Constructional Project

MOTORISTS' BUZZ-BOX

TERRY de VAUX-BALBIRNIE

A multi-purpose test instrument for the intrepid car owner.

THIS easy-build Buzz-Box is a test instrument having six useful functions. It would be ideal for anyone involved with fitting car accessories and for checking bulbs, fuses, switches, ignition leads and "earth" points. Since the unit receives power from the car electrical system, it does not need any internal batteries so will always be ready to use.

One particular advantage of this circuit is that most of the tests are provided by audible signals. This means that the user can concentrate on the task in hand without having to look at a display!

NEGATIVE ONLY

The Buzz-Box is suitable only for vehicles having a 12V ***negative earth*** system. That is, the negative terminal of the car battery is connected directly to the vehicle's metal structure ("earth" or "ground"). It is usual for the car body to provide the return path for the various circuits and this saves a lot of wiring.

Practically all cars in use today use the negative earth system although certain old models are "positive earth" (where the positive terminal of the battery is connected to the chassis). It is a simple matter to check this point if in doubt. ***Damage will be caused to the unit if it is connected with incorrect polarity.***

OVERVIEW

The instrument is built in a small plastic box. On top there is a meter, a rotary control with scale, a pair of terminals, pair of sockets and two metal contact "rails" (see photograph). On the side, there is a further socket which accepts a test meter type probe. A long piece of twin wire is used to connect the unit to the car cigar lighter socket for powering it.

The Buzz-Box provides the following functions:

1. ***Earth Test***. When the probe is applied to some point which has a small resistance with respect to the car chassis, an internal buzzer will emit a short bleep. This will be found useful for finding a good "earth" point when wiring an accessory or for checking the quality of an existing connection. Rust at a securing screw is a common problem and will result in increased resistance.

2. ***12V Test***. When the probe is touched on to some point which is within approximately 300mV of supply voltage (nominally 11·7V), the buzzer will emit a long bleep.

3. ***Low Resistance Test (20Ω)***. When the terminals of a low-resistance component bridge the test rails, the buzzer will sound continuously providing its resistance lies between zero and 20 ohms approximately. Several items associated with the car electrical system have near-zero resistance. Examples include fuses, pieces of wire and "closed" switch contacts.

However, the "cold" resistance of a low-power bulb may exceed ten ohms. A facility for giving a bleep with a resistance less than 20 ohms or thereabouts is therefore useful. This may be used as a quick "continuity" check on any low-resistance item.

4. ***Ignition Lead Test (Hi-R)***. The lead is connected to the Hi-R (high resistance) test position. The knob on the rotary control is turned until the buzzer just sounds and the resistance read off on a scale from ten kilohms (10kΩ) to 50 kilohms (50kΩ).

5. ***Battery Voltmeter***. While the unit is connected to the car system, a narrow-scale analogue meter gives a read-out of the battery voltage from 10V to 14V. This may be used to check the charge state of the battery.

It also provides a "crank test". This gives a battery "goodness" check by measuring the voltage under the heavy load over the starter motor.

6. ***Loudspeaker Test***. When loudspeaker leads are connected to the terminals, the loudspeaker will emit an audible tone. This is useful when it is not known which set of loudspeaker leads is which. It will also identify faulty units and connections. *Note that this test does not determine how well the loudspeaker is working.*

In order to set up the voltmeter section at the end of construction, you will need brief access to a good-quality test meter.

Since the circuit receives current from the car system, the 0V line will be automatically connected to the car chassis through the low resistance of the feed wire. The positive line will be at whatever voltage exists across the car battery terminals. This will be approximately 12V but will vary to some extent depending on the state of charge of the battery.

HOW IT WORKS

The full circuit diagram for the Motorists' Buzz-Box is shown in Fig.1. In the descriptions which follow, the supply voltage is assumed to be 12V. However, it turns out that the exact value of the voltage (within operating limits) does not matter and this point will be explained later.

Note that there is *no* reverse-polarity protection provided. This would introduce a voltage drop which would interfere with correct operation of the circuit.

However, providing the unit is correctly wired to the cigar lighter plug, the circuit cannot be connected incorrectly. Fuse FS1 provides some protection against overheating if a short-circuit were to occur. However, it does not provide any protection against reverse-polarity.

DOWN TO EARTH

The "earth test" centres around IC1a which is one section of quad op.amp (operational amplifier), IC1. This contains four identical units – the other three are associated with other tests.

The non-inverting input (pin 3) of IC1a is connected to a potential divider having fixed resistor R1 as the top arm. Resistor R2 appears in series with the resistance between the probe and the 0V line. This is labelled "*R*" (the "earth resistance") in Fig.1. Resistor R2 and *R* form the lower arm of the potential divider.

It will be noted that resistors R7 and R8 connected in series, appear in parallel with *R*. When the probe is connected to an earth point there will be only a very small resistance between itself and the 0V line so the effect of resistors R7 and R8 (having a combined resistance much higher than R) is negligible.

When the probe is left unconnected, the non-inverting input (pin 3) will be at 9·7V approximately. This is due to the potential divider which now consists of resistor R1 in the top arm and R2 in series with R7 and R8 in the lower one.

When the probe is connected to an "earth" point, *R* will have a very low value. Assume for the moment that this is zero. The upper and lower arms of the potential divider connected to IC1a non-inverting input will now be equal. The voltage here will then be one-half that of the supply – that is, 6V approximately.

However, if the earth resistance was, say, 0·5 ohm the lower arm would have a greater resistance that the upper one. In this case, calculation shows that the voltage at IC1a non-inverting input would be 6·03V, 30mV more than before.

