Constructional Project

12V BATTERY TESTER

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A "health" check for lead-acid batteries.

TWELVE-VOLT lead-acid batteries are now found in many walks of life. The most familiar is, of course, the type used in cars. However, smaller ones are used for mobile radio rigs, alarm systems, solar-charged circuits and other specialised applications.

The project to be described here is an instrument which will determine the charge state of such a battery.

OVERVIEW

The 12V Battery Tester is built in the style of a logic probe which gives a neat appearance (see photographs) and also allows for easy use with one hand. The display is provided by a row of l.e.d.s (light-emitting diodes) giving a simple "Low", "Medium" and "High" readout.

There is also a "Crank Test" display l.e.d. for checking car batteries under a high load. This identifies a failing battery and provides a similar result to the device used for the purpose in service centres. It also doubles as a "danger level" signal.

It is important to note that the circuit is only suitable for testing *12V lead-acid batteries*. It will not give accurate results with any other type.

If you are a motorist and do a lot of start-stop driving (therefore using the starter motor excessively), drive mostly with the headlights switched on and use the heated rear windscreen for long periods, the battery may soon lose its charge. This problem will be aggravated if it is nearing the end of its service life. It would then be a good idea to use this instrument every so often and re-charge the battery before it lets you down.

The user of a small battery for some special application often does not know, until the equipment fails, that it has gone "flat". Not only is this inconvenient but it may damage the battery.

This is because leaving it in a poor state of charge (even in a half-charged condition) will cause deterioration over time. This will result in reduced capacity and service life. Having this instrument available will enable you to check the condition of the battery as frequently as you wish.

MEASURING CHARGE

Many lead-acid batteries used today are of the "sealed-for-life" variety. This makes topping-up with distilled water unnecessary and (depending on type) allows them to be used in any orientation.

Some years ago, every self-respecting user had a "battery hydrometer". This consisted of a rubber bulb which, when squeezed and released, allowed a sample of battery acid to be drawn into a glass tube.

In this was a sealed glass capsule often marked with red, yellow and green coloured sectors. The higher the capsule floated in the liquid, the greater was its density ("specific gravity") and the higher was the state of charge. The coloured bands were arranged to give a simple "poor", "medium" and "good" indication.

Hydrometers are still available but they cannot be used with most batteries because the electrolyte is not accessible. This device aims to give a readout which is just as simple but does the job with much less fuss.

CHARGE CHECK

The state of charge of a battery may be determined by measuring its terminal voltage. This falls with loss of charge in a more-or-less linear way. Fig.1 shows a graph of the voltage of a nominal 12V lead-acid battery against charge state. Although there will be small variations, this is largely independent of the physical size or manufacturer.

Note that, over the useful range of charge, the difference is only 1V or so. It is important to also note that "zero" charge means the *practical* end point – not true zero! A battery discharged below this level is likely to suffer irreversible damage even though it would still be capable of delivering current.

In this circuit, the voltage (hence charge) is measured using a set of l.e.d.s – one each, Green, Yellow, Orange and Red. These show though holes in the top of the box. The first three are grouped together but the red is slightly displaced because it performs a different function (the crank test or danger level signal).

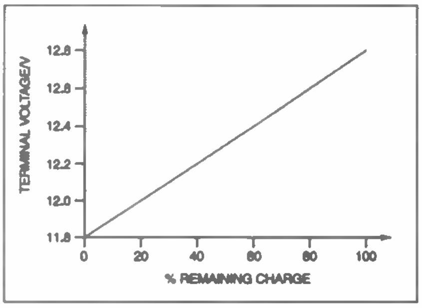


Fig.1. Graph of the voltage of a nominal 12V lead-acid battery against charge state.

To use the instrument, a flying lead is clipped on to the negative (–) battery terminal. Holding the box in one hand, the probe is now touched on to the positive (+) terminal and the l.e.d.s observed.

Some, or all of them, should light up according to the state of charge. Thus, all l.e.d.s on signifies "high", all except green "medium", only orange and red "low".

Disregarding the crank test for the moment, the red l.e.d. will always be on unless the battery is seriously discharged. If it is off ("danger level") the battery must be charged urgently and, depending on type, it may never recover its full capacity.

OPERATING POINTS

Rather than to indicate "full", "half" and "zero" charge, it was decided to provide the "good" point at around 80 per cent but the "low" one towards the end of the useful remaining charge. The orange l.e.d. therefore represents a "charge now" signal.

