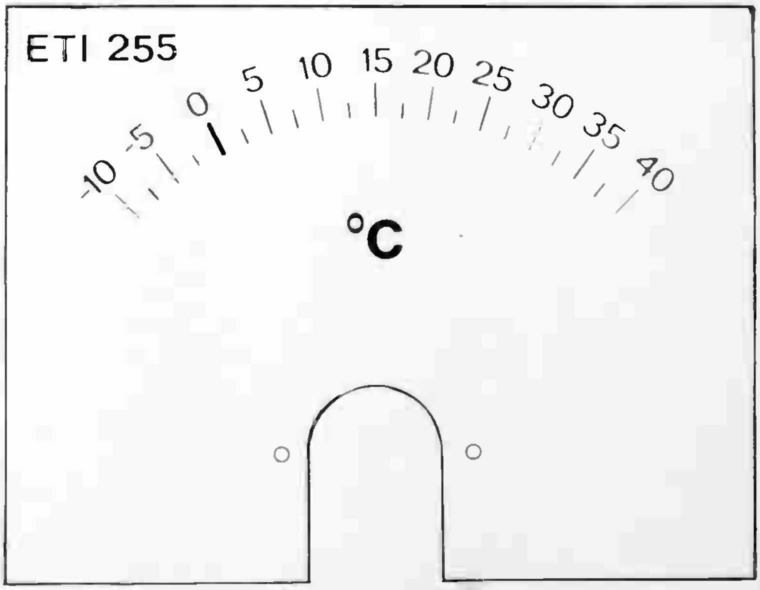
Apply power and adjust the zero set trimpot which should be capable of adjusting the reading about +/- 10°C.

Calibration

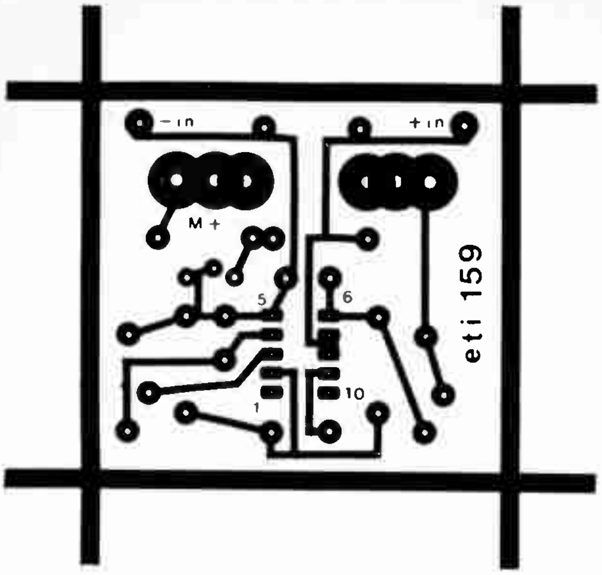
Place the unit and a reference thermometer (choose a good one) in a cool place close together and after a few minutes note the difference in readings. Adjust the trim pot for the correct reading.

Two different meter face scales have been included for two temperature ranges, −10°C to 40°C and −10°C to 90°C. Values have also been calculated for 0°C to 50°C and 0°C to 100°C scales to allow standard scales on 50 µA and 100 µA meters to be used. ●

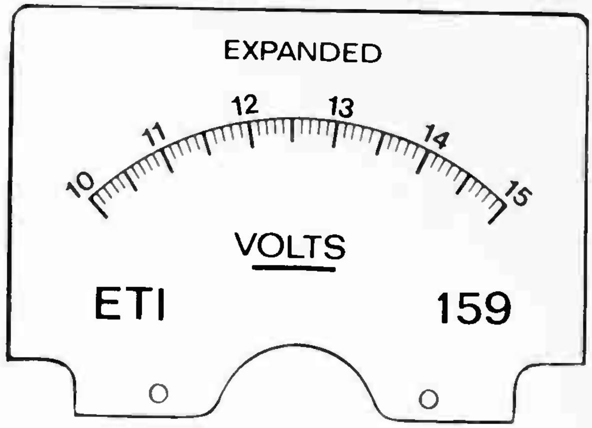
Full size artwork for meter scale covering −10°C to +40°C. Scotchcal meter scales will be available from suppliers — see Shoparound on page 97.



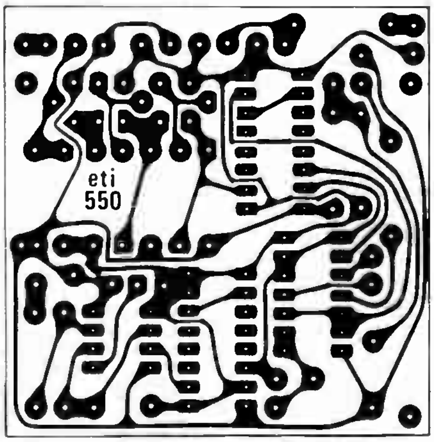
PCBs



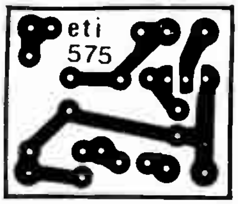
− in
+ in
M +
5
6
1
10
eti 159



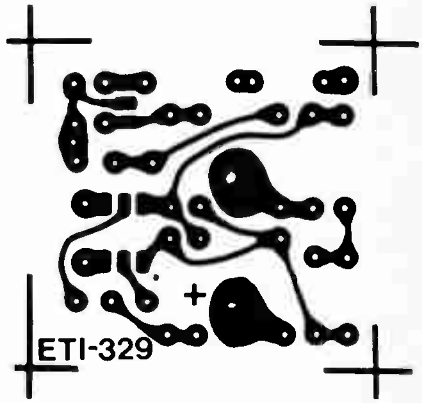
EXPANDED
10
11
12
13
14
15
VOLTS
ETI
159



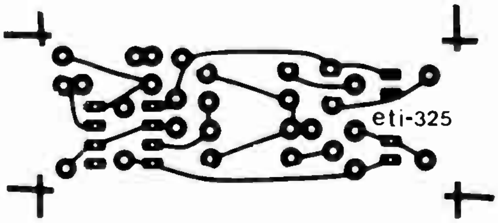
eti
550



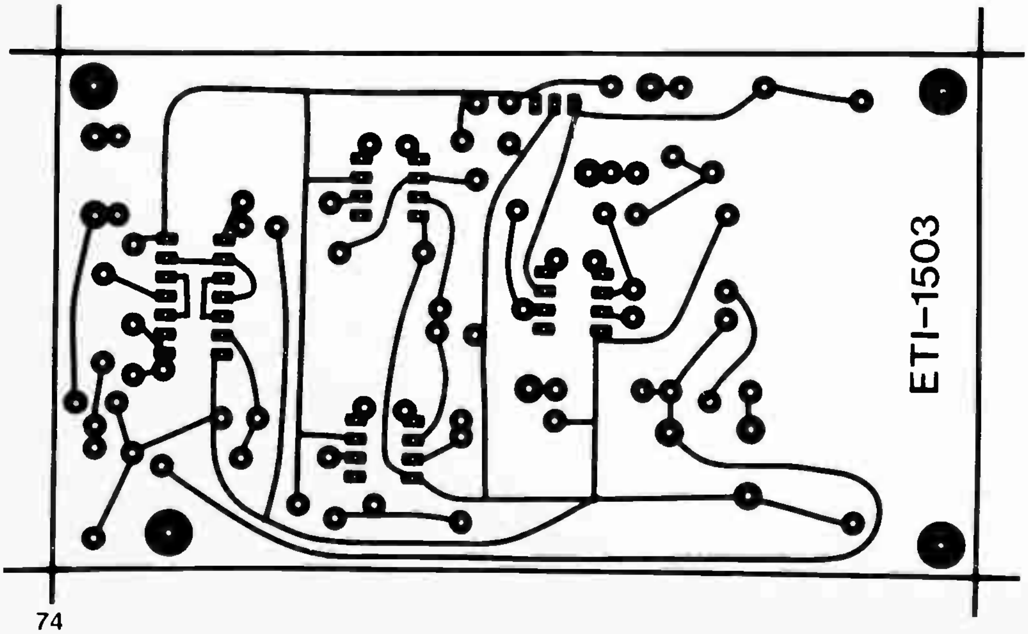
eti
575



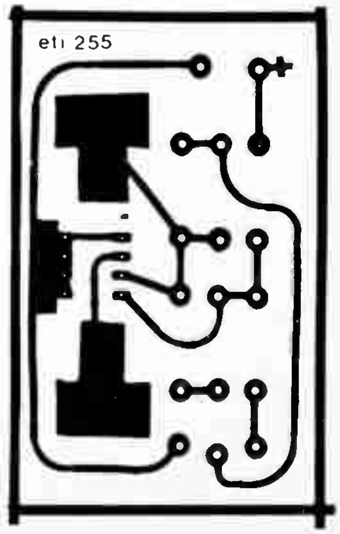
+
ETI-329



eti-325



ETI-1503



eti 255
+

'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.

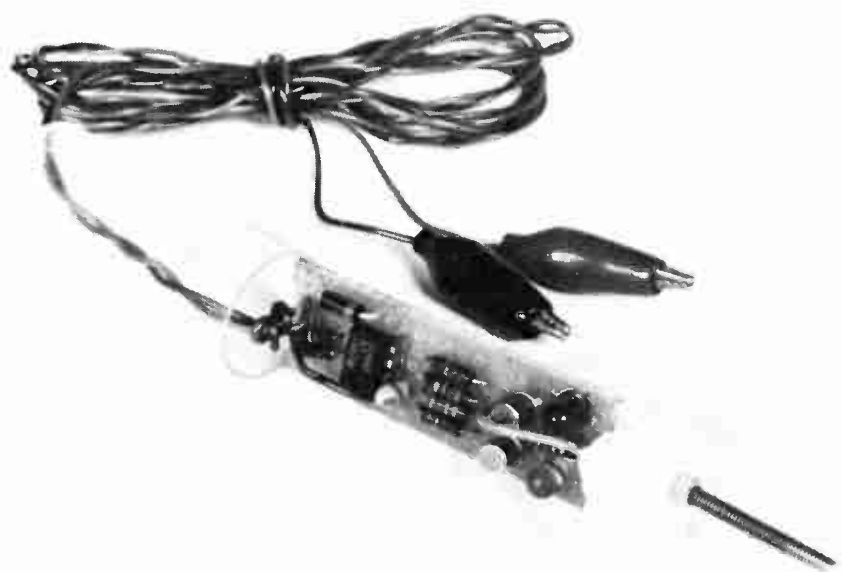
Sorting out the wiring can be a nightmare – especially on motorcycles.

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

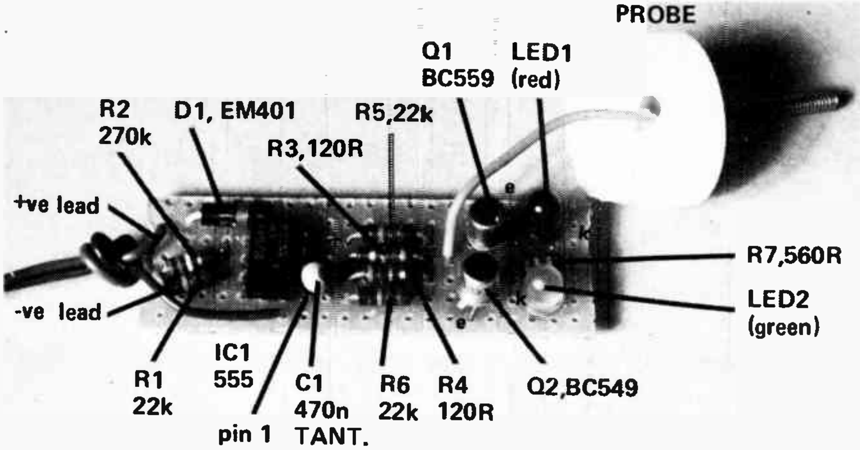
Let us consider the case of a car radio that has 'stopped working'.

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.

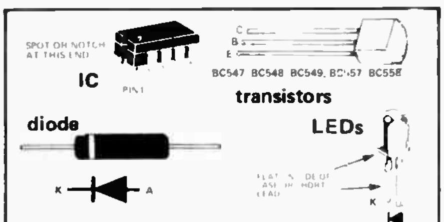
many late-model vehicles) a resistance lead is used – they're hard to spot.

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).