POTENTIALLY MORE

The inverting input of IC1a (pin 2) is also connected to a potential divider. This comprises resistor R3 (the top arm) and the network of resistors R4, R5 and preset potentiometer VR1 connected in series (the bottom one). When preset VR1 is set to minimum, the voltage at the inverting input will be 5·8V and when at maximum, 6·1V approximately.

By adjusting preset VR1 at the end of construction, the inverting input voltage can be made to exceed that at the non-inverting one when *R* is between zero and some chosen value. The op.amp will then have its output (pin 1) low.

Some adjustment is needed to provide the required "low" point taking account of component tolerances and the resistance already existing in the connecting wires. In the prototype unit, the low point was set at 0·3 ohm approximately.

With the probe unconnected, the voltage at IC1a pin 3 (9·7V) exceeds that at pin 2 (6V approx.) so the op.amp output is high. This has no further effect.

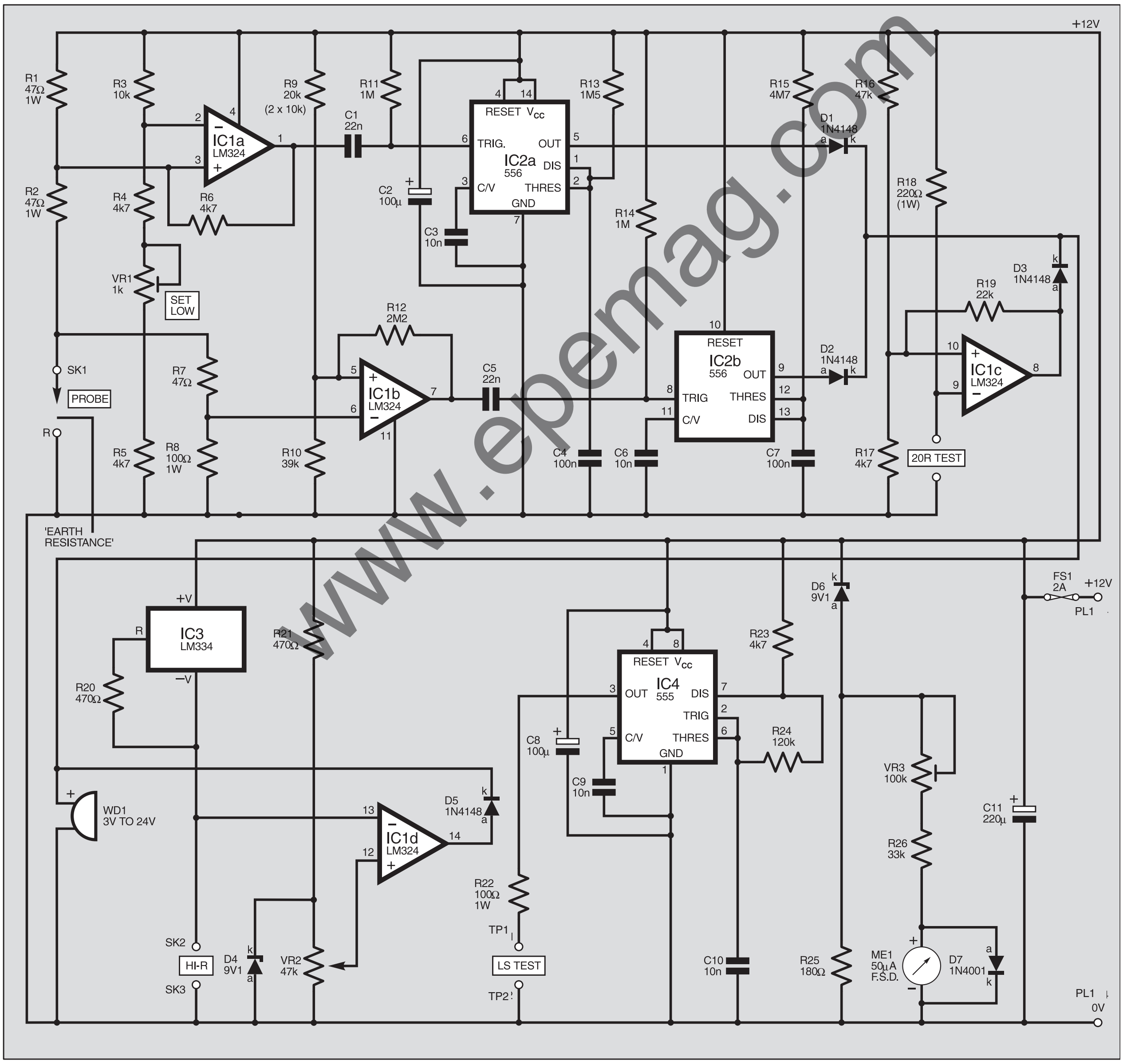


Fig.1. Complete circuit diagram for the Motorists' Buzz-Box. Note that some resistors must be rated at 1W.

GOOD ENOUGH!

When the probe detects a sufficiently "good" (that is, low resistance) earth point, the low logic state of IC1a output (pin 1) applies a short duration low pulse to IC2a pin 6 (the trigger input) via capacitor C1. IC2 is a dual timer with both sections, IC2a and IC2b configured as monostables.

In the case of IC2a, the time period is set by the value of resistor R13 and capacitor C4 and with those used here, it will be rather less than 0·2 second. During this time, the output (pin 5) goes high then reverts to low. While high, current flows through diode D1 to buzzer WD1, which gives a *short* bleep.