However, the green one will be on even when the battery is slightly discharged. This prevents it going off almost straight away after a period of use. Experience with the particular application will soon show how these operating points need to be interpreted.

Some manufacturers state that re-charging *must* be carried out on their batteries when the voltage falls to 12V. Others allow it to fall to, say, 11·7V. Taking this into account, these are the selected operating points:

High	*Medium*	*Low*	*Crank Test/ Danger Level*
12·6V	12·3V	12·0V	9·8V

For ease of construction, these operating points are preset and *cannot* be altered unless you are competent at re-calculating the resistor values in a potential divider chain.

HOW IT WORKS

The complete circuit diagram for the 12V Battery Tester is shown in Fig.2. The principle component is a quadruple bipolar op.amp (operational amplifier), IC2, which contains four identical units in a single 14-pin package. The individual op.amps are referred to in the text and in the diagram as IC2a to IC2d. The power supply to the circuit is obtained from the battery "on test" via fuse FS1.

All four op.amp inverting inputs (pins 2, 6, 9 and 13) are connected together and, in turn, connected to the "regulation" (Reg) pin of IC1, a 5V voltage reference device. This behaves rather like a Zener diode, and is connected and drawn as such.

However, it behaves with much greater precision. A voltage equal to or very close to 5V will therefore appear at all the inverting inputs of IC2. IC1 requires a certain small reverse current to flow through it to allow regulation to take place and this is the purpose of resistor R6. Correct operation will be maintained down to a level much lower than that of a battery at its end point.

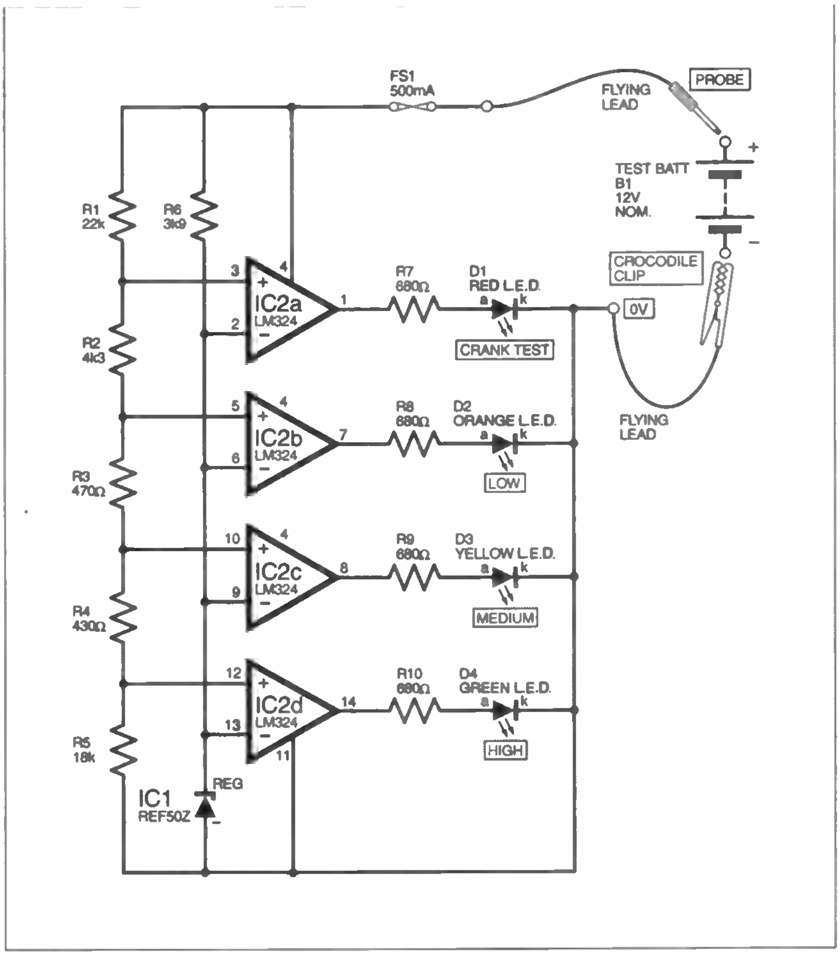


Fig.2. Complete circuit diagram for the 12V Battery Tester.