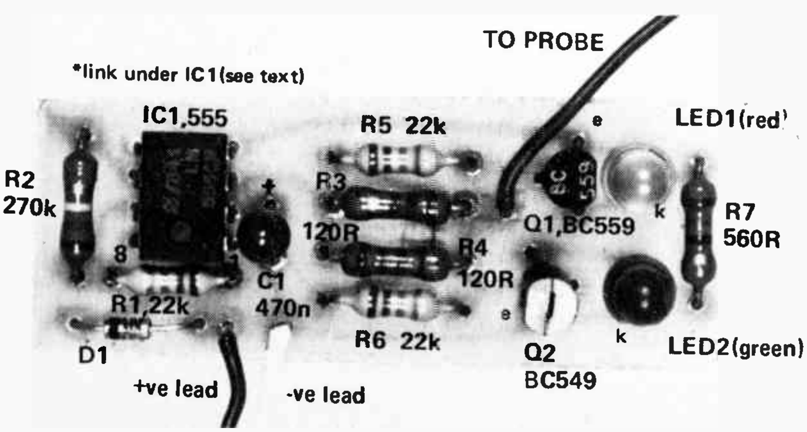
It is probably easiest to commence by mounting the two LEDs and the two transistors. You have to take some care when assembling a project on matrix board as the connections between the components are made under the board, using the component leads. Carefully study the overlay picture to see where the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

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).

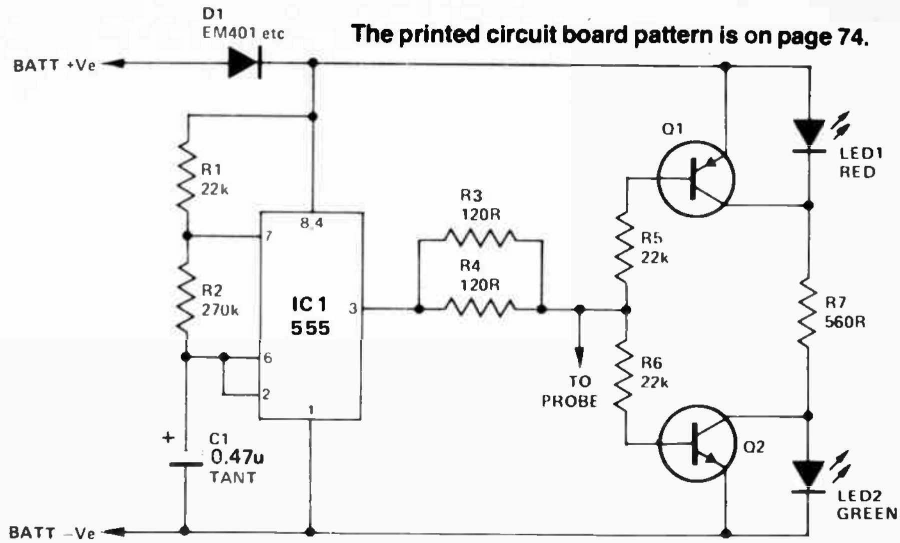
READERS PLEASE NOTE
We do not sell kits or components for the projects described in this book. To find out who may be stocking kits or components for the projects featured, please refer to the 'Shoparound' page on page 97.

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 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.



The printed circuit board pattern is on page 74.

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 current flowing from pin 3 of the 555, via R3/R4, is insufficient to develop 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.

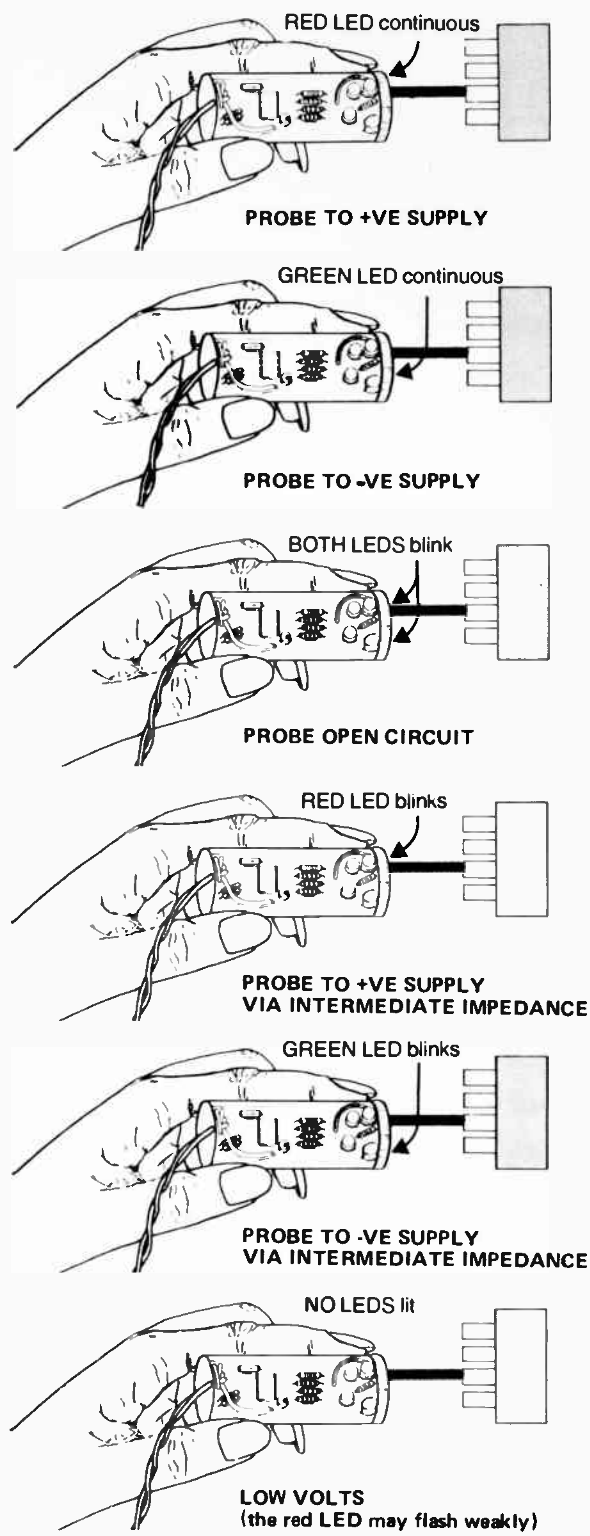
However, if the resistance is not high enough to allow the junction of R5/R6 to go far enough positive the red LED will not turn on. This gives green only blinking.

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

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

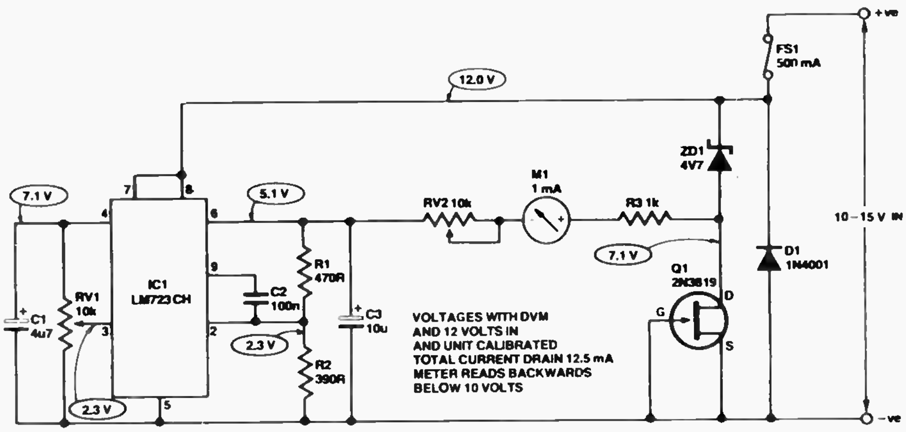
Roger Harrison

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, page 50) 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

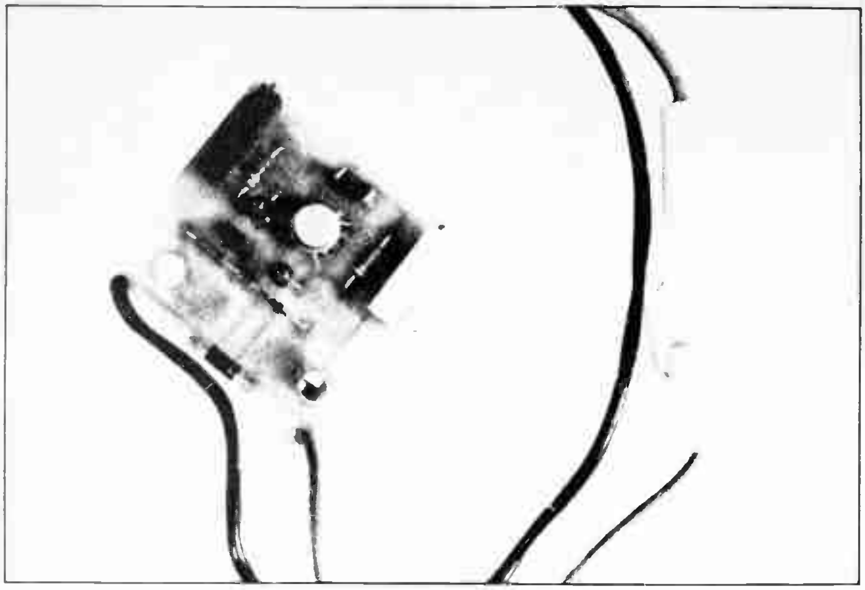
HOW IT WORKS — ETI 159

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.

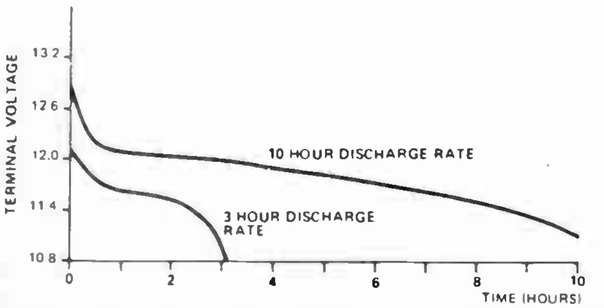


Figure 1 Typical discharge characteristics of a 12 V (nominal) lead-acid battery.

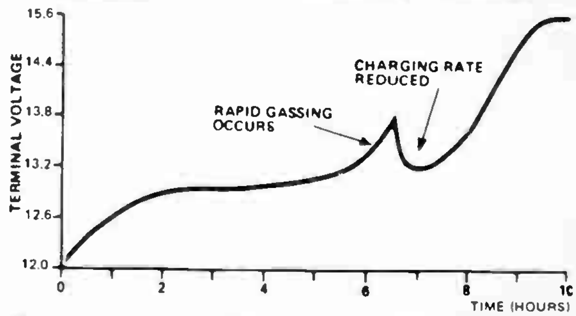


Figure 2 Charging characteristics of a 12 V (nom.) lead-acid battery. The 'kink' in the curve near 6 hrs is explained in the text.

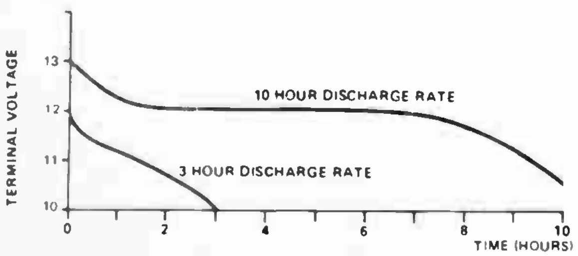


Figure 3 Typical discharge characteristics of a 12 V (nom.) nickel-cadmium battery (usually consisting of 10 cells in series).

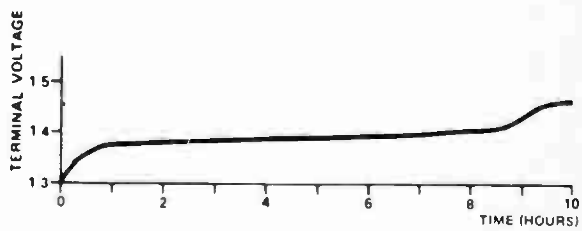


Figure 4 Typical charging characteristics of a 12 V NiCad battery (10 cells) charged with a constant current at one-tenth rated capacity (0.1C).

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.