Resistor R11 maintains IC2a pin 6 in a high state in the absence of a trigger pulse and this prevents false operation. Resistor R6 applies a little positive feedback to the op.amp (IC1a) system and this sharpens the switching action.

12 VOLT TEST

For the 12V Test, op.amp IC1b (another section of quad op.amp, IC1) and IC2b (the other section of dual timer IC2) are used. It will be noted that the same probe is used for both the "Earth" and "12V" tests and this is particularly convenient when making checks.

The action of the 12V test is best described by considering what voltage exists at IC1b inverting input (pin 6) when the probe is (a) connected to a point at +12V, (b) unconnected and (c) when connected to 0V (that is, while performing an earth test).

In the case of (a), IC1b pin 6 may be considered to be connected to a potential divider having resistors R7 in the upper arm and R8 in the lower one (remembering that the top end of R7 is now connected to +12V). This gives a voltage of 8·16V.

In the case of (b) pin 6 is connected to the potential divider comprising resistors R1, R2 and R7 in series in the upper arm and R8 in the lower one. This provides a voltage of almost 5V. In the case of (c) the top end of R7 and the bottom end of R8 are both connected to 0V so the voltage at pin 6 is zero.

MORE POTENTIAL

The non-inverting input of IC1b is connected to another potential divider comprising resistor R9 in the upper arm and R10 in the lower one. With the values specified, the voltage applied to this input will be 7·93V.

If the probe is touched on a point within about 0·3V of the positive supply voltage, the inverting input voltage will exceed the non-inverting one. The output at pin 7 will then go low. This low state is applied, via capacitor C5, to the trigger input (pin 8) of the monostable based on IC2b.

The time period of this section is related to the values of resistor R15 and capacitor C7, and with those specified it will be 0·5 second approximately. During this time, the output at pin 9 goes high and current passes via diode D2 to the buzzer. This then emits a *long* bleep.

The trigger input at pin 8 of IC2b is maintained in a normally-high state using resistor R14. Resistor R12 provides a little positive feedback to op.amp IC1b and this sharpens the switching action.

COMPONENTS

Approx. Cost Guidance Only **£15** excluding case & meter

See SHOP TALK page

Resistors

R1, R2	47Ω 1W (2 off)
R3	10k
R4 to R6, R17, R23	4k7 (5 off)
R7	47Ω
R8, R22	100Ω 1W (2 off)
R9	20k (2 off 10k units – see text).
R10	39k
R11, R14	1M (2 off)
R12	2M2
R13	1M5
R15	4M7
R16	47k
R18	220Ω 1 watt
R19	22k
R20, R21	470Ω (2 off)
R24	120k
R25	180Ω
R26	33k

Plus 0·22W test resistor – see test. Also 10kΩ and 47kΩ test resistors.

All resistors, apart from the 0·22Ω test resistor, are of the 1% metal film type. Unless otherwise indicated, they should be rated at 0·6W. The 0·22Ω test resistor may be of any type.

Potentiometers

VR1	1k min. preset, vert.
VR2	47k min. rotary carbon, lin.
VR3	100k min. preset, vert.

Capacitors

C1, C5	22n polyester, 5mm pin spacing (2 off)
C2, C8	100µ radial elect. 25V (2 off)
C3, C6 C9, C10	10n polyester, 5mm pin spacing (4 off)
C4, C7	100n polyester, 5mm pin spacing (2 off)
C11	220µ radial elect. 25V

Semiconductors

D1 to D3, D5	1N4148 signal diode (4 off)
D4, D6	9V1 Zener diode (2 off)
D7	1N4001 50V 1A rect. diode
IC1	LM324N dual op.amp
IC2	556N dual timer
IC3	LM334N adjustable current source
IC4	555 timer

Miscellaneous

ME1	50µA full-scale deflection (f.s.d.), moving coil panel meter – see text
SK1, SK2, SK3	4mm chassis sockets (3 off) matching plugs (2 off) – see text.
TP1, TP2	small terminal posts (2 off)

Printed circuit board available from the *EPE PCB Service*, code 278; plastic box, size 150mm x 100mm x 60mm external; 8-pin d.i.l. socket; 14-pin d.i.l. socket (2 off); test meter probe to fit SK1; screw terminals (2 off); 5A terminal block (2 sections); 5A flexible twin wire (or ready-made cigar lighter extension lead (PL1)) – see text; materials for test rails; strain relief bush; control knob for VR2; self-adhesive p.c.b. stand-off pillar (2 off); solder etc.

TWENTY OHM TEST

The 20 Ohm Test or "low resistance test" is centred on IC1c, the third section of quad op.amp IC1. The non-inverting input (pin 10) is held at a potential of just over 1V due to the potential divider R16/R17. The inverting input (pin 9) is held at +12V due to resistor R18.

The metal rails on top of the unit form the "20R test" position. When a low-resistance item bridges the rails, this becomes the lower arm of a potential divider with resistor R18 as the upper one.

If the component on test has a resistance less than 22 ohms approximately, the inverting input voltage will fall below that at the non-inverting one. The output at IC1c pin 8 will then go high. The high state will pass, via diode D3, to the buzzer, which will sound.

When the test position is not occupied, the inverting input voltage exceeds the non-inverting one and the output will be low. This state is blocked by diode D3 and has no effect.

Timer IC2 is a robust bipolar device. It needs small-value capacitors connected between the control voltage pins (pin 3 and pin 11) and the 0V line (C3 and C6 respectively. Also, because momentary large current "spikes" occur on the supply rails, capacitor C2 is included to provide a charge reservoir.

