Project 325

'Auto-probe' for testing vehicle electrical systems

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

Jonathan Scott

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

Damned annoying, isn't it!

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

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

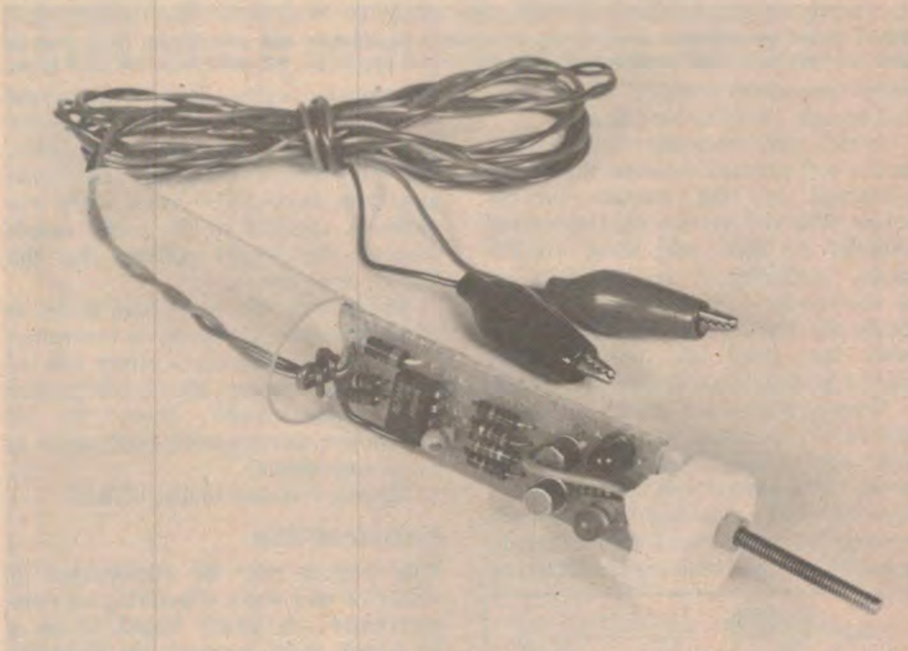
Sorting out the wiring can be a nightmare — especially on motorcycles.

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

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

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

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



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

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

The problem

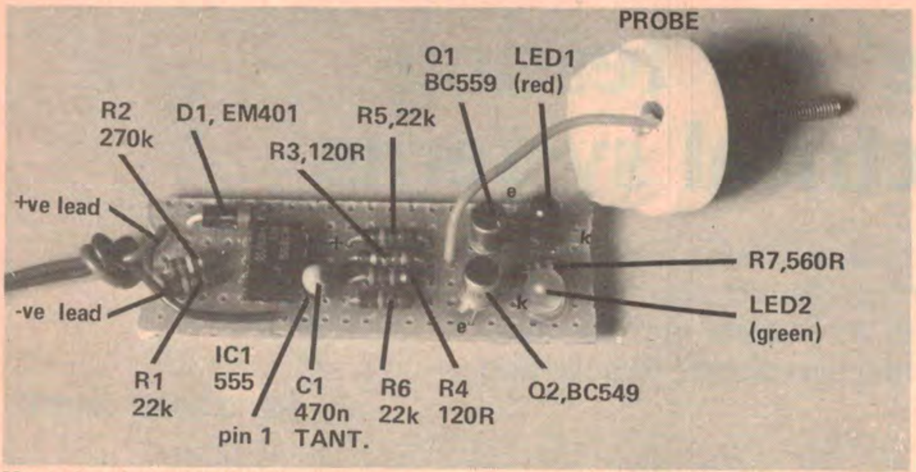
Let us consider the case of a car radio that has 'stopped working'.