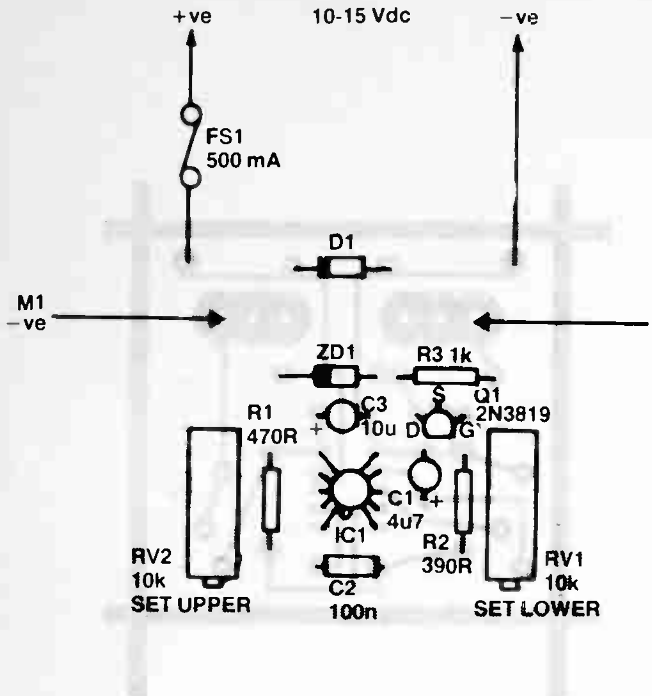
That's all very well for common wet cell batteries, but measuring the electrolyte S.G. of sealed lead-acid or nickel-cadmium batteries is out of the question.

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

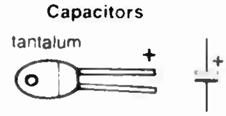
Fortunately, the terminal voltage is a good indicator of the state of charge or discharge. In general, the terminal voltage of a battery will be at a defined minimum when discharged (generally between 10 and 11 volts), and rise to a defined maximum when fully charged (generally around 15 volts). Under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

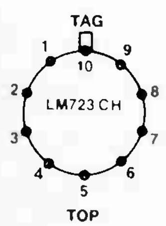
Hence a voltmeter having a scale 'spread' to read between these two extremes is a very good and useful indicator of battery condition. It's a lot less messy and more convenient than wielding a hydrometer to measure specific gravity of the electrolyte!

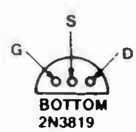
The charge and discharge characteristics of typical lead-acid and sealed NiCad batteries are given in the accompanying figures.

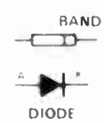


Capacitors









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 74.

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. ●

Versatile electronic stethoscope

Design: Ray Marston
Development: Simon Campbell

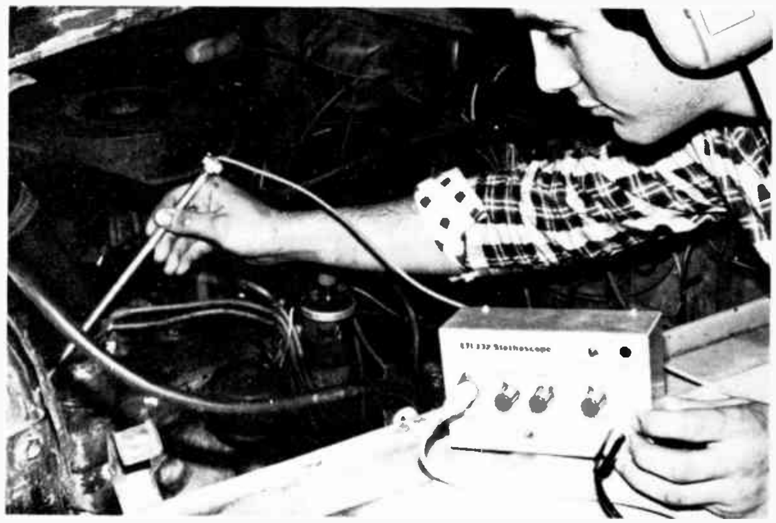
This unusual device can be a very handy tool for those who work with mechanical contrivances — anything from tractor engines to drill presses to watch mechanisms. Thrill to the clatter of clagged-out tappets, the grind of graunched bearings, the tick-tock of escapements . . .

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

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

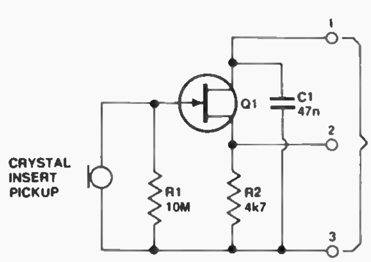
The stethoscope comprises an acoustic probe unit using some sort of microphone (several combinations are possible), the electronic 'clever bits' and a pair of standard stereo headphones. The probe unit is arranged to make mechanical contact with the machinery or object being examined and is coupled to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

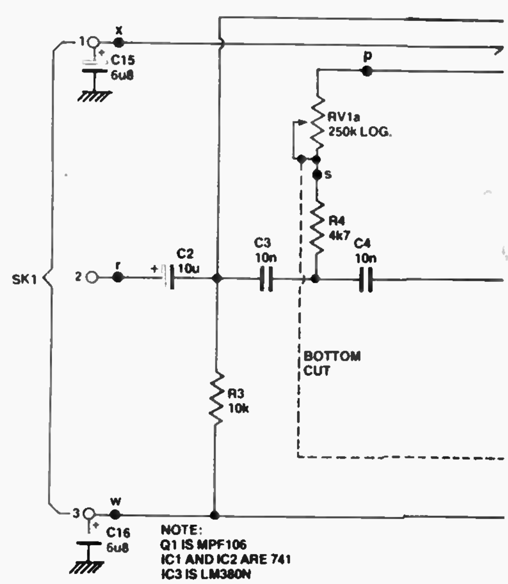
Sound is readily transmitted through the housing of any machinery, be it the engine block of a petrol motor, the case of a watch or clock, etc. This can be further transmitted through an object, such as a metal rod or a screwdriver, brought in contact with the machinery.


Using the stethoscope to listen to the water pump in a car engine.

The electronics

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





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

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

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

Construction

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

HOW IT WORKS — ETI 332

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

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

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

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

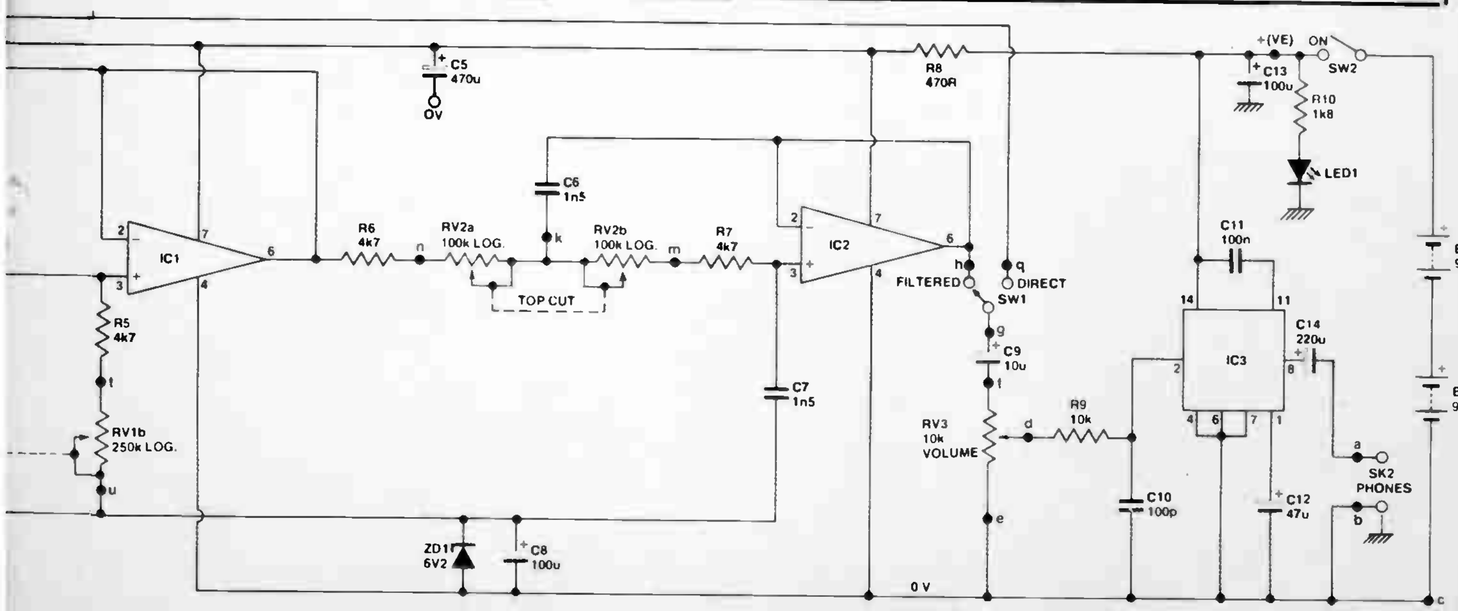
As stated earlier, high impedance crystal type mics require a high-to-low impedance buffer. This is the function of Q1 and associated components, R1, R2, C1. This is a simple source follower circuit, Q1 being a JFET device. Capacitor C1 provides a supply rail bypass.

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

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

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

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



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

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

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

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

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

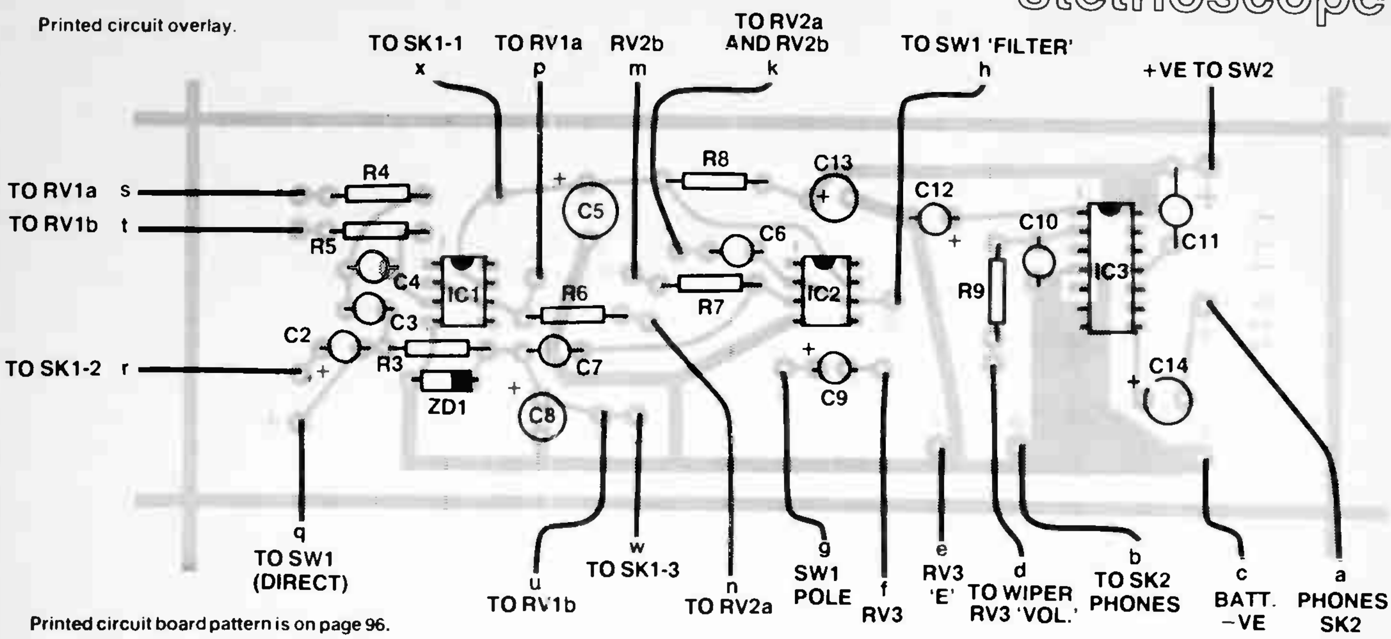
The wiring between the pc board and external components may be tackled next. Follow the wiring diagrams for this stage of the construction, checking each set of wires as you proceed.

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

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

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

Printed circuit overlay.



Printed circuit board pattern is on page 96.

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

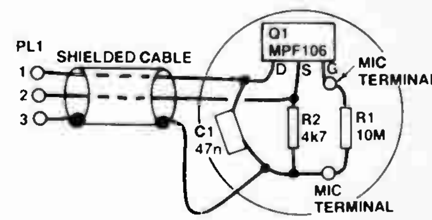
When you've finished your probe you can test it by simply coupling it to the speaker of a small portable transistor radio. Check that the filter controls function by varying them across the full range.