CHAIN REACTION

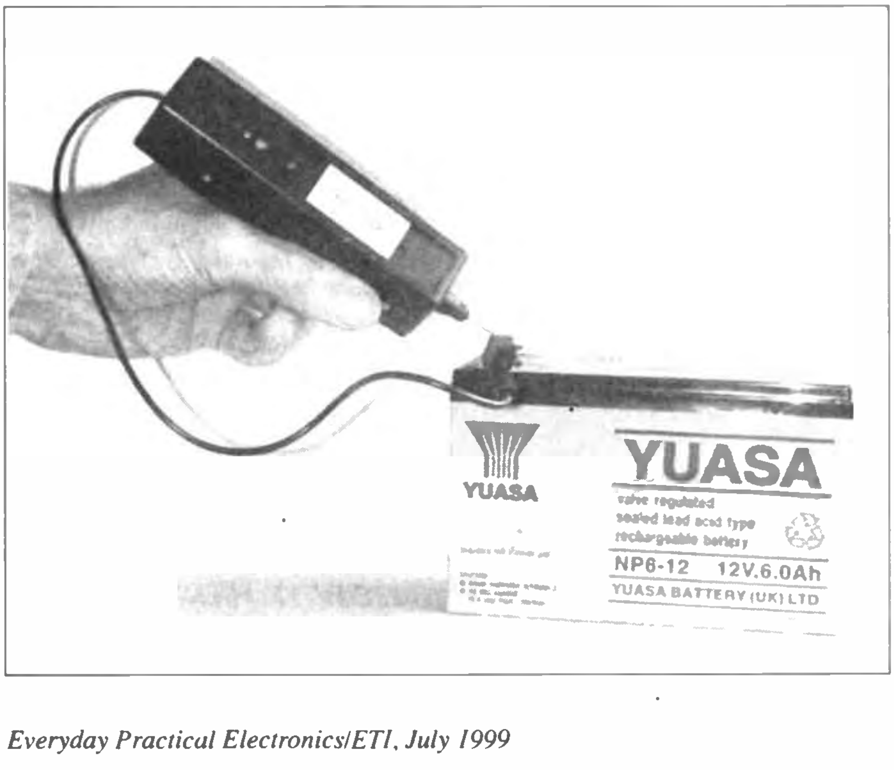
The non-inverting inputs of IC2a to IC2d (pins 3, 5, 10 and 12 respectively) are connected to various points along the potential divider chain, made up of resistors R1 to R5. The ends of the chain are connected across the supply so that, according to the individual resistor values, the voltage appearing at these points will be a known fraction of the battery voltage.

They have been selected to provide 5V when the terminal voltage of the battery is at the operating points. Thus, 5V will appear at the non-inverting input of IC2d with a supply of 12·6V, at IC2c with 12·3V, IC2b at 12·0V and IC2a with 9·8V.

With increasing supply voltage (and therefore battery charge), the non-inverting supply voltage of IC2a to IC2d will therefore exceed that at the inverting ones. As this happens, the corresponding output will go high and the l.e.d. (D1 to D4) associated with it will operate. Each l.e.d. has its operating current limited by one of resistors R7 to R10 to a nominal 15mA.

Since the operating points must be known with a fair degree of accuracy, the resistors used in the potential divider chain are *1 per cent tolerance* types. Not only do these have accurately-known values but they will maintain them over time.

A fuse, FS1, is included to protect the tester in the event of an error which may result in a short-circuit to the supply. A lead-acid battery can deliver a very high current under such conditions and this could result in wiring or p.c.b. tracks melting. The fuse should protect the circuit in the event of incorrect connection and more will be said about this later.



The usual method of including a diode for reverse-polarity protection is inappropriate here due to its forward voltage drop. This, being slightly voltage-dependent, would change the operating characteristics of the circuit in an unpredictable way as the various l.e.d.s came on.

CONSTRUCTION

All the components for the 12V Battery Tester, except the fuse, are mounted on a single small printed circuit board (p.c.b.) which has been designed to fit the specified probe box. The component layout and full-size copper foil master are shown in Fig. 3

NOTES ON USE

In any particular application, experience will best decide how to interpret the operating points. However, the following hints should help those using the instrument for the first time.

1. Always connect the unit with the correct polarity.
2. Do not perform a test with a charger connected. In fact, allow the battery to rest for at least one hour after charging to allow the voltage to stabilise. This is because it falls slightly with time.
3 Remove any load and allow the battery to rest for a while before testing. This is because the voltage rises slightly so failing to do this would result in an incorrect reading.