In the Earth Test, 12V Test and 20 Ohm Test, both inputs of the op.amp involved have applied voltages which are derived from potential dividers. These are connected to the same supply lines. Thus, as the supply voltage rises or falls, the voltages at both op.amp inputs will rise or fall in sympathy. It, therefore, does not matter what battery voltage actually exists within operating limits.

TAKING THE LEAD

Ignition leads have a relatively high resistance and this is built into the design to suppress RFI (radio-frequency interference). This would otherwise cause severe noise in the loudspeaker connected to audio equipment and it would even affect radios in nearby cars.

The voltage used in the ignition system is very high (tens of kilovolts) so the relatively high resistance of the leads still enables sufficient current to flow to provide an effective spark at each plug gap.

However, if the resistance rises too much mis-firing occurs. This usually varies with factors such as engine speed and load. If the lead becomes open-circuit, the corresponding cylinder will not fire at all. Any such faults will plays havoc with a catalytic converter.

Unfortunately, problems with ignition leads are fairly common so some means of quickly measuring their resistance is useful. This enables the user to check how the resistance of the various leads compare and to determine whether or not they fall within manufactures' tolerances if this data is available. By "wiggling" the leads as the tests are made, it is possible to check for intermittent faults.

The High Resistance test is centred on IC1d, the fourth section of the quad op.amp. The lead is connected between the inverting input, pin 13, and the 0V line. A fixed current is now passed through it from the adjustable current source device IC3. This is programmed using resistor R20 and with the specified value, will be some $140\mu A$.

With a constant current flowing through the lead, the voltage across its ends will be proportional to its resistance. It turns out that with a resistance of 64kΩ, the voltage across it will be nearly 9V and, of course, with zero ohms it is 0V. With no lead connected, virtually no current flows so IC3 obviously cannot maintain its regulation. However, this is of no consequence.

RESISTANCE TRACKING

Operational amplifier IC1d non-inverting input (pin 12) is connected to the sliding contact of panel-mounted potentiometer VR2. The track is connected in series with fixed resistor R21 across the supply.

Zener diode D4 operates in conjunction with R21 to provide a stable 9·1V (regarded as 9V) across VR2 track despite changes in supply voltage (down to around 9·5V). The difference between these two voltages appears across resistor R21. Since VR2 is a linear device, its angle of rotation will be approximately proportional to the voltage at the sliding contact rising from zero to 9V.

With the ignition lead in "Hi-R" position, VR2 control knob is slowly rotated. At some point, the voltage at the non-inverting input will exceed that at the inverting one. The output at pin 14 of IC1d will then go high and provide a feed to the buzzer WD1 through diode D5.

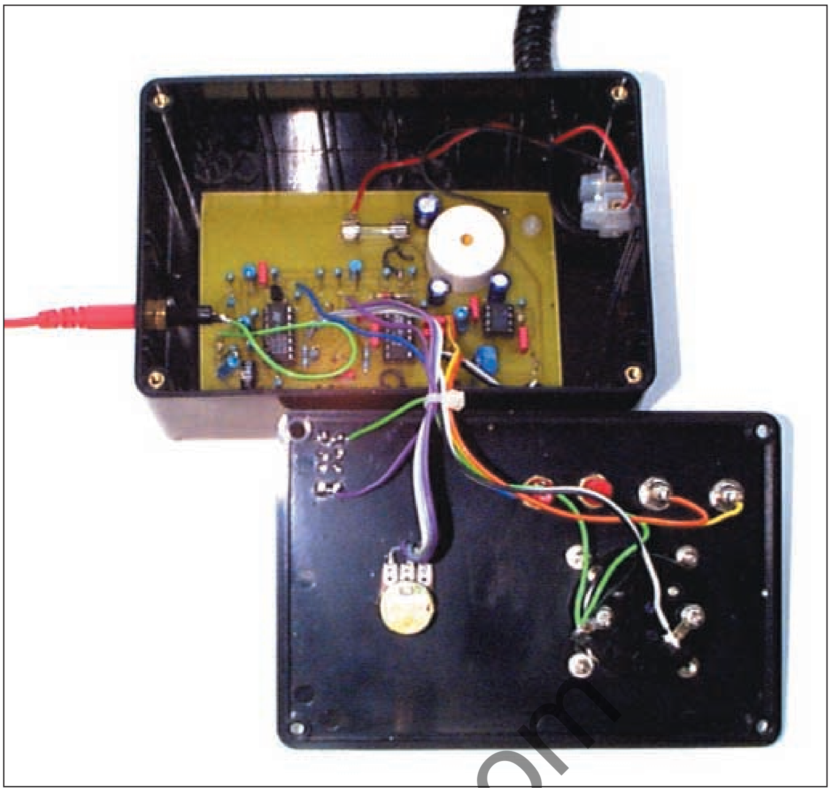
By adjusting the control knob, the position can be found where the buzzer just sounds. The resistance of the lead may then be read off a scale. Marking the scale 0 to 50kΩ (50 kilohms) is a simple matter and will be carried out at the end.

LOUDSPEAKER TEST

For the Loudspeaker Test a single 555 timer, IC4, is used. This is of the same type as the dual unit used for IC2. However, here it is configured as an astable. Thus, as long as a supply exists, the output at pin 3 of IC4 will provide a continuous train of on-off pulses.

The output from IC4 pin 3 is connected to one of the loudspeaker terminals (TP1), via resistor R22, while the other one (TP2) is connected to 0V. Providing the pulse frequency lies within the audible range, a loudspeaker connected to the terminals will produce a sound. Remembering the description of IC2, capacitor C9 is the control voltage capacitor and C8 provides a charge reservoir.