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

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

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

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



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

PARTS LIST — ETI 325

Resistors .... all ¼W, 5% unless noted
R1, R5, R6 .... 22k
R2 .... 270k
R3, R4 .... 120R, ½W, 5% (GLP type) see text
R7 .... 560R

Capacitors
C1 .... 0.47u Tantalum (35V)

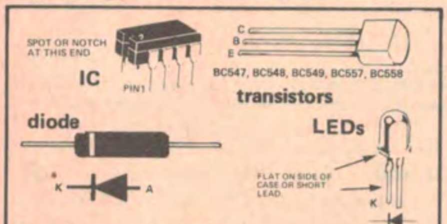
Semiconductors
IC1 555
Q1 .... BC559, or similar
Q2 .... BC549, or similar
D1 .... EM401, or similar
LED1 .... TIL220R or similar, red
LED2 .... TIL222 or similar, green

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

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

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

Tracing wiring and switch operation can be a real hassle. Does this motorbike operate its horn by supplying power or a ground connection via the horn switch? If touching the two switch contacts in turn shows first a steady green LED then a blinking red LED, the



Component orientations

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?

Construction

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

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

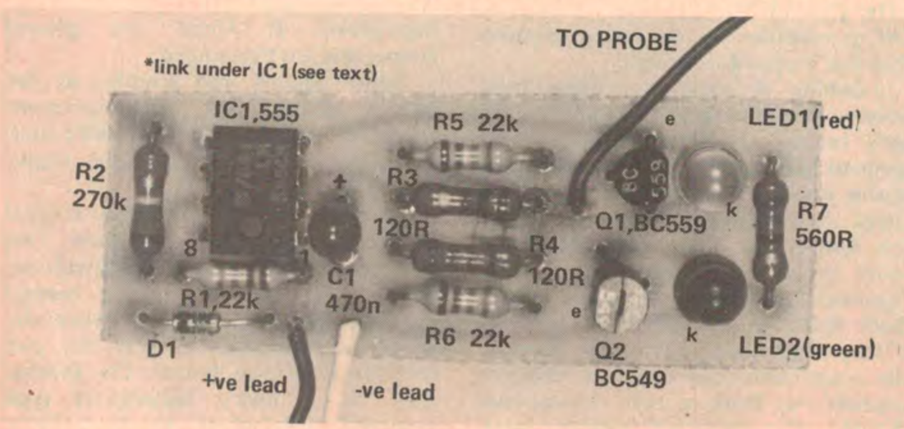
It is probably easiest to commence by mounting the two LEDs and the two transistors. You have to take some care when assembling a project on matrix board as the connections between the components are made under the board, using the component leads. Carefully study the overlay picture to see where the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

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

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

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

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



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

READERS PLEASE NOTE

We do not sell kits or components for the projects described in the magazine. To find out who may be stocking kits or components for the projects featured in this issue, please refer to the 'Shoparound' page. Suppliers for past projects are listed on the 'Kits for Projects' page.

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.

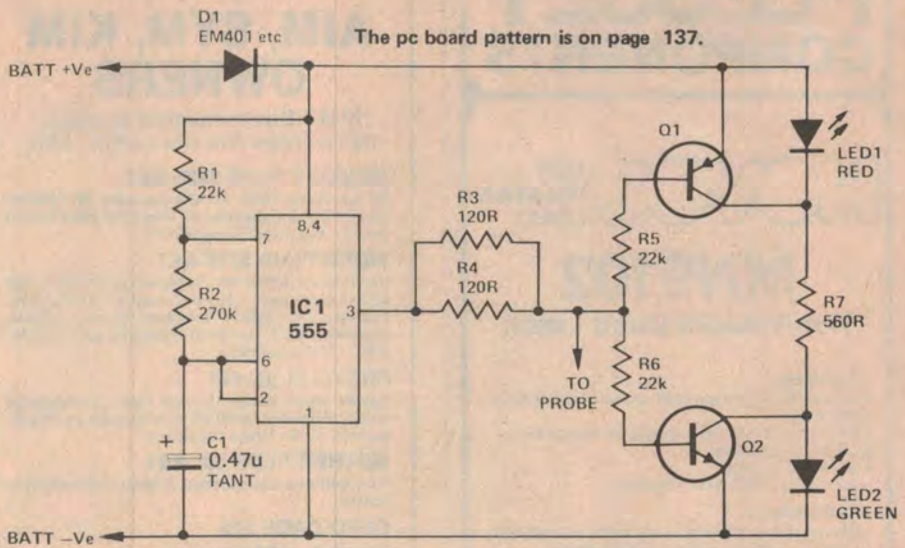
Connect the appropriate leads to the board and tie a knot close to the board (see photograph).