Most of the change happens in the first few minutes. However, best results will be obtained if the battery is left idle for at least one hour.

and photographs. This board is available from the *EPE PCB Service*, code 234.

Referring to the component layout in Fig.3, drill the two mounting holes then solder IC2 socket in position (but *do not* insert the i.c. itself at this stage). Follow by soldering all other components in position except IC1 and the l.e.d.s. Take special care to solder each resistor R1 to R5 into its correct position or the operating points will be incorrect.

Taking extra care with the polarity, solder the l.e.d.s in position so that their tops stand about 10mm above the circuit board. They should be level and in a straight line or it will result in a poor appearance to the finished instrument. Note that the cathode end (k) is labelled in each case (this having the slightly shorter end lead).

Before handling IC1, observe some precautions to prevent possible damage to it by static charge which may exist on the body. The simplest method is to touch a water tap immediately before unpacking it and touching the pins. This will earth the body and allow any charge to flow away harmlessly.

Refer to the pinout details in Fig.3 and look at the flat face of IC1. Cut off the *left-hand* end wire (this is connected internally to the substrate and does nothing). Solder the remaining wires in position with the flat face of the i.c. towards the left-hand edge of the p.c.b. (An alternative TO92 pinout outline is included as this version may be offered to readers.)

Solder a 5cm piece of stranded connecting wire to the point labelled +V on the *copper track* side of the p.c.b. and 30cm of black *extra flexible* wire to the 0V point on the topside (this will be the flying lead).

Finally, insert IC2, taking care over its orientation, into its stocket. This is a bipolar device and requires no special handling precautions.

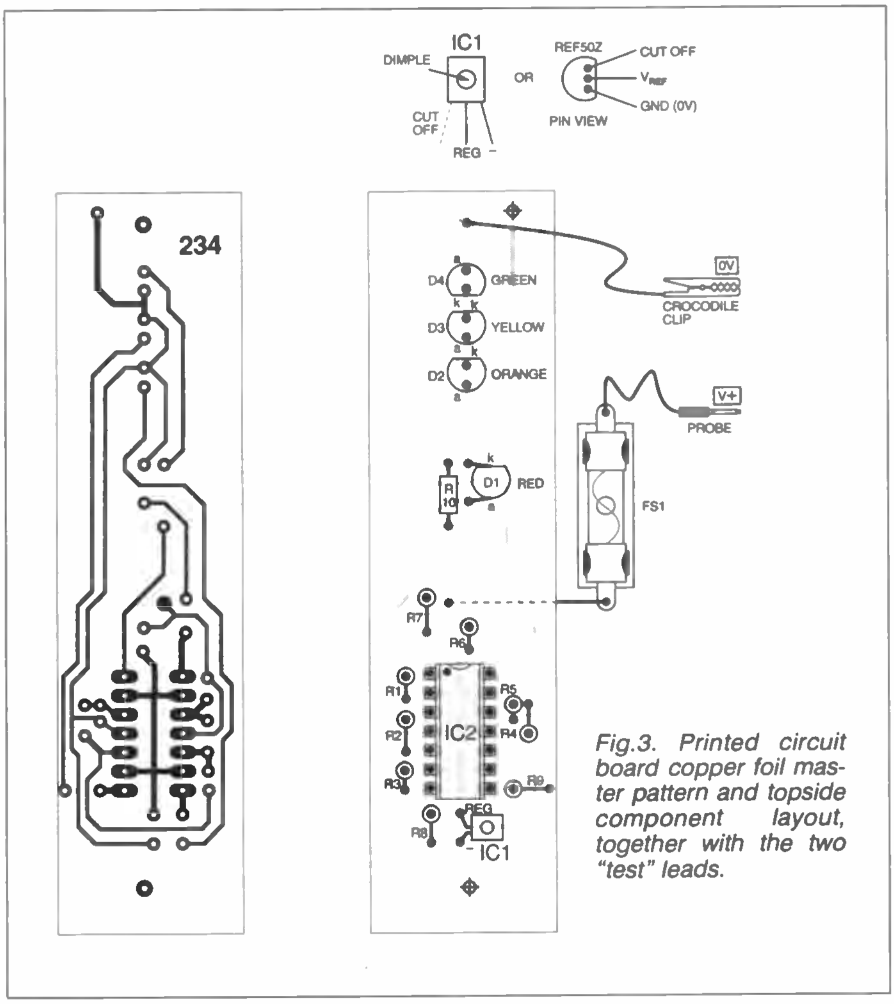


Fig.3. Printed circuit board copper foil master pattern and topside component layout, together with the two "test" leads.