The components which determine the pulse frequency are resistors R23, R24 and capacitor C10. Using the specified values, this frequency will be 600Hz approximately. The ears are sensitive to this frequency and the loudspeaker will reproduce the sound well.



Layout of components inside the plastic box and wiring to components mounted on the lid.

Because the signal is a simple square wave, the power has been kept low to prevent possible damage. This is the reason for including resistor R22 in series with the output. This limits the peak current to 120mA or thereabouts.

This is not a precision signal designed to assess the performance of the loudspeaker. It is used simply to find which pair of leads is which and to identify non-working units, loose connections and so on.

VOLTMETER

The read-out of the supply voltage is provided by panel meter ME1. This is scaled 0 to $50\mu A$ but it is modified to show a d.c. range voltage from 10V to 14V.

The supply is connected to a 9·1V (regarded as 9V) Zener diode, D6, connected in series with fixed resistor R25. As long as the supply is a little more than the Zener breakdown voltage, the diode will conduct and this voltage will appear across it. The difference between the supply voltage and 9V will then appear across R25.

If the supply voltage is less than the Zener breakdown voltage, the diode will not conduct and therefore the voltage across resistor R25 will be zero. With a supply voltage of 14V (the maximum value in practice), the voltage across R25 will be 5V.

Meter ME1 operates in conjunction with preset potentiometer VR3 and fixed resistor R26 to provide a voltmeter having a full-scale reading of 14V. With an applied voltage less than about 9·5V, it will read zero.

The region between 9V and 10V must be regarded as a "grey area". This depends on exactly when the Zener diode begins to conduct. Also, at the beginning it does not do this sharply.

Values below 10V are therefore not known with any accuracy. At 10V the Zener diode will be behaving as it should and the scale after that will be more-or-less linear (equal changes in voltage producing equal steps on the scale). This is why there is space between the rest position of the pointer and 10V (see photograph).

METER CHOICE

The values of components have been chosen for a meter having a full-scale deflection of 50μA (although a 100μA unit would also work). Preset VR3 will be adjusted to give the correct full-scale reading at the end of construction. The internal resistance of the meter itself will be a few kilohms. However, the exact value does not matter because it is taken into account when VR3 is adjusted.

Diode D7 is connected in parallel with the meter movement as a protection device. Thus, if due to a fault an excessive current would otherwise flow through the meter, the voltage across it would be limited to 0·7V approximately (the forward voltage drop).

Normally, a smaller voltage than this exists across the meter (with the specified device carrying 50μA it is about 0·2V). Under normal conditions, therefore, the diode will have no effect. Under fault conditions, the current will be around 200μA but the meter will probably not be damaged.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full size underside copper track foil master are shown in Fig. 2. This board is available from the *EPE PCB Service,* code 278.

Begin construction by drilling the two fixing holes then solder the sockets for IC1, IC2 and IC4 in position (but do not insert the i.c.s themselves yet). Solder the fuse clips in place. If these are not available, you could use a small fuse block instead. If necessary, this could be mounted off board and hard-wired to the FS1 points on the p.c.b. later. Solder in position the single link wire, just above IC2 socket.

Add all resistors and the preset potentiometers. Note that some of the fixed resistors *must* have a power rating of one watt minimum. This is because they can become quite warm in prolonged tests.

Although five per cent tolerance would be sufficient for some of the resistors, some must have a tolerance of one per cent. To avoid confusion, one per cent tolerance resistors have therefore been specified throughout.

Resistor R9 must have a value of 20kΩ. It will probably be easier to use two 10kΩ units connected in series. Space has been left for two such resistors on the p.c.b. Note that they are *both* labelled R9 on the component layout, Fig.2.

Solder the capacitors in place. It is essential to place the electrolytic capacitors – C2, C8 and C11 – with the correct polarity. Solder all diodes in position taking care over their polarity, noting particularly the orientation of Zener diodes (D4 and D6). Add the audible warning device (WD1), taking note of its polarity (which is marked on top).

Next, solder 15cm pieces of light-duty stranded connecting wire to the following points on the p.c.b.: +12V; 0V; ME1 (2 off); VR2 (3 off); Probe; TP1; TP2; HI-R and 20Ω. By using different coloured wires (pieces of "rainbow" ribbon cable), problems will be avoided later.

Solder IC3 in position (the flat face is towards the left-hand side of the p.c.b.) keeping its end leads at least 5mm in length. Solder it quickly to avoid damage. If necessary, use a simple heat shunt – this may be nothing more than a pair of fine-nose pliers. These are used to grip each lead between the body of the device and the p.c.b. as it is soldered.

BOXING-UP

Begin the boxing-up procedure by making the holes for the meter. Mark out the large one and the small fixing ones using the template supplied with it. The large hole can be made by drilling a series of small holes around the outline. These are then joined together using a small hacksaw blade. The holes will be covered by the meter face so there is no point in trying to make a perfect job.

Place the p.c.b. in position on the base of the box. Mark through the fixing holes. Remove the p.c.b. and drill these through.

Decide on positions and drill holes for VR2 bush, also for terminals TP1/TP2 (for the loudspeaker test) and sockets SK2/SK3 (for the Hi-R test). Place the control knob on the potentiometer spindle and measure how much needs to be cut off. Mark this, remove the knob and cut off the excess using a small hacksaw.

While doing this, hold the spindle (not the potentiometer body) in the vice. *Gripping the body of the device is likely to damage it.* File the cut edge smooth.