Using it

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

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

Happy listening! ●



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

PARTS LIST — ETI 332

Resistors	all ½W, 5%
R1	10M
R2, 4, 5, 6, 7	4k7
R3, R9	10k
R8	470R
R10	1k8
RV1	250k/C dual log
RV2	100k/C dual log
RV3	10k/C log
Capacitors	(all electros single-ended)
C1	47n polycarbonate
C2, C9	10u/25 V electro
C3, C4	10n greencap
C5	470u/25 V electro
C6, C7	1n5 greencap
C8, C13	100u/25 V electro
C10	100p ceramic
C11	100n greencap
C12	47u/25 V electro
C14	220u/25 V electro
C15, C16	6u8/25 V tantalum
Semiconductors	
IC1, IC2	741
IC3	LM380
Q1	MPF106 or similar
LED1	TIL220R red LED, or sim
Miscellaneous	
SW1	SPDT toggle switch
SW2	SPST toggle switch
PL1	3-pin DIN plug
SK1	3-pin DIN socket
SK2	6.5 mm stereo headphone socket (or to suit plug-on headphones)
B1, B2	No. 216 9 V batteries and clips to suit

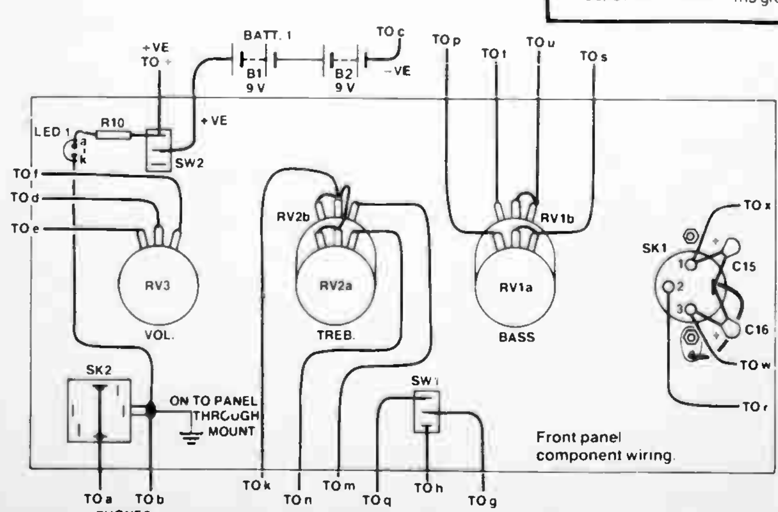
ETI-332 pc board, case — 150 x 95 x 55 mm or similar (we used a K&W model C642), three small collet knobs or similar, Scotchcal front panel, one crystal earpiece or crystal mic insert, rod or tube for probes, two-core shielded cable, one pair of 8 ohm headphones (higher impedance types will also be OK),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

Price estimate

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

$35 - $40

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



Front panel component wiring.

INSTALLING A RIG IN YOUR VEHICLE WITHOUT HASSLES, HICCUPS OR HOWLS OF RAGE

INSTALLING a transceiver in your car or other vehicle requires some planning and forethought to obtain the best utilisation of the equipment (apart from the general technical requirements of an installation).

Most transceivers are supplied complete with suitable mounting brackets, a typical mounting being illustrated in Fig. 1. The transceiver may be mounted to the underside of the instrument panel or the dashboard of a truck or car, etc, by means of this bracket.

Choose a location for the transceiver which allows easy access to all the controls. As transceivers and their mounting arrangements differ (as do dashboards), how you go about this depends on your individual situation. Picture (left) shows a transceiver mounted in a Range-Rover.

In some vehicles it may be better to mount the transceiver on top of the instrument panel, the mounting bracket then going under the transceiver, opposite to the arrangement illustrated in Figure 1. Another alternative is to mount the transceiver from the roof of the vehicle out of the way of the driver's head.

An external speaker is an advantage in many situations particularly where the internal transceiver speaker is partially obscurred — most transceivers have the speaker mounted on the underside of the case. Car radio speaker installations are perfectly well adapted to this use.

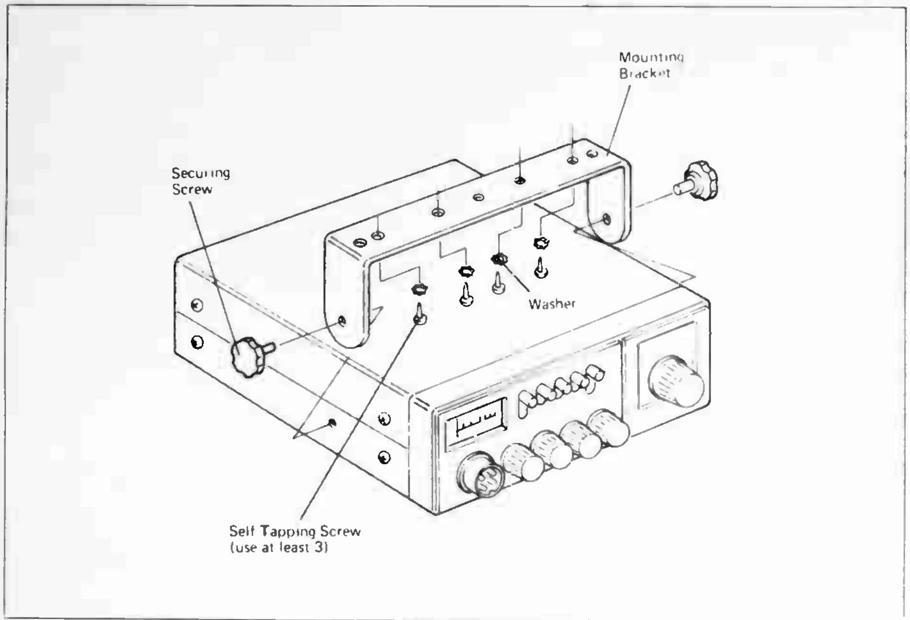


Figure 1. (Above) Typical installation arrangements for a mobile CB rig.

Speakers made for vehicle installation are readily available and anything suitable may be used as an external speaker for your transceivers generally have an 'external speaker' socket and a suitable plug can be obtained. Connections should be made in accordance with the manufacturer's recommendation, or you can get a qualified person to do it.

DC POWER CONNECTIONS

As the majority of transceivers made are intended generally for mobile operation from a vehicle of some sort, they are run from a nominal 12 Vdc power source, this being what most vehicles use for their battery electrical systems (in practice the voltage will be more like 13.8 V). Most transceivers can operate from either a negative earth or a positive earth electrical system, but it is wise to check this before installing (or buying!) your equipment. If the transceiver works only on positive earth systems, your vehicle must have a positive earth electrical system.

In general, transceivers are supplied with a power lead and connector. The leads are usually colour-coded: red for the positive lead and black for the negative lead.

Before making any power connections, determine whether the vehicle, boat, etc, has a negative or positive earth electrical system. Reverse connection could damage or destroy the transceiver circuitry. The red power lead connects to the '+' (positive) side of the electrical system and the black lead to the vehicle '—' (negative) side of the electrical system.

For *negative* earth systems, connect the *red* lead to the accessory terminal on the ignition switch, the voltage regulator side of the ammeter, or the accessory side of the fuse block. The *black* lead should be connected to the chassis of the vehicle in the case of cars, trucks etc, or any point which is connected to the *negative* side of the vehicle electrical system (earth).

For *positive* earth systems, connect the *black* lead to the accessory terminal on the ignition switch, the voltage regulator side of the ammeter, or the accessory side of the fuse block. The *red* lead should be connected to the chassis of the vehicle in the case of cars, trucks etc, or any point which is connected to *positive* side of the vehicle electrical system (earth).

An 'in-line' fuse may be included in the power lead of the transceiver or you may delete this and use the vehicle fusing system. In either case a fuse of a suitable rating should be used; generally a 3 A or 4 A fuse is suitable for most 5 W, 27 MHz transceivers.

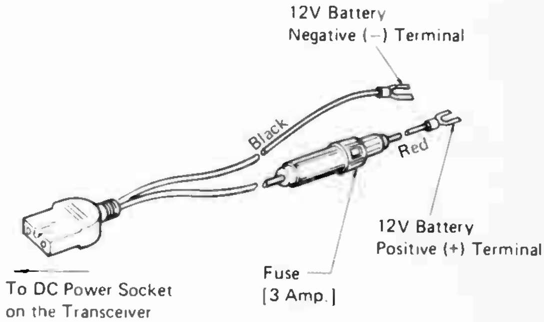
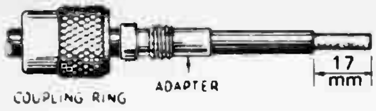


Figure 2. The DC power lead of most mobile CB rigs includes an 'in-line' fuse and is connected as illustrated.

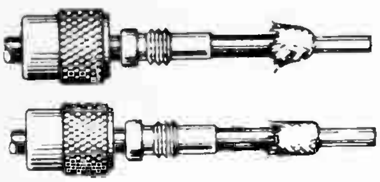
ANTENNA INSTALLATION

Whatever antenna is chosen, it should be installed, so far as is possible under the circumstances, as high as possible on the vehicle or boat, and as centrally as possible. This ensures that the antenna radiates well in most (or all) directions towards the horizon.

On a car, mounting the antenna in the centre of the roof is the best position — except on convertibles or soft-tops. The antenna may be mounted on one of the front or rear cowls however, or at the centre of the car, over the trunk compartment or boot. Gutter mounted antennas are available also, and represent a reasonable compromise. Bumper mounted whips are generally not as good as any of the others,

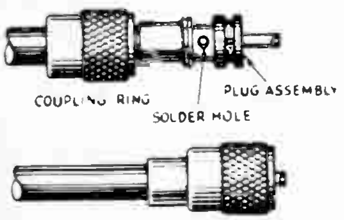


(a) Cut end of cable evenly. Remove vinyl jacket for 17 mm back from end . . . don't nick the braid. Slide coupling ring and adapter on cable.



(b) Fan out the braid slightly and fold it back over the cable. Then compress the braid around the cable.

(c) Position the adaptor shoulder about 37 mm back from the end of the cable. Press the braid down over the body of the adapter to the dimension shown and trim it. Next, bare the centre conductor at the end by removing 13 mm of the insulation . . . don't nick the centre conductor. Tin the exposed portion of the centre conductor.



(d) Screw the plug assembly on the cable and adapter. Solder the centre conductor into the centre pin of the plug assembly. Solder the braid to the plug assembly through the solder holes. Use a hot iron with good heat capacity. Finally, screw the coupling ring onto the plug assembly.

Figure 3. How to correctly assemble a PL259 coax plug on coaxial cable.

although some special types may be obtained which overcome the disadvantages of this method of mounting but they are generally quite large compared to other types available.

Roof mounted antennas have the drawback that they are prone to being 'wiped-off' by trees, low awnings, garage doors etc.

Care should be taken when mounting the antenna that it is not close to any large structure on the vehicle — particularly if it is of metal. Cowl mounted antennas should be mounted somewhat away from the passenger compartment on a car so as not to upset the antenna performance — it is influenced, but this can be minimised by installing the antenna as just mentioned. A good bond to the metal chassis of the vehicle is required as part of the antenna feedline connection — depending on the particular construction of the antenna. Follow the manufacturer's instructions.

THE ANTENNA FEEDLINE

A coaxial cable is used to connect the antenna to the transceiver. This consists of a flexible inner conductor surrounded by plastic insulation which is in turn covered by a woven wire braid. This is then covered by a protective plastic sheath. The most common type used is called RG58 and is about 6-7 mm overall diameter. Antenna manufacturers generally provide either some sort of connecting terminals for the feedline, or a socket.

The most commonly used socket on antennas and transceivers is the type SO-239 coax socket. This accepts a type PL-259 plug which is assembled on to the feedline. Apart from basic plugs and sockets, a wide range of adaptors and other connectors are available; such as female-female connectors (back-to-back sockets) for joining lengths of cable with PL-259 connectors on the end, right angle connectors that have a plug on one end and a socket on the other, tee-connectors, etc.

The common PL-259 plug requires soldering but solderless types are available and are equally as good if properly assembled. Step by step instructions for installing the common PL-259 plug are given in Fig. 3.

The length of feedline between the transceiver and the antenna should be as short as practicable, but route it so that it is not likely to be trodden on or damaged in any other way. Sharp bends should be avoided and the cable protected from chafing or any other sort of wear. Connections and connectors should be protected to prevent the ingress of moisture, particularly at the feedline connection to the antenna. Wrapping joints and connectors in insulation tape should only be regarded as temporary measures. Sealing compounds which remain pliable, such as Silastic or Selley's sealing compound, offer excellent protection and can be moulded to suit the application.

HOW TO STOP THAT POP IN YOUR SET

Anything that makes a spark, no matter how tiny that spark may be, transmits a burst of radio 'noise' that is heard in your receiver as a 'pop' or 'click'.