COMPONENTS

Resistors

R1	22k	See
R2	4k3	SHOP
R3	470Ω	TALK
R4	430Ω	page
R5	18k	
R6	3k9	
R7, R8, R9, R10	680Ω (4 off)	

R1 to R5 must be of the 0·6W metal film type having 1% tolerance. All other resistors may be of the 5% 0·5W carbon film type.

Semiconductors

D1	3mm red l.e.d.
D2	3mm orange l.e.d.
D3	3mm yellow l.e.d.
D4	3mm green l.e.d
IC1	REF50Z 5V reference voltage
IC2	LM324N quad op.amp

Miscellaneous

FS1 20mm chassis mounting fuseholder, with 500mA 20mm quickblow fuse.

Printed circuit board available from the *EPE PCB Service*, code 234; logic probe box (with probe), size 130mm x 34mm x 30mm approx; 14-pin i.c. socket; stranded connecting wire; extra flexible wire; self-locking cable tie; crocodile clip (with black insulation cover), to suit the application; 12·7mm plastic spacers (2 off); solder, etc.

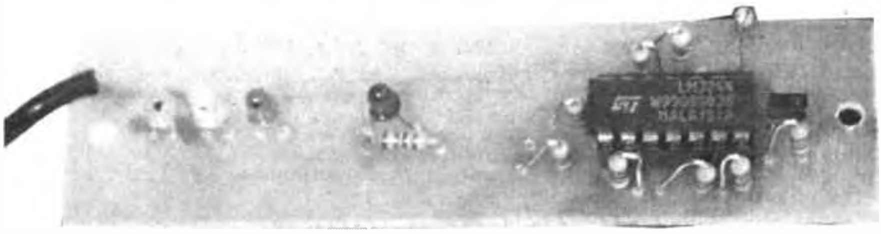
Approx. Cost Guidance Only £15

BOXING UP

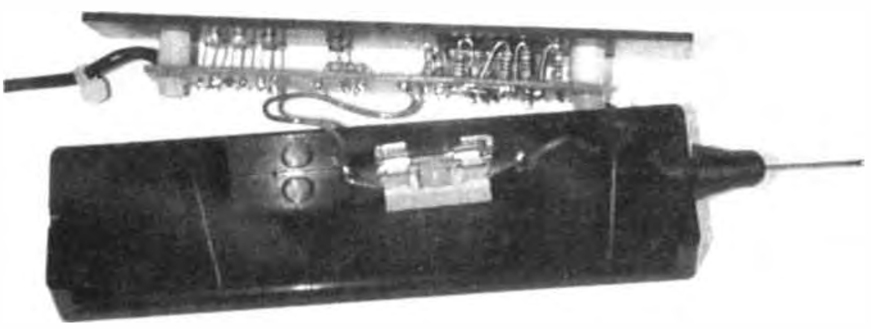
The p.c.b. may now be prepared for mounting on the removable side panel of the specified box. Note that this is done with the copper track side facing outwards – see photographs.

Check the position of the p.c.b. and, by careful measurement, mark the mounting and l.e.d. holes on the panel. Drill all these holes.

In the prototype, those for the l.e.d.s were made slightly smaller in diameter than that of the l.e.d.s themselves. This is because they did not actually protrude through the holes and this was thought to give a better appearance to the finished unit.



Layout of components on the completed circuit board. The method of mounting the p.c.b. on the removable panel and positioning of the fuseholder is shown below.



Having finalised the positioning of the p.c.b., the next task is to establish the position of the fuseholder in the case. This is mounted on the box base and a small hole should be marked and drilled to take the holder fixing bolt.

Now attach the p.c.b on the removable panel, using small nuts and bolts with spacers between to allow the l.e.d.s to take up their correct positions. The spacers are trimmed to the required length by cutting them to size with a small hacksaw. Secure the fuseholder in position and solder the +V wire leading from the p.c.b. to one end of it.

PROBING QUESTION

Prepare the probe which is supplied with the specified box. This needs care and patience. Cut off a 5cm piece of stranded wire and strip a small section (about 2mm) of insulation from the end. Solder "tin" the bared wires and insert them into the hole in the probe.

Now "feed" solder into it until it is almost level with the rim of the hole – it must not bulge above it. *It is very easy to make a poor joint which parts easily* – check carefully.