Place the potentiometer bush through its hole and secure it loosely. Mark a suitable position for the anti-rotation lug on the inside. Remove the potentiometer again and drill a small hole to be a tight fit with the lug.

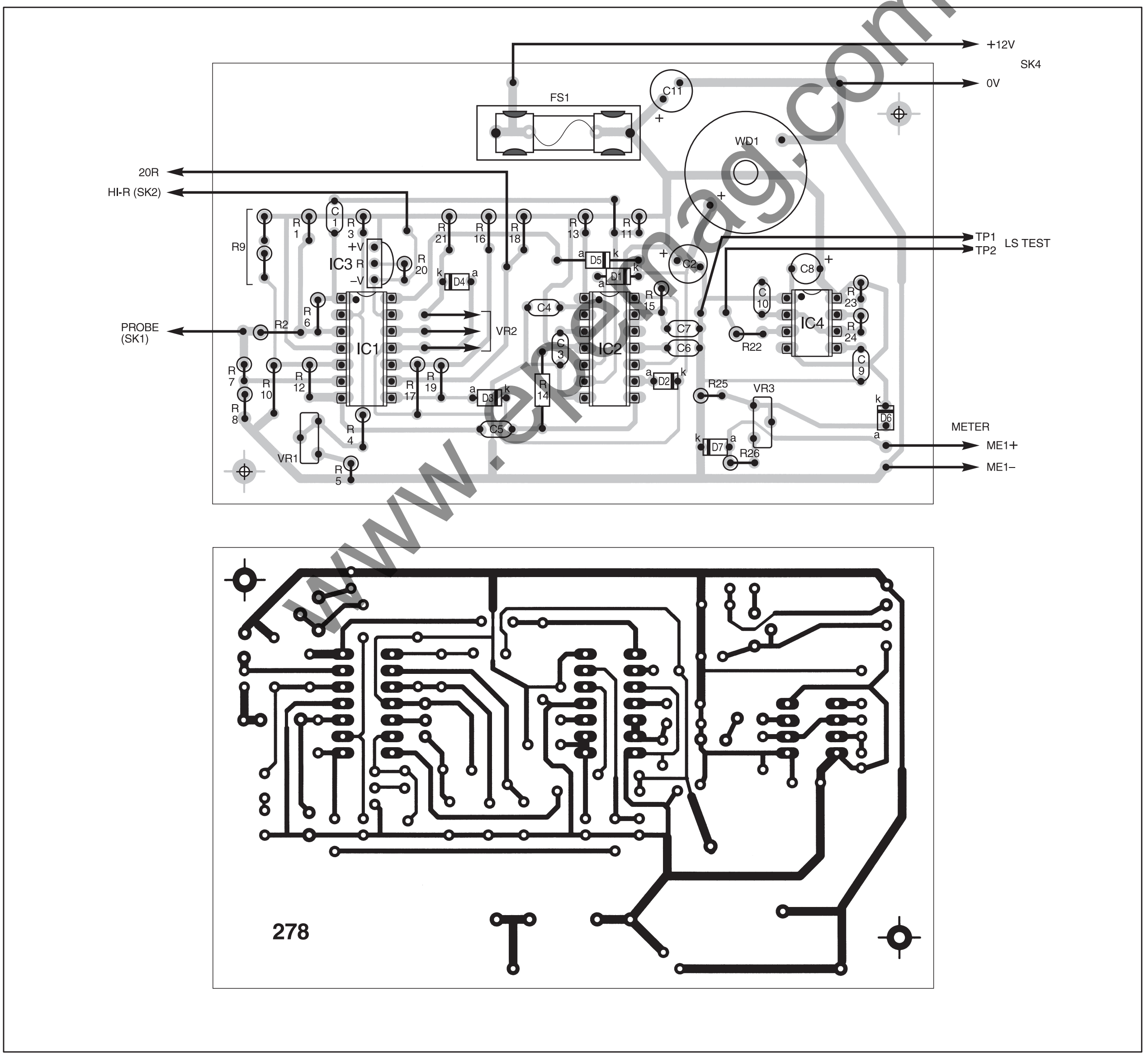
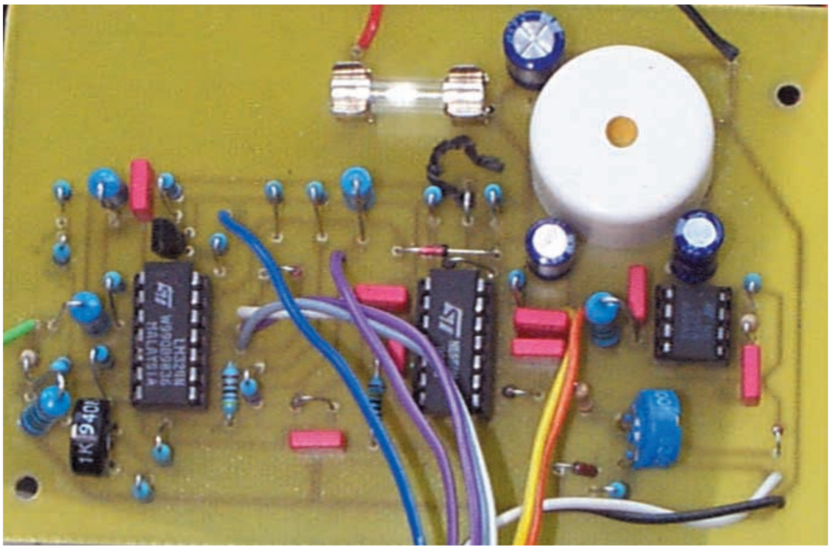


Fig.2. Printed circuit board topside component layout and full-size copper foil master for the Motorists' Buzz-Box.