When there are lots of sparks coming close together, as they do in an engine ignition system, a receiver close by can be overwhelmed by the continuous noise it receives.

All CB transceivers have some means of counteracting this noise in the receiver circuitry. These 'automatic noise limiters' and 'noise blankers', while effective if the interfering noise is not too strong, fall down when it comes to strong noise — like that from your own car engine.

In a similar fashion, alternators, generators and battery regulators can produce intolerable noise interference in a CB transceiver installed in a vehicle. However much of the noise generated by a vehicle's electrical system can be suppressed or eliminated by taking some simple precautions or, in stubborn cases, by the addition of components which will effectively suppress the noise.

SUPPRESSION FUNDAMENTALS

Two fundamental approaches are used in suppressing vehicular radio interference.

1. Reduce the strength of the interference from each individual source as much as possible.
2. Confine the interference . . . make the engine compartment as efficient a shield box as possible.

Basic components and techniques used in suppression include capacitors, bonding, routing of wiring, and high voltage suppressors.

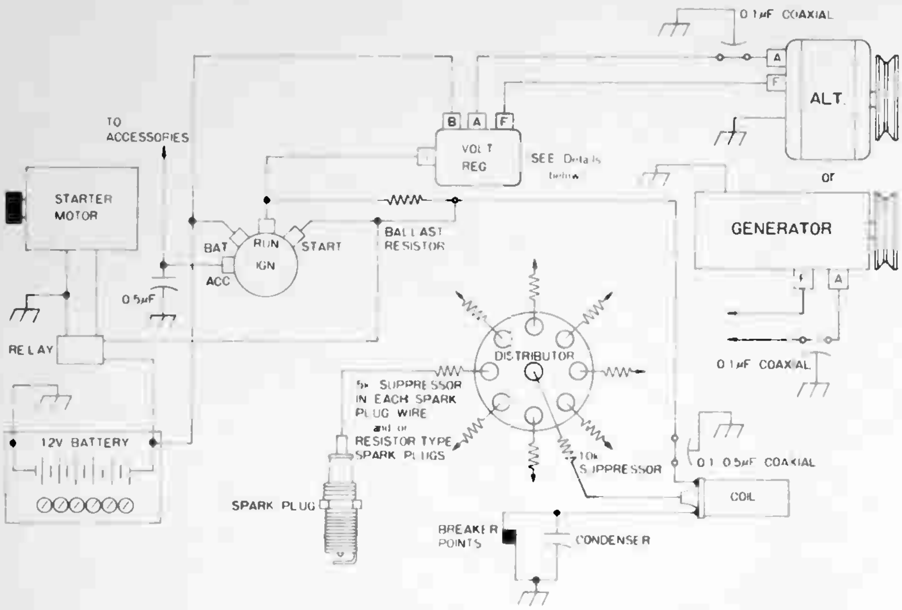


Figure 4. General circuit of a vehicle ignition and alternator/generator electrical system showing where suppression components are connected.

CAPACITORS

A capacitor will, in effect, pass alternating current but block the flow of direct current. Since interference is an alternating or impulse signal, a capacitor will bypass most of it to ground without affecting the direct current circuit. Conventional bypass capacitors are satisfactory for broadcast-band suppression, but they are not very effective at higher frequencies. Communications frequencies up into the UHF range make the use of coaxial capacitors necessary.

BONDING

Bonding provides a common ground for radio interference signals. It keeps the interference generated by the ignition and charging systems from travelling throughout the vehicle, reduces intercoupling, and prevents re-radiation. It also minimizes RFI radiation from the vehicle by connecting the metal parts together to form an effective shield.

Wiring must be carefully routed to avoid transfer of interference from one circuit to another, particularly from the high voltage ignition cables.

Resistors in various forms are used in the high voltage ignition circuit to reduce the level of radiated interference. This subject is of utmost importance because the ignition system is by far the greatest offender. It is discussed in detail later.

SIMPLE PRECAUTIONS

Ensure that the engine is reasonably well tuned.

Clean the battery connections. Leave off the battery positive cable (for negative-earth systems) or the negative cable (for positive-earth system) before proceeding with any electrical work.

When completed, tighten the battery connections after replacing the cables on the terminals, and smear Vaseline over the terminals to inhibit corrosion which is the main cause of bad contact here.

Clean and tighten the alternator or generator connections, battery regulator and ignition coil connections.

Clean all spark plug insulators, clean and adjust the gaps (or have them adjusted) according to the engine manufacturer's recommendations.

Replace plugs if necessary, and the points too if pitted or worn.

In vehicles more than a few years old, check and clean the alternator rings or generator brushes and commutator. If you don't feel competent enough to do this yourself, have your local garage or automotive electrical shop do it for you.

Even if the noise generated by these components is minimal the maintenance will do them good anyway!

It is a wise idea to check all crimped electrical connections to the spark plugs, coil and distributor, for looseness or fraying of the stranded wire. Use a light soldering iron (15 to 40 watts) on all crimped connections for best electrical connection. This is not absolutely necessary, simply a precaution because soldered connections are likely to last much longer.

Examine all the high-tension cables to each spark plug and between the coil and distributor.

Any frayed or cracked cables should be replaced. If 'resistor' or 'suppressor' high-tension cables are used they should be replaced with ordinary flexible wire high-tension cable. The resistance type of cable tends to deteriorate with age and can actually be a source of increased noise rather than assisting to suppress it.

Remove the distributor cap and inspect the rotor and contacts inside. Clean out any residue or dirt with methylated spirits or proprietary cleanser. Check the contacts and ensure that they are not badly eroded and that there are no carbon tracks between contacts or elsewhere inside the distributor cap. Replace the distributor cap and rotor if any of these faults are found.

Ensure that your antenna and transceiver connections are properly grounded. The coaxial cable between the antenna and transceiver won't work well unless it is properly grounded at the antenna base mounting and the plug on the transceiver.

At the base mount of the antenna, at least one screw of the mount, or that part of the mount made for the purpose of grounding, should bite into bare metal. Clean the appropriate area with steel wool

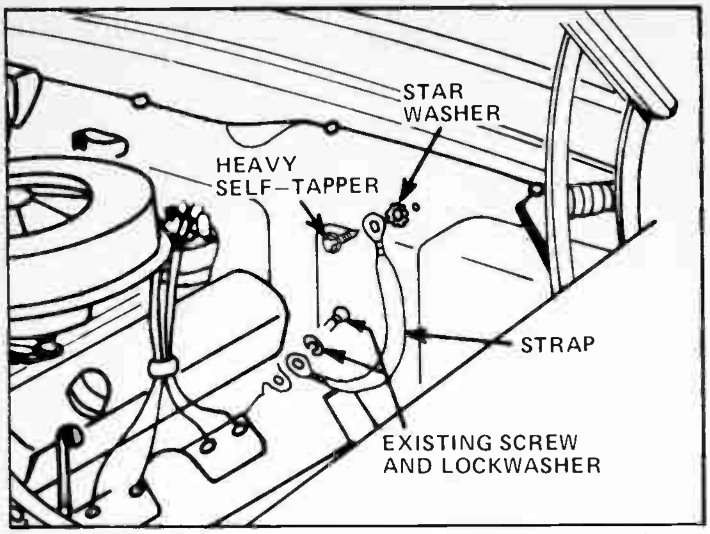


Figure 5. The engine block should be connected to the vehicle chassis to help reduce electrical noise problems.

or emery cloth if necessary. If your antenna uses a spring clip mount, it should make good contact with bare metal.

If a 'gutter-gripper' mount is used make sure the chrome gutter is actually earthed — many are not.

The transceiver itself should have a good electrical bond between the cabinet and the car chassis. This is often provided through the mounting cradle. If the bolts securing the mounting cradle to the dashboard or whatever bite into metal, then the transceiver should be well and truly 'earthed' to the vehicle chassis. If this is not the case, a separate wire should be run from the mounting cradle to an earth lug under a self-tapping screw attached to a convenient place on the firewall or general chassis of the vehicle.

Some transceivers provide a third wire in the power cable which separately connects to the transceiver chassis. This should be earthed in a similar manner to that just described.

The positive and negative power leads from the transceiver should be connected properly. Whichever one is 'earthed' — depending on whether the vehicle has a negative-earth (most common) or a positive-earth electrical system — ensure that it is properly connected to the vehicle chassis or frame.

IDENTIFYING INTERFERENCE

Each type of interference you hear on the receiver gives a clue to its identity by its characteristic sound. You can check them by driving to a fringe reception area, or doing the checks during a quiet period at night.

Ignition System: Popping sound . . . increases in tempo with higher engine speed. It stops instantly when the ignition key is shut off at fast idle.

Generator and Alternator: High pitched musical whine . . . increases in frequency with higher engine speed. It does not stop instantly when the ignition key is shut off at fast idle.

Voltage regulator: Ragged, rasping sound . . . occurs at an irregular rate . . . usually heard in conjunction with generator or alternator whine. It does not stop instantly when the ignition key is shut off at fast idle.

Instruments: Hissing, crackling, clicking sounds . . . occur irregularly as the gauges operate, usually worse on rough roads. Verify by jarring the dash.

Loud intermittent hash . . . sometimes worse when the dash is jarred. Caused by the voltage limiter used with fuel and temperature gauges, mounted behind the instrument cluster.

Disconnect the gauges or their sender units one at a time . . . the RFI should disappear. Bounce the vehicle to activate the fuel gauge sender unit.

Accessories: Make a preliminary check with all accessories turned off. Turn them on one at a time, listen for increased RFI.

Wheels and Tires: Irregular popping or rushing sound . . . occurs only in dry weather at higher speeds. It disappears when the brakes are lightly applied.

STOPPING THE NOISE

Having taken all the simple precautions as outlined, the next step is to suppress the noise being generated by components in the vehicle electrical system.

The obvious first place to start is the ignition system. If your vehicle has an electronic ignition system installed, then consult your dealer or specialist serviceman before proceeding.

To reduce ignition noise, commence by installing resistor-type spark plugs if these are not already installed. (Ask your local automotive spares shop for them. If these are unobtainable, install 'suppressor resistors' in each spark plug lead as well as the distributor lead as indicated in the diagram here. These can be obtained from many garages or automotive spares suppliers. Alternatively, spark plug 'suppressor caps' which include a resistor inside the plastic moulding of the cap, may be installed between the spark plug connector and the high-tension cable termination. Instructions are usually supplied with these suppression components.

Complete ignition suppressor kits can be obtained from both automotive suppliers and specialist transceiver suppliers for four, six and eight-cylinder engines.

In persistent cases, or if you really want to go the whole hog, completely shielded ignition systems using special spark plugs, shielded coil and distributor, may be installed. These are obtainable from very few specialist communications equipment suppliers.

You'll have to hunt around!

As mentioned previously, avoid using 'suppressor' or 'resistor' high-tension cable in the ignition system. It is primarily intended to suppress ignition noise in ordinary (broadcast band) car radios and often proves ineffective with CB. It also tends to deteriorate with time, affecting engine performance and often increasing ignition noise!

Special 'coaxial' suppressor capacitors should be installed on the 'hot' terminal of the ignition coil primary, in the armature lead of a generator or the output lead of an alternator as illustrated in the accompanying drawings.

The conventional type of bypass capacitor, as normally connected across the hot terminal of the ignition coil, is quite unsuitable for suppressing noise at 27 MHz. An extra capacitor, as illustrated here, can be installed on the terminal that leads from the coil primary to the points to further aid suppression of noise from this source. It is often found unnecessary and may be omitted — except in stubborn cases.

The coaxial capacitors mentioned are available from specialist component suppliers, some transceiver suppliers or specialist automotive suppliers.

Clicking noises are often generated by the battery regulator. Coaxial capacitors should be installed as illustrated here for vehicles with either a generator or an alternator.

A 'whining' noise, which varies with the engine speed and (in cars etc) which continues with the engine ignition turned off and the vehicle coasting in gear, is

Figure 7. The components of a 'Hot Line' filter. Manufacturers supply details on how to connect them.

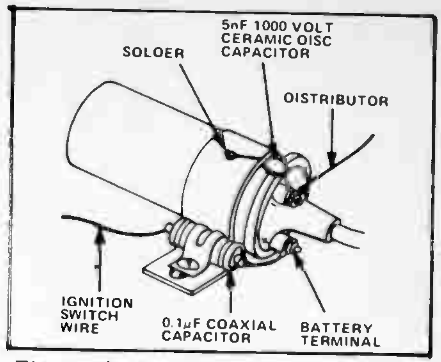


Figure 10.