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. ▶



The pc board pattern is on page 137.

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.

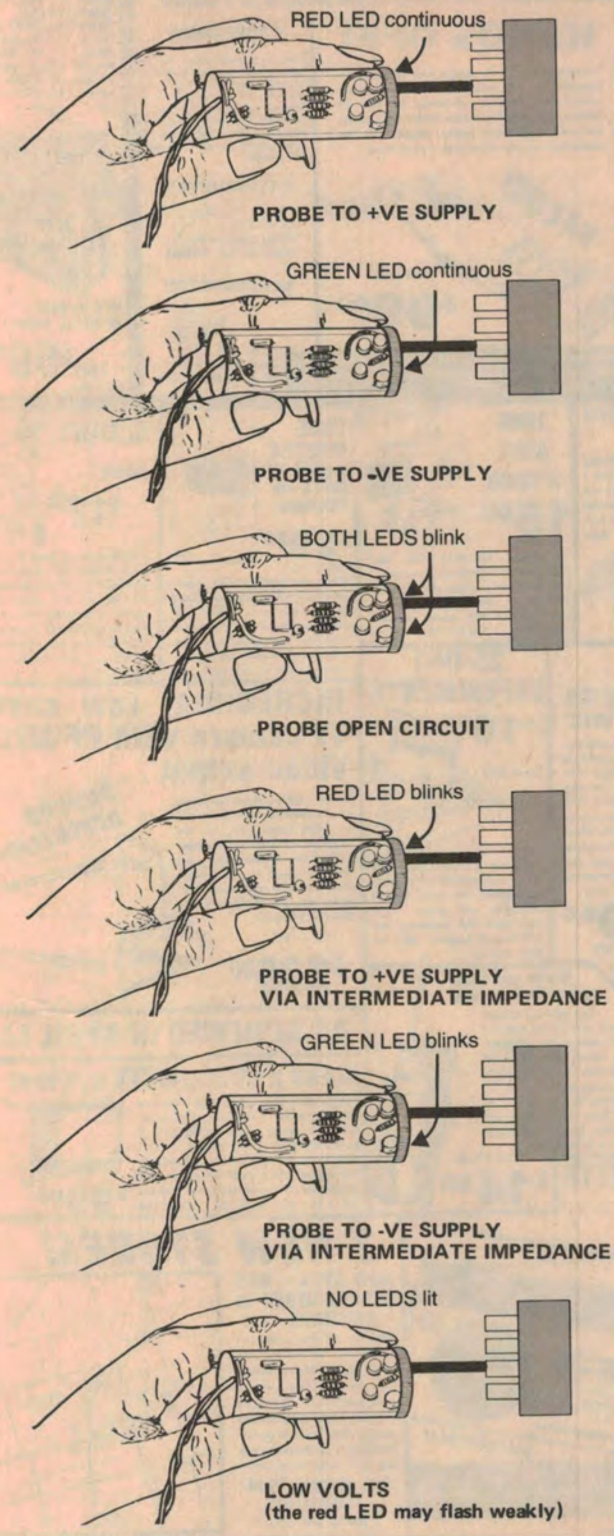
However, if the resistance is not high enough to allow the junction of R5/R6 to go far enough positive the red LED will not turn on. This gives green only blinking.

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