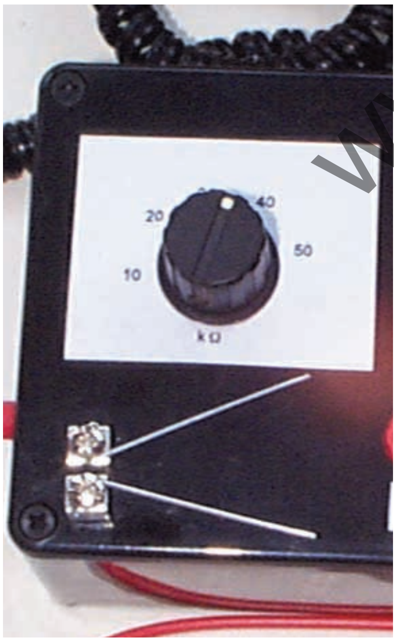
Completed prototype circuit board. Use different coloured wires (rainbow ribbon cable) to ease identification.

Drill the hole for probe the socket, SK1, in one side panel of the box and attach it. Drill a hole in the rear of the box for entry of the input wire. This must be large enough to accommodate the strain relief grommet.

ON THE RAILS

Refer to the photographs and make the test "Rails". In the prototype unit, these were constructed using paper clips which were secured in place using screw terminals of the type shown. This method gives a neat finish and also allows the rail wires to be easily replaced if they become damaged in use.

The screw terminals used in the prototype were of the p.c.b. mounting type. These had four lugs which were made to be pushed through holes in a panel and soldered into position. However, if tight holes are drilled in the box, the lugs may be pushed through then secured by bending them slightly.



The "test" rails made from paper clips and the cardboard "resistance" scale.

The narrow end of the rails should be only a few millimetres apart (to allows for the testing of small bulbs) and about 35mm apart at the other end to enable testing of 1¼in fuses. The suggested method raises the rails above the top face of the case and this allows for the easy testing of small bulbs.

Attach potentiometer VR2 securely with the anti-rotation lug engaged in its hole. This lug prevents the body from possibly rotating in service (due to harsh use or loosening of the fixing nut). This would result in incorrect readings and could even snap off the connecting wires. Mount the p.c.b. on short plastic spacers and all remaining components.

Refer to Fig.3 and complete all the interwiring between the p.c.b. and off-board components. This should be done slowly to avoid errors in view of the fact that there are several components involved. Note particularly which wire from the p.c.b. connects to which VR2 tag (the diagram gives a rear view). Only if they are correct will the high resistance (Hi-R) section work properly with clockwise rotation corresponding with increasing resistance.

SUPPLY LEAD

The cable used for the supply voltage input lead ***must be rated at 5A minimum.*** This will avoid excessive voltage drops due to resistance. In the prototype, a ready-made "curly" extension lead was used with the line socket end cut off.

Fit the 2-core cable wire through the strain relief bush. *Make sure it is secure.* Leaving a little slack, connect the ends to a 2-section piece of screw terminal block mounted inside the case. Connect the p.c.b. wires to this making certain that the polarity is correct.

Adjust preset VR1 fully clockwise (with respect to the left-hand side of the p.c.b.) and preset VR3 to approximately mid-track position.

TESTING

Double-check that the polarity to the circuit is correct before plugging in.

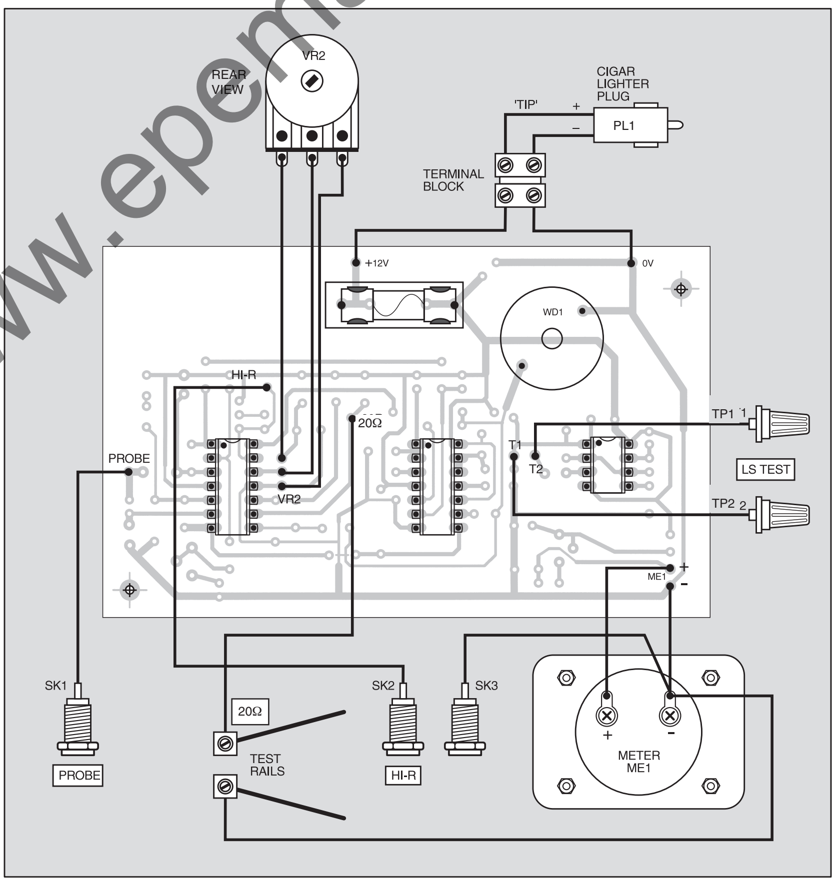


Fig.3. Interwiring from the printed circuit board to off-board components. The general layout within the case can be seen in the photographs.