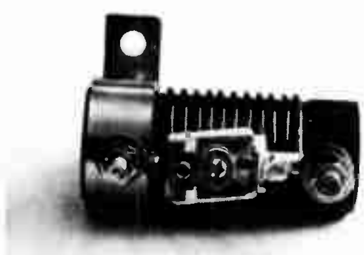


Figure 8. This 'tuned' alternator/generator hash suppressor is useful in stubborn cases.

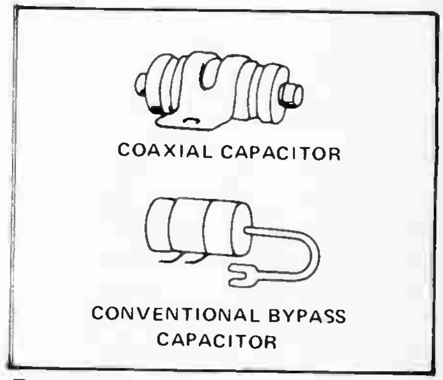


Figure 9.

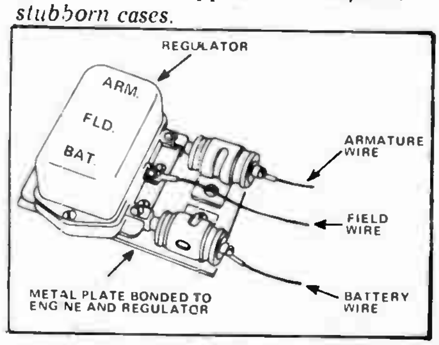


Figure 11.

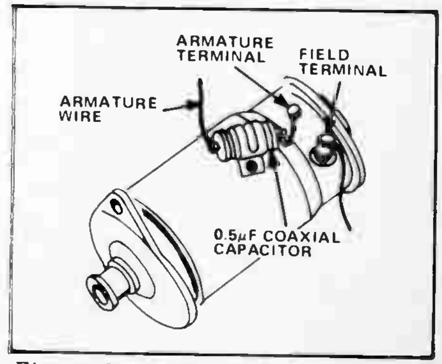


Figure 12.

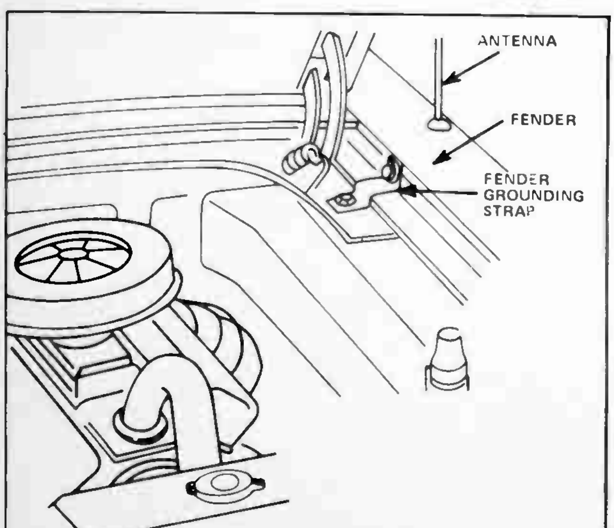


Figure 6. It is essential that the body panel on which the antenna is mounted is properly bonded to the vehicle's general chassis. This won't be necessary on vehicles having welded body panels. This precaution not only aids noise reduction but ensures proper antenna operation.

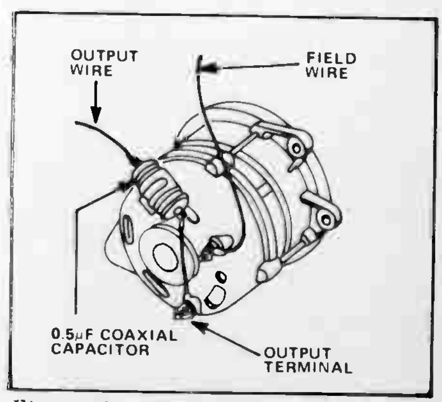


Figure 13.

characteristic of the alternator or generator.

WARNING: If you do this don't take out the ignition key, as on most modern vehicles this will activate the steering lock.

Check and clean the rings (or generator commutator) if this has not already been done.

Special filters are available to 'tune out' this noise (see illustration) and are generally quite effective in troublesome cases. These filters usually consist of a coil of heavy-gauge wire with a 'trimmer' capacitor connected in parallel. they should be installed as per the manufacturer's recommendations or instructions, mounting the assembly as close as possible to the alternator or generator 'hot' output terminal, using as short a connecting lead as possible. The trimmer capacitor is adjusted (it has a slotted screw to take a small screwdriver) to minimise the whine heard in the receiver.

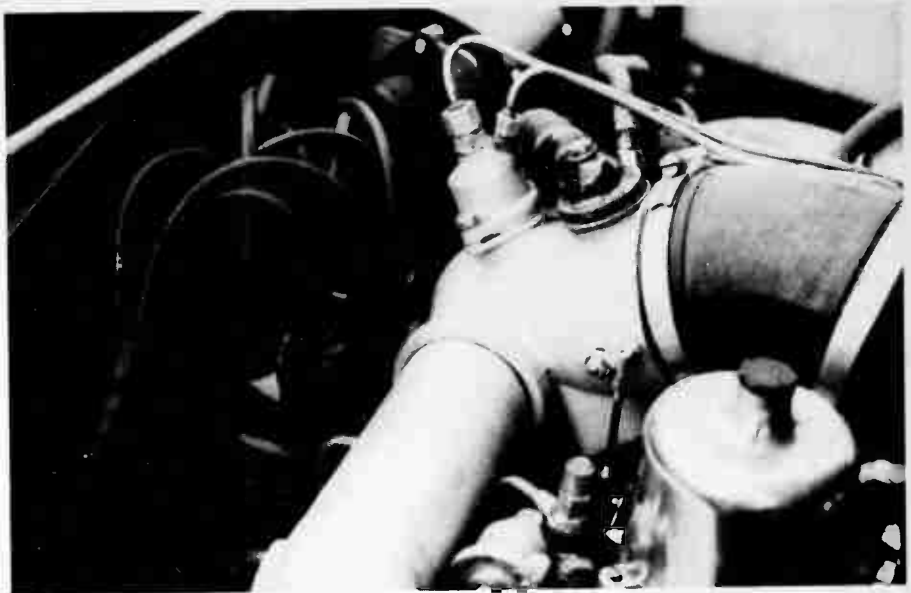
In cars and trucks, irregular, loud popping and crackling noises can be heard. These may be caused by static discharges at any of several locations on the vehicle or bad electrical contact between different portions of the vehicle.

Tighten loose nuts and bolts and bond large areas such as the fenders, exhaust pipe (particularly) the firewall etc, to the vehicle frame using lengths of heavy braid (obtainable from automotive suppliers). Ensure that good electrical contact is made by using a 'star washer' under the bolt and grounding lug as shown in the accompanying illustration.

It is also advisable to install a bond between the vehicle chassis or nearest frame member and the panel on which the antenna is mounted (except for roof-mounted antennas of course).

If the antenna is mounted on the boot lid, or the boot lip, bond the panel to the main chassis of the car using a braid strap. If it is mounted on a fender, bond the fender to the main chassis — as illustrated.

Additional suppression can be added in the transceiver 'hot' power lead. A 'Hot Line Filter' can



The distributor on an engine is most often the culprit in severe ignition interference problems.

An often completely effective method to get rid of the problem is to screen the distributor with ordinary fly-screen mesh as illustrated.

suppress electrical noises carried along the power leads to the transceiver. It consists simply of an iron-cored inductor (very like a small transformer) and a large capacitor.

It should be connected in accordance with the instructions supplied.

Gauges and sender units can generally be silenced by installing 0.47 μF capacitors at their terminals.

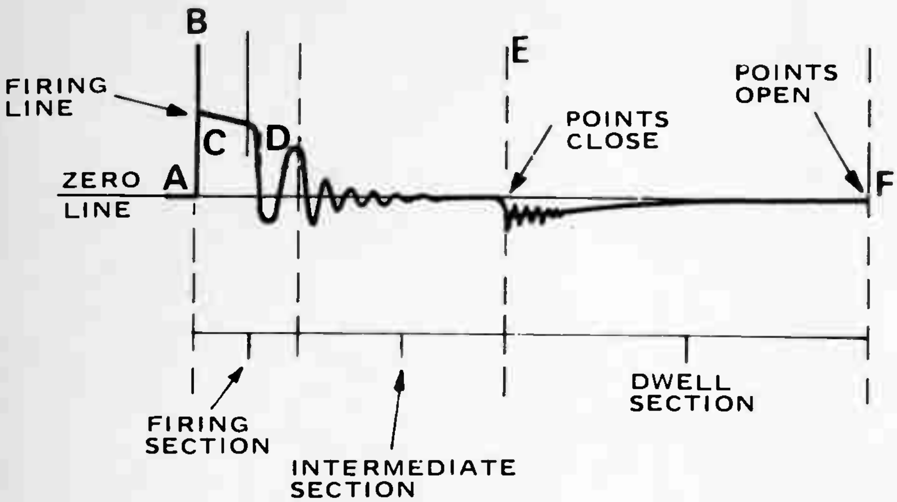
Install a 0.5 μF capacitor at the battery terminal of the voltage limiter . . . or try a 0.1 μF radio-type pigtail capacitor directly across the limiter terminals. A stubborn case may require a hash choke in series with the battery lead.

Turn signals, stop signals, electric windshield wipers, blowers or fans, window openers — any brush-type motors — can generally be suppressed by installing 0.27 μF capacitors at their terminals.

Front wheel static can be cured by installing static collector rings or springs inside the front wheel caps.

'Scope test your car

How to use your 'scope to check out a car's carburetion and ignition systems.



AUTOMOBILE ENGINE TUNING IS A grossly misused and misunderstood operation. To many it implies some esoteric knowledge or ability — of listening to an engine and somehow deducing that the ignition must be advanced — or the mixture strength richened a bit on the front carburettor.

In reality it consists almost entirely of ensuring that ignition and carburetion is adjusted to the vehicle manufacturer's specifications.

No more — no less.

But to do this it is virtually essential to use at least some basic instrumentation; a dwell meter, a tachometer, a good exhaust gas analyser — and preferably an ignition analyser.

Many car enthusiasts have at least a tacho/dwell meter — but few have access to an ignition analyser for such devices are costly indeed. Nevertheless if a few limitations are accepted virtually *any* standard oscilloscope can be used as an ignition analyser simply by making a couple of very simple capacitive probes — which can be as simple as clothes pegs and a few square inches of aluminium foil.

An ignition analyser displays waveforms from the primary or secondary side of the vehicle's ignition system. Surprisingly perhaps, this waveform provides information not only about the ignition system in general but also about carburetion, and a number of mechanical conditions.

The analyser can do this because the voltage required to fire a petrol/air mixture in an engine is affected by many different variables including air/fuel ratio, cylinder compression, ignition timing, ignition polarity, spark plug gap and condition etc, etc.

THE SECONDARY WAVEFORM

The simple waveform shown at the beginning of this article is a typical secondary waveform that is derived from the secondary (or high voltage) side of the ignition system. This waveform is the one most commonly used since phenomena occuring in the primary side of the system will be reflected through the coil windings and appear in the secondary pattern.

Point A: is the instant at which the contact points open thus causing the magnetic field to collapse through the coil's primary winding. A very high voltage is thus generated in the secondary winding and this continues to rise — until a spark jumps across the distributor rotor gap and the spark plug gap (point B). The voltage at which this occurs is known as the 'ionization' or the 'firing' voltage and may be anywhere between 5 kV and 15 kV depending on the factors outlined above.