When satisfied, push the larger plastic bush over the probe. Pass the wire through the smaller bush and engage it with the larger one. This leaves a recess which will be gripped in the larger of the two holes in the ends of the case when this is assembled.

If the recess is too wide, the soldered joint is probably too thick. Solder the end of the wire to the free terminal of the fuseholder. Check the position of the flying lead in the other recess and, leaving a little slack, place a tight cable tie around it to provide strain relief.

Assemble the case using the plastic bushes and screws provided with it. Make sure the probe and flying lead are correctly located in the holes and check that the flying lead cannot be pulled free by any reasonable amount of force.

Make a label to cover the rectangular opening in the face of the front panel of the box. Fit a crocodile clip appropriate to the size of battery to be tested to the end of the flying lead.

TESTING

Testing is not absolutely necessary. You could use a "proof is in the pudding" approach. However, some kind of basic check is probably a good idea and if you have a digital voltmeter, you could confirm the operating points. In the prototype unit, these were all within 0·05V (50mV) of the nominal values.

Always take care to connect the circuit with the correct polarity. In two tests on the prototype, incorrect polarity resulted in the fuse blowing but everything else survived.

However, this *MUST NOT* be relied on and damage could occur. The value of the fuse is higher than is strictly necessary because the very low values have a significant resistance which would result in an unacceptable voltage drop.

If you are using the instrument to check the state of charge of a small battery, it will be convenient to use a direct method of testing. Begin with a fully-charged battery and run it down using the piece of equipment with which it will be used or a small bulb of comparable power rating.

Completed "checker" with the removable side panel, holding the p.c.b., slotted into position ready for closing-up the box.

Aim to discharge to the low point over a period of 10 to 15 hours – do not try to hurry the job by applying a large load. For example, if the capacity of the battery is 7Ah, it will discharge to the end point if 500mA was drawn for about 14 hours.

This could be obtained using a 5W or 6W car-type bulb. In practice, the capacity may be considerably less than the nominal value depending on the amount of service the battery has given and how carefully it has been used.

TAKING THE LOAD

Connect the load (bulb) for 15 minutes, disconnect it and allow the battery to rest for about 15 minutes. Connect the Tester and note that all l.e.d.s come on.

Connect the load again and continue discharging for set intervals (say, 30 minutes), allowing a 15-minute rest in each case before making the check. Keep track of the total elapsed discharge time.

You should find that the green, yellow and orange l.e.d.s go off at reasonably-spaced intervals. ***Do not wait until the red l.e.d. goes off – you could damage the battery.*** If it happens by accident, re-charge promptly.

If you are using the unit to test a car battery, it would not be advisable to run it down in the way described above because the car is likely not to start afterwards! Either the operating points will need to be taken on trust or you could test the unit with a bench power supply having a continuously-variable output voltage. Again, a digital voltmeter would determine the operating points accurately.

A BIT CRANKY

As stated previously, the red l.e.d. will normally remain on during the test unless the battery is seriously discharged (below a terminal voltage of 9·8V). You could regard this as corresponding to the minimum state of charge which could be reached by accident and which would demand immediate re-charging. It also provides the "Crank Test" (see below) which is only applicable to car batteries.

A lead-acid battery has such a low internal resistance, that any normal load placed on it will result in only a small voltage drop (very small indeed with a physically large battery such as a car battery). Thus, virtually the full available voltage will appear across it.

However, when the battery is subjected to a very heavy load, even this small internal resistance will result in a significant voltage drop and this is subtracted from the supply to give the "terminal voltage". In this case, it does not mean that the battery is necessarily low on charge.

In a car, the heaviest load is imposed by the starter motor while turning the engine ("cranking"). The voltage may then fall to some 10V.

With a battery nearing the end of its service life, the internal resistance tends to rise and the voltage will fall still further. Eventually, it will reach the point where the starter motor fails to turn quickly enough to start the engine. It may not even turn at all.

To perform a crank test, first ensure that the battery is in a good state of charge. It will be helpful if you can prevent the car from starting (consult the workshop manual to make sure this is safe/possible). The tester is then applied to the battery while an assistant operates the starter. Take great care to avoid hot or moving parts!

The red l.e.d. should remain on (although it may flicker a little). If it goes off immediately or very quickly afterwards, the battery should be renewed.

Do not run the test for more than a few seconds since the battery will run down rapidly and may not start the car next time. There could also be problems with the engine flooding making it more difficult to start. □