Connect the unit to the lighter socket. In some cars the ignition must be switched on for this to operate. The monostables will probably self-trigger and the buzzer give a bleep. The meter should read somewhere on the scale. Adjust preset VR3 slightly if necessary.

Plug the probe into socket SK1. Touch this on an "earth" point. The buzzer should give a short bleep. If not, adjust preset VR1 so that it does. Touch the probe on a point at positive supply voltage. The buzzer should give a longer bleep.

Check that the 20Ω test works by bridging the rails with a piece of wire. The buzzer should sound continuously.

METER SCALE

Remove the front cover from the meter by *gently* pulling or careful levering using a thin knife blade. Exercising great care, remove the scale fixing screws using a small screwdriver. Slide out the scale taking care not to touch the pointer.

Cut out a paper scale to glue on top of the existing one. By pressing them in contact, you will see through sufficiently to mark with a pencil the positions of 10µA, 20µA, 30µA, 40µA and 50µA. Mark these 10V, 11V, 12V, 13V and 14V respectively using dry print lettering. Put a light pencil dot at the zero position.

You can, if you wish, "Tippex" or white-out the old scale (so that it does not show through the paper). Glue the new scale over it and re-assemble the meter. Attach the front taking care that the adjustment peg engages with the fork in the movement.

Check that the pointer rests at the zero dot. If not, adjust the screw on the top face until it does.

MAKING ADJUSTMENTS

Start the adjustment procedure with the Voltmeter. If you have access to a variable voltage power supply unit, you could use that to set VR3 to give a full-scale reading when 14V is applied. You will then find that the other markings correspond fairly well. Adjust preset VR3 to give the best compromise on these figures.

However, if you do not have access to a suitable power supply, plug the unit into the cigar lighter, measure the battery terminal voltage and adjust preset VR3 to correspond. The whole of the scale will then be reasonably accurate.

GOOD OLE' EARTH

To adjust the Earth Test low point, take the 0·22 ohm test resistor (or some other chosen value) and connect the probe to one end of this. Connect the other end to the negative terminal of the battery or a good earth point. Adjust preset VR1 until the buzzer just sounds.

R-SCALE CALIBRATION

Now for potentiometer VR2's front panel "resistance" scale and calibration. Make a thin cardboard scale and secure it temporarily behind the control knob. Pencil in the zero position (knob turned full anti-clockwise).

There is no point in marking the scale with great accuracy. It may be assumed that this is linear – that is, equal increases in resistance correspond with equal steps.

Testing an ignition (plug) lead. The new meter scaling can also be seen here.

Take the 10kΩ test resistor and connect it to the Hi-R test position. Rotate VR2 control knob to the point where the buzzer just sounds. Make a pencil mark. Repeat using the 47kΩ (regarded as 50kΩ) test resistor, again, making a mark.

Remove the scale and, by measurement, make marks for each 10kΩ step from 10 to 50. Mark these permanently. Label the scale "kΩ" then attach the scale in its original position. Check that the "zero" point is still correct.

USING THE BUZZ-BOX

There are several points to observe when using the test probe. ***This must be applied with care and with reference to the car wiring diagram. It may be used on items which carry supply current direct to some accessory (e.g. at a fuse, switch or connector) or an earth point. Do not probe around indiscriminately.***

On no account use it inside pieces of electronic equipment. If, for example, it was used inside an electronic control unit severe damage could result to the control unit.

Do not apply it to any connector associated with an engine management system, ABS unit or any other electronic system or sensor. Do not apply it to any wires inter-connecting such circuits.

Do not apply it to points on any diagnostic socket. Do not use it in the engine compartment with the engine running.

When using the loudspeaker test, disconnect **both** of the wires involved *before* connecting them to the unit.

CRANK TEST

The unit is not really designed to be used with the engine running except for a "crank test". To do this, watch the voltmeter as the starter motor is operated. If the needle drops immediately below 10V and the battery is known to be well charged, it is likely to be at the end of its useful life.

It would be worth checking the battery connectors (for tightness and lack of corrosion) and the connection of the earth strap to the car chassis since trouble here could produce a similar result. A good battery should be capable of maintaining a voltage of 10V or more for a few seconds until the engine fires.

STATE OF CHARGE

The charge state of the battery is found by measuring the voltage but this needs some interpretation. It will only be meaningful if the battery has not been charged for a few hours before the test is made.

A terminal voltage less than 11·5V indicates a battery which is "flat" (possibly irreversibly so). A voltage of 12·5V or more indicates a good state of charge and near 13V indicates full charge.

Take great care to avoid touching the probe on a +12V point and the car chassis or other earth point at the same time. *If you did, there would be a short circuit and damage could be caused.* In the prototype unit, the end of the probe was insulated using heat-shrinkable sleeving so that only a little bare tip remained. This reduced the likelihood of causing a short circuit.

UP TO YOU

Ignition leads could be connected to the test position in various ways. The method used in the prototype was to solder short pieces of stiff wire to the 4mm plugs. The other ends of the wire were bent into a loop to make contact with the connectors when inserted in the ends of the leads (see photograph).

Several ignition leads were tested and these had a resistance between 5kΩ and 20kΩ. Without specific data, compare the resistances of the leads. If one has a markedly higher value than the rest, it should be replaced and, preferably, the whole set renewed. □