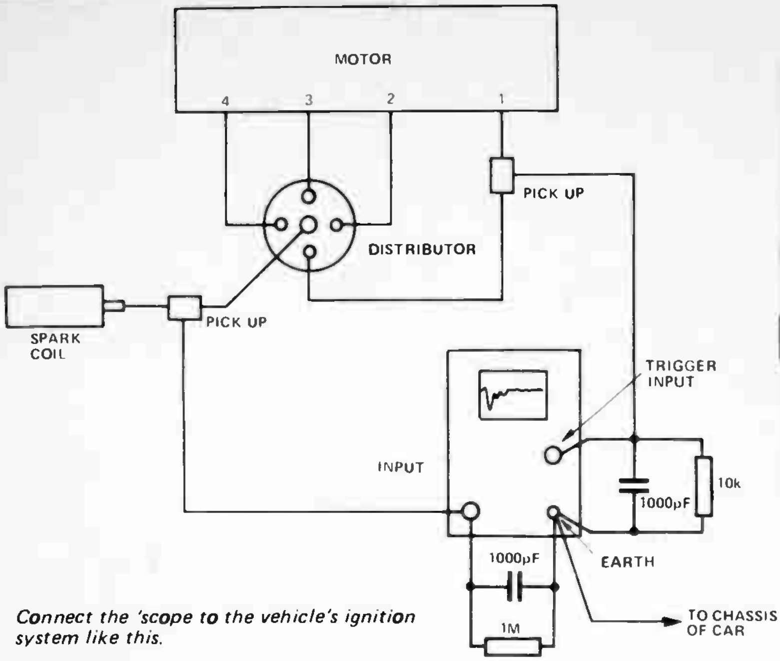
Points C—D: after a very short time the voltage drops substantially but the arc is maintained (point C). The subsequent section from point C to point D is known as the spark line and when viewed on a 'scope the amount by which this line slopes away from the horizontal is directly related to resistance in the plug and coil ht leads (ignition suppression). A slope of 30° or so is OK — if it's more than that then it's worth checking lead resistance with an ohmeter. The total resistance between the centre terminal of the coil and the centre electrode of the plug should not exceed about 20 k assuming the rotor gap is shorted out of course! Actual resistance is not critical but anything more than 30 k may cause problems. Resistance over 50 k almost certainly will.

Point D: the section immediately following the end of the spark line (point D) should be a series of diminishing oscillations. These should appear as our illustration. If there are no oscillations — or just one or two — then it's a safe bet that there's a shorted turn in the coil. It may not have broken down completely yet but it's a safe bet it shortly will. (See also below).

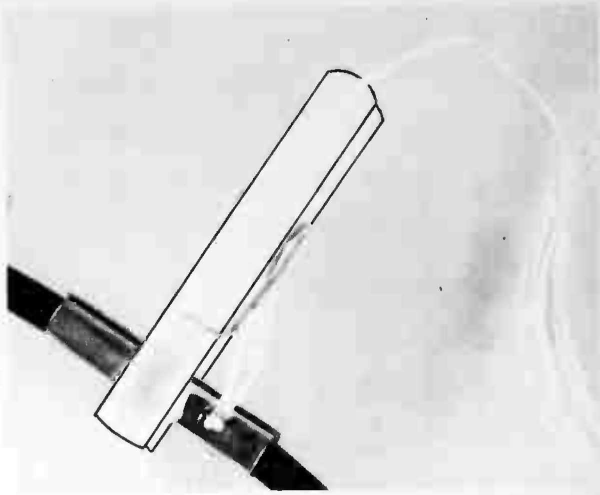
Point E: is where the contact breaker points close. It is essential that there is a gap between the last oscillation of the preceding section and point E for otherwise the diminishing coil energy will be fed into the now closed points thus preventing the coil re-building its magnetic field for the next cycle of ignition.

A great deal may be learnt by studying point E carefully, point misalignment, point bounce, burnt points etc may be spotted at this part of the waveform. The correct waveform at point E should be a short downward line followed by six or so diminishing oscillations.

Point F: magnetic energy will now build up in the coil until Point F. This is in effect the same point as our previous point A but in the next firing sequence. The section from points E to F is



Connect the 'scope to the vehicle's ignition system like this.



A simple pick-off can be made by glueing short lengths of split metal tube to a clothes peg.

CONNECTING THE 'SCOPE

A motor vehicle's ignition system produces output voltages varying from 3 kV to 20 kV or more. These high voltages must be reduced to a workable level before coupling into an oscilloscope.

The simplest way of doing this is via a resistive voltage divider – however a capacitive divider will work equally well (we are dealing with ac signals) and is simpler to connect.

We can make one of the capacitors by wrapping a piece of Alfoil – about 50 mm long – around the required lead and connecting this foil to the scope. A more professional approach is to glue a short length of split tube to a clothes-peg – as shown in the accompanying photograph. This will have a capacitance of about 1 pF – not much but ample for the massive signals we are sampling.

A second capacitor of about 1000 pF should be connected as shown. The capacitive divider thus formed divides the input signal by about 1000:1 thus reducing the input signal to a workable 3–20 volts. A 1 M resistor should be connected across the 1000 pF capacitor to provide a dc load.

The technique in use: Place the 1 pF capacitor over the main lead from the coil to the distributor and connect it to the 'Y' input of the scope.

If the scope has a trigger input this may be used to lock in the ignition signal. Just make up a second capacitive pick-up and place this around number 1 plug lead. Once again use a 1000 pF capacitor as a divider but bridge this capacitor with a 10 k resistor – not 1 M as previously.

Start the motor and adjust the 'Y' gain and timebase frequency to give four (or 6 or 8) complete firing sequences across the screen. The first complete pattern will be number 1 cylinder and the rest will follow in the engine firing order.

All waveforms may be superimposed by expanding the trace and triggering via the X input.

If the scope does not have a trigger input, synchronization is slightly harder to achieve. Number 1 cylinder may be identified simply by shorting out that cylinder momentarily.

When the scope is connected as described above, the ignition waveform will appear inverted relative to that seen on a commercially produced ignition analyser – and the waveforms shown in this article. It is surprisingly easy to adapt to an inverted picture, however if this is found to be a problem it can be remedied simply by coupling the signals into the scope via a simple 1:1 transformer. Details will vary from one scope to another but all that is basically needed is two coils of wire taped together. It may be necessary to reduce the 1000 pF capacitor/s to 470 pF. Just connect the secondary to give the correct picture.

If possible arrange to calibrate the scope's vertical axis so that the magnitude of the signals may be measured. This is best done simply by taking average indications from several vehicles and 'calibrating' by transferring data from the graphs in this article. The result may not be accurate but only a rough guide is required.

'Scope test your car

known as the dwell section and should occupy roughly the proportion of the total waveform as shown in our main drawing. Dwell is adjusted by varying the contact breaker gap and should be set using a dwell meter.

SPECIFIC INDICATIONS

Firing waveforms should be observed with the engine warm and running at about 1000 rpm – that is about 400 rpm higher than normal tickover speed.

Check each section of each firing sequence slowly and carefully. The various figures shown in this article indicate how specific faults will show up.

FIRING LINE

All firing lines should be of roughly equal height. If any plug is 10-15% or more higher than the rest, connect a jumper lead to earth and short out at the plug terminal. If the firing line now decreases the fault lies within that cylinder – either a faulty plug or unusually weak mixture (probably caused by a leaking inlet manifold gasket). If the firing line does *not* decrease there is a partial open circuit in the associated plug lead or that lead is not making firm contact with the connector within the distributor cap.

If the firing lines are unequal on a multi-carburettored engine check to see if the lines which are higher correspond to those cylinders fed by one common carburettor. If so it is probable that the mixture from the carburettors is unbalanced. A further but less common fault that may be spotted this way is an eccentric distributor cap — the gap between rotor and distributor contacts being wider on one side than the other.

At some time during the check 'snap' the throttle wide open momentarily, meanwhile watching the firing lines. They should all rise by about the same amount. If one or more lines rise substantially higher than the others then there is an open circuit plug lead or resistor, a wide plug gap or badly deteriorated plug electrode.

One or more lines staying lower than normal indicates spark plug breakdown or insulation breakdown in the circuit concerned.

COIL OUTPUT AND INSULATION TEST

While the engine is running disconnect a plug lead and observe the firing pattern for that cylinder. The firing line should rise to about two to three times its previous level (to about 20 kV) and should extend below the base line by about half the upward distance.

If the firing line is short or intermittent — or if the lower section does not appear — then there is an insulation breakdown in the distributor cap, plug leads, rotor or coil.

COIL AND CAPACITOR

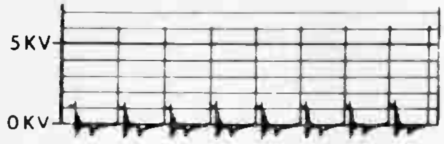
A series of diminishing oscillations should be observed at point D in the waveform. If these do not appear, or are truncated, there is either a shorted or crossed turn in the coil — or the capacitor is breaking down.

BREAKER POINTS

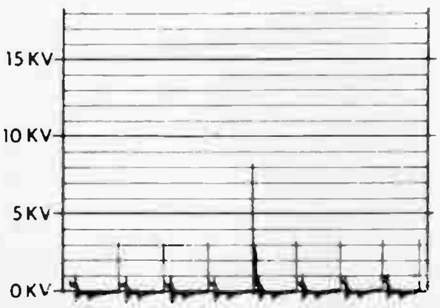
Point E on the main waveform. The drawings accompanying this article show various fault indications. Note however that faulty point action may also show up at the point opening position (A). Check breaker point action with the engine running at all speeds. Weak or incorrect breaker springs will cause the points to bounce — and this is readily seen on the scope pattern.

FIRING LINE INDICATIONS

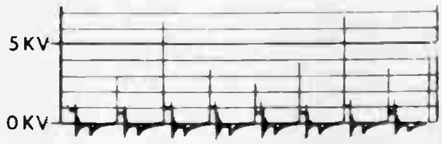
Normal pattern:
Note that the firing line for cyl. 1 appears at the extreme end of the trace. The remaining cylinders then appear in engine firing sequence.



Firing lines even but high:
Excess plug gaps, rotor gap, break in coil ht lead, mixture too lean ignition retarded.

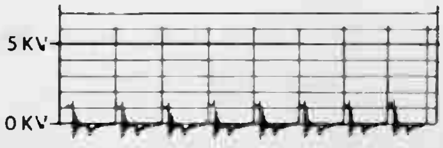


Firing line high on ONE cylinder:
Break in plug lead, broken electrode in spark plug. To test short plug — if line drops, problem is within cylinder.

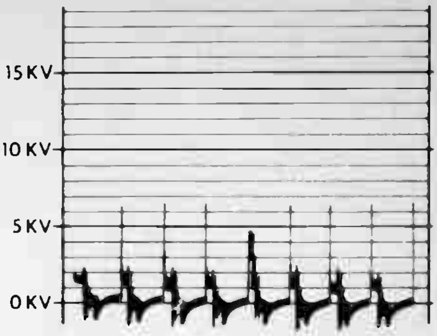


Firing lines uneven:
Break in plug leads, worn plugs, burnt distributor cap contacts, uneven air/fuel mixture.

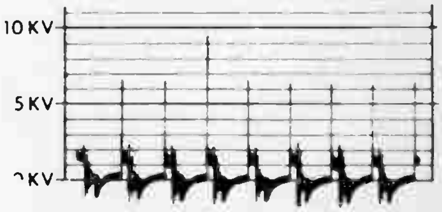
SNAP THROTTLE INDICATIONS



All lines should rise but remain even.

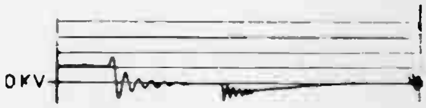


One line breaks up. Insulation break down — probably spark plug fouling. Extreme cases will show similar signal under normal steady running.



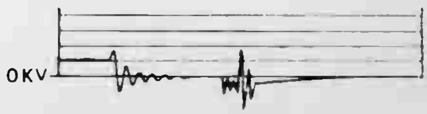
One line rises above rest. Wide plug gap, partial break in suppression resistor, plug lead etc.

CONTACT POINT INDICATIONS

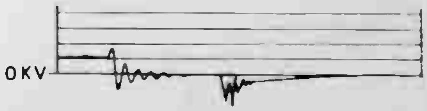


Unusual point opening signal (note hash extreme right of picture) burnt or arcing points.

Spike on spark line. Point arcing caused by faulty capacitor.



Points bouncing probably caused by weak closing spring.



Points misaligned — or dirty.

COIL

With very few exceptions — notably on some Citroens — the high voltage side of a vehicle's ignition system is designed to have positive earth — *regardless of overall vehicle battery polarity*.

The reason for this is that electrons are emitted more readily from a hot surface than a cold one so as a spark plug centre electrode always runs hundreds of degrees hotter than the side electrode the ignition system is devised so that a negative potential is applied to the centre electrode.

If this polarity is reversed, the plug will require an extra 5 kV or more to fire it — and that voltage may not be available from the coil under heavy load — or when running at light throttle at high speed (remember a weak mixture needs a higher voltage to ignite it than a rich one).

If you are checking polarity on a specialist ignition analyser then the polarity is correct if the pattern is as shown in the illustrations in this article. If you are checking it with a standard scope (with no inverting device) then the pattern should be upside down if polarity is correct. (See inset for full explanation).

Polarity is corrected simply by reversing the coil terminals. (Incorrect polarity is usually caused by a mechanic replacing a coil intended for a negative earth vehicle with a coil meant for a positive earth vehicle — or vice-versa. It may also, but less probably, be caused by an incorrectly manufactured coil, or less likely, by the vehicle's polarity being accidentally reversed by the battery being connected the wrong way round).

MIXTURE STRENGTH

This section is intended for the lucky man who has access to an exhaust gas analyser and tachometer as well as a scope.

If cylinder compression pressures are identical, plugs in good order and evenly gapped, and plug leads and distributor in good order — then any significant difference in firing line heights will almost certainly be caused by differing mixture strength from one cylinder to another.

The voltage required to fire a rich mixture is substantially less than for a weak mixture: for instance a 12:1 ratio may need 3 to 4 kV — whilst a 15:1 ratio may need 7 to 9 kV (typically). Thus even quite small differences in mixture strengths will be reflected quite dramatically in firing line height.

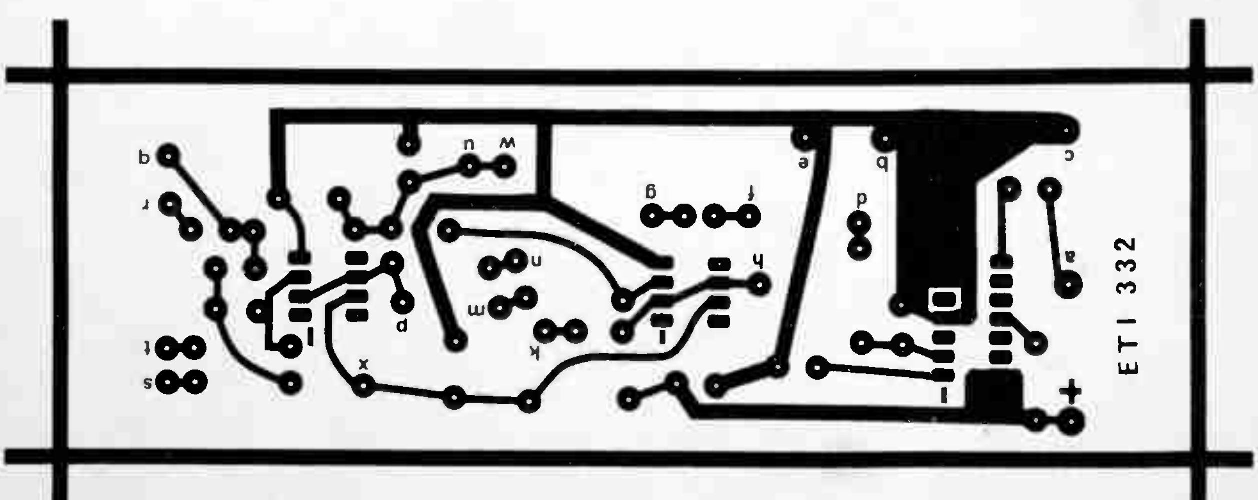
The only accurate way to adjust mixture strength is as follows:

Connect a tachometer to the engine and adjust slow running to 1000 rpm. *Without looking at the gas analyser* adjust mixture strengths so as to produce the highest tickover speed whilst maintaining the firing lines at an even height. If necessary reduce the tickover speed to keep it around 1000 rpm. Finally richen the mixture a shade until tickover speed drops by about 50 rpm.

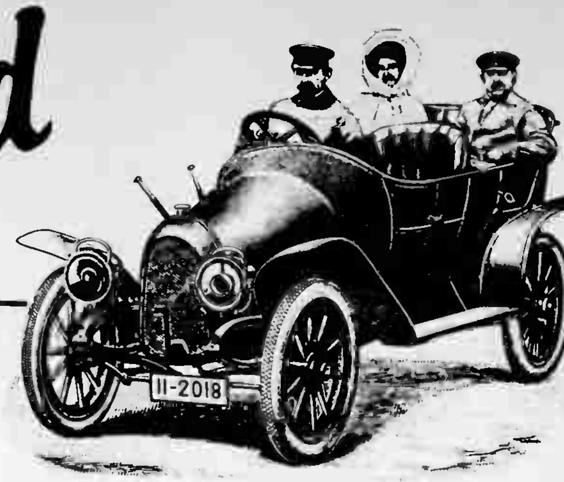
Then *and only then* — look at the gas analyser. You should now have a reading somewhere between 14:1 and 15:1. If you haven't then there's something wrong with the carburetion system — an air leak in the induction manifold: incorrect float chamber level: blocked slow running jet or *something*.

Never ever tune an engine by using a gas analyser alone — or in any other sequence than that spelled out above. If you do it's a certainty that sooner or later you're going to start with one fault and end up with two or more. ●

PCBs



Shoparound



ETI-316 transistor-assisted ignition

To our knowledge, All Electronic Components is the only company which stocks this project as a kit. However, all the components are readily available items so you should have little difficulty assembling this one. Printed circuit board suppliers are listed at the end of Shoparound.

ETI-232 courtesy light extender

This project is made up from off-the-shelf components — you should be able to find them in your junk box, even! No pc board is required.

ETI-327 turn & hazard flasher/beeper

You should enquire with All Electronic Components, Rod Irving Electronics and Electronic Agencies for kits or components for this project. Most components are readily available. Printed circuit boards may be obtained from suppliers listed later, apart from those firms mentioned here.

ETI-319 variwiper

So far we know, only All Electronic Components stock this as a kit. As with most of these projects, no special parts are required and you should have little difficulty obtaining them. See suppliers list at the end of this column for where to get pc boards.

ETI-321 fuel level monitor

As with the ETI-319 Variwiper, it seems only All Electronic Components stock this as a kit. Parts are commonly available and pc boards should not be difficult to get.

ETI-313 car alarm

All Electronic Components should have kits. Components are readily obtainable and pc board suppliers are listed here, so you should be able to get this one together with little trouble.

ETI-322 over-rev alarm

Rod Irving Electronics and All Electronic Components should be able to supply kits, but parts will be readily available for this project. Printed circuit board suppliers are listed at the end of this column.

ETI-333 reversing alarm

This project is widely stocked as a complete kit. Electronic Agencies, All Electronic Components, Altronics, Rod Irving Electronics and probably a few more we don't know about should be able to supply you. As ever, pc boards may be obtained from the suppliers listed at the end of Shoparound and components are widely available. The Murata piezo alarm featured in this project is stocked by David Reid Electronics, Radio Despatch Service, Electronic Agencies, Rod Irving Electronics and All Electronic Components. However, it's not the only piezo alarm that can be used and many common types may be substituted.

ETI-324 LED tacho

Dick Smith Electronics stores, All Electronic Components, Electronic Agencies and Rod Irving Electronics stock this project as a complete kit. There are no secialised components so by rooting in your junk box for parts and buying the rest you should have little trouble. See the list at the end of Shoparound for pc board suppliers.

ETI-081 simple tacho

The old standby, All Electronic Components, stocks this as a kit. Parts are common and pc boards are obtainable from the suppliers at the end of this column.

ETI-328 LED oil temp. meter

This project is available as a kit, with the special dipstick probe, from All Electronic Components. The VDU dipstick probe is stocked by the following stores in each state:

General Auto Instrument Service
47 Egerton St
Lidcombe NSW

Automotive Instrument Service
180 Coventry St
South Melbourne Vic

M.A.X. Instruments
662 Beaudesert Rd
Salisbury Qld

Auto Instrument Service
11 Dequetteville Terrace
Kent Town SA

Auto Instrument Service
153 Francisco St
Belmont WA

Philco Electronics
1134 Sturt Hwy
Winnellie, Darwin NT

ETI-329 ammeter

Only All Electronic Components and Rod Irving stock kits for this project. If you want to hunt around for the components, fortunately most are readily available. The LM394 IC is stocked by Rod Irving Electronics, Ellistronics, All Electronic Components, Jaycar, Electronic Agencies and Applied Technology. Most of these suppliers also stock suitable meters. Scotchcal meter panels are available from the suppliers mentioned later.

Shoparound

ETI-320 battery condition indicator

All bog-standard bits here. Kits from Dick Smith and All Electronic Components. The pc board and components can be obtained at Radio Despatch Service.

ETI-326 expanded scale LED voltmeter

Designed around the LM3914, which is widely stocked by suppliers, this project should not be difficult to get together. The pcb and components are stocked by Ellistronics and Radio Despatch Service, kits by Dick Smith and All Electronic Components.

ETI-1503 battery charger

Only All Electronic Components carry this as a kit, to our knowledge. The only 'stock' transformer suitable for this project that we can find is the Dick Smith Model M-2000. The DEC type MC2U relay is also a Dick Smith part, No. S-7200. The Fujitsu type FRL264/DO12/02CK is also suitable and is distributed by IRH Components through a number of suppliers. The Arcol HS25 0R22 resistor (R1) is obtainable from Everest Electronics, 61 Compass Drive, Seaford SA 5169. The project is housed in a K&W case, No. C1066. These are widely available. The meter, M1, is by University Graham Instruments and available through Radio Despatch Service and Magraths.

ETI-550 digital dial

Only All Electronic Components carry this as a kit, without the case. Suppliers of pc boards are listed later.

ETI-239 breakdown beacon

Getting this project together should present few problems as the components are generally easy to get. No pc board is required.

ETI-575 light wand

You'll have to hunt around for suppliers of suitable fluorescent tubes for this project, but they are generally easy to obtain — especially from 'speciality' lighting suppliers and electrical wholesaler retailers. Radio Despatch Service and George Browns in Sydney can supply the potcores. Printed circuit board suppliers are listed later.

ETI-255 electronic thermometer

Complete kit is stocked by All Electronic Components. Parts and pcbs from Tasman Electronics, Altronics, Ellistronics, Magraths and Radio Despatch Service.

ETI-325 auto-probe

A kit for this project is stocked by All Electronic Components. Printed circuit boards and the components are stocked by Dick Smith Electronics, Radio Despatch Service, Ellistronics and Rod Irving.

ETI-159 10-15 V voltmeter

It seems only All Electronic Components carry a kit for this project, but all parts are readily available. The pc board has been designed so that it can be secured to the connecting terminals on the rear of any of the common panel meters, so you can use a meter of your choice.

Multiturn trimpots are reasonably common, so you should be able to locate the right ones for this project with little difficulty.

ETI-332 electronic stethoscope

Kits for this project are stocked by Rod Irving Electronics and All Electronic Components. Radio Despatch can supply all the components but doesn't stock a kit.

PC boards, panels etc.

Every pc board for the projects published in this anthology may be obtained from the following firms:

RCS Radio
651 Forest Rd
Bexley NSW 2207

All Electronic Components
118 Lonsdale St
Melbourne Vic. 3000

In addition, many of the boards are stocked by Radio Despatch Service. If they haven't got your requirements in stock, they can have them made to order for you. Here they are:

Radio Despatch Service
869 George St
Sydney NSW 2000

The same three firms can provide Scotchcal front panels for our projects, too.

Many of the pc boards and panels for the projects published here may be obtainable from the following firms:

Mini Tech
P.O. Box 9194
Auckland N.Z.

Rod Irving Electronics
425 High St
Northcote Vic. 3070

James Phototronics
522 Grange Rd
Fulham Gardens SA 5024

Sunbury Printed Circuits
10 Counihan St
Sunbury Vic. 3429

Jemal Products
P.O. Box 168
Victoria Park WA. 6100

Kits & Components

All Electronic Components
118 Lonsdale St
Melbourne Vic. 3000

Altronics
105 Stirling St
Perth WA. 6000

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

George Brown & Co
174 Parramatta Rd
Camperdown NSW 2050

David Reid Electronics
127 York St
Sydney NSW 2000

Electronic Agencies
115-117 Parramatta Rd
Concord NSW 2137

Ellistronics
289 Latrobe St
Melbourne Vic. 3000

Dick Smith Electronics
Mail Order
P.O. Box 321
North Ryde NSW 2113

Jaycar
125 York St
Sydney NSW 2000

Kalextronics
101 Burgundy St
Heidelberg Vic. 3084

Magraths
208 Little Lonsdale St
Melbourne Vic. 3000

Martin de Launay
287 Clarence St
Sydney NSW 2000

Radio Despatch Service
869 George St
Sydney NSW 2000

Radio Parts
562 Spencer St
West Melbourne Vic. 3003

Tandy Electronics
280 Victoria Rd
Rydalmere NSW 2116

Tasman Electronics
12 Victoria St
Coburg Vic. 3058

ISBN 0 86405 002 X