

Using a multimeter on a vehicle electrical system.

There are numerous informative threads here on the forum dealing with vehicle electrical systems but unfortunately very few about what to use to make the necessary measurements or how to use such a device.

Many vehicle owners might have available an electrical test meter but might not know how to use it so here I'll try to demystify the multimeter.

Types of meter.

There are generally three types of meter talked about on the forum;

1. An analogue multimeter. This type has a moving pointer to indicate the measured value.
2. A digital multimeter. This type of meter has a digital readout of the measured value.
3. A clamp meter. This is a meter which can read the value of a current flowing through a wire just by surrounding it with a device to analyse the wire.

1. The analogue meter.

There probably aren't many of these around by now. They tend to be much less robust than the digital meters and also much more expensive to purchase and maintain.



The Avometer. AVO 8. MkIII.

The Avometer was at one time an “industry standard” for portable multimeters and most owners of such a device will have some knowledge regarding its general use.

Owing to its internal circuitry there might be some interactions with the circuit under test which don't really apply to the digital types of multimeters (see: “Errors of measurement”), but operation is generally similar to a digital meter.

2. The digital multimeter.



A typical low cost digital multimeter

Often abbreviated to DMM (Digital Multi Meter) or DVM (Digital Volt Meter). The digital display is often specified in what might seem to be a strange way, cheaper units will usually be listed as 3½ digits, more expensive units could be 4½ digits. This means 3 or 4 full digits which can show as 0-9 and the half digit which will only show a 1 or -1.

Consequently, the maximum range of values which can be displayed is from -1999 to 1999. Any decimal point will be inserted in the correct place automatically or by the internal circuitry attached to the switch. For this reason you will see the ranges as 2 something, e.g. 2, 20, 200, 2000 or 2k, etc.

Some of the more expensive DMMs are “auto-ranging” which means that the operator need only select the function and the DMM will automatically decide whether the range needs to be 0-2 or 0-200 or whatever.

The modern cheaper DMM will often have a single rotary switch to select the measuring function and range of the meter. The functions will generally be to measure DC volts, DC current or amps, Resistance, AC volts and AC current or amps. There could also be some other functions, most of which will never be used in basic operations. Some of the more expensive meters such as some of the Fluke range of products might have buttons to select the function and a single rotary switch to select the measurement range. The rotary switch will have some method of identifying which way it's pointing on it, often a small arrow, a bevel or a dimple at one end of the knob.

In vehicle electrical systems the functions you will use most often will be DC volts, resistance and less frequently DC current.

Continuity check of the leads.

Prior to carrying out any tests a user is advised to first check the operation of the DMM by carrying out a continuity check on the test leads. With the test leads in the sockets, red in the socket marked VΩmA and the black lead in the “COM” socket, select the resistance function and the lowest resistance range, 200 ohms and touch the two test probes together. The display should then show a near zero reading, disconnecting the probes will cause the reading to show a single 1 on the display.

Depending on the type of DMM there might be a beep when the two probes are connected together. This is the audible signal of continuity and not a fault condition.

To measure DC volts on a vehicle.

Safety note: Making voltage measurements will require that the user must work on live or active circuits. Proceed with caution.

The voltage usually encountered on a vehicle is nominally 12 volts but this can rise to a maximum of about 15 volts. Some vehicles such as ex-military vehicles might have a 24 volt system, for the purposes of these notes I'll deal only with the 12 volt system.

Switch the DMM on, this might require pressing a separate button or just turning the range switch away from the OFF position, then select the 20 volts DC range. The DC function is indicated by the marking "V" with a straight line and usually a broken line under it. The display should then show zero either as a single "0" or three "000", depending on the type of meter.

Connect the test leads to the DMM taking care to observe the polarity, red lead in the red socket and the black lead in the black socket. The sockets might be marked as VΩmA for the red or positive socket and "COM" for the black, negative socket.

To make a voltage measurement connect the measuring probes to the circuit, for instance across a battery and read the voltage shown on the display. If the reading shows a negative (minus) value then reverse the probes on the testing points. The red lead will indicate which is the positive end of the circuit. If you don't know what value to expect when measuring a voltage, start with the highest range and gradually turn the range switch down until a sensible reading is shown.

A flashing display showing 1999 or a display showing just a 1, depending on the DMM is usually taken as being "over-range". If this happens then the next highest measurement range should be selected.

The maximum voltage which can be applied to most DMMs without causing damage to the meter is usually about 600 volts, but DO NOT TRY to measure such a voltage without experience and training.

Measuring resistance.

Never make resistance measurements on live circuits, always switch the power to the circuit off before proceeding.

Switch the DMM on, this might require pressing a separate button or just turning the range switch away from the OFF position, then select the resistance function usually shown by the omega symbol Ω. The range will depend on the expected value of resistance of the circuit or device being tested.

Connect the test probes to the circuit under test and read the value on the display. If the reading continues to show a 1 then increase the range until a sensible reading is shown. If the display continues to show a 1 even at the highest range, e.g. 2000k or 2M then an open circuit condition is indicated. This might be a fault such as a blown bulb or fuse, or it could be a switch in the off position for instance.

Be careful when making very high resistance tests, your fingers could quite easily alter the reading confusing the results.

The resistance function might also have another little symbol which looks like a diode. This is a useful function when faced with the large amount of electronics in modern vehicles and is the setting for testing diodes. A diode is a device which allows current to flow in one direction but blocks the current in the opposite direction. To test a diode, select that range (usually the 2k range) and connect the probes to the diode observing the reading. Then connect the probes to the diode the opposite way round and note that reading. You should see a high value one way round and a low value the other way round. The low value will be when the black test lead is connected to the positive end of the diode, the end with the band. When the red test lead is connected to the positive end of the diode, the reading will be a high value.

Measuring current.

Measuring current often confuses new or inexperienced users. In almost all cases it will require breaking into the circuit, unlike taking a voltage reading where the meter is connected “across” the circuit under test. In the case of almost all digital multimeters the maximum current which can be measured is 10 Amps and the meter will often contain a fuse to protect the internal circuitry.

Whenever a measurement is to be made, the operator should first estimate the maximum value likely to be observed during measurement and set the range as appropriate. If such an estimation can't be made the highest possible range should be selected first and then reduced until a sensible reading is obtained.

To select the highest range for measuring current, switch the DMM on, this might require pressing a separate button or just turning the range switch away from the OFF position, then select the current function then select the 10 Amps DC range. The DC function is indicated by the marking “A” with a straight line and usually a broken line under it. The display should then show zero either as a single “0” or three “000”, depending on the type of meter.

Transfer the red test lead from the normal $V\Omega mA$ socket to the 10A socket leaving the black lead in the COM socket. Some models of DVM might not have the separate 10 A socket, others might not be able to measure 0-10 Amps. *Damage could occur to your multimeter if you exceed the maximum allowed current.* Check your user's handbook for further information.

Connect the test leads to the circuit under test, you might find that using some crocodile test clips are useful here and activate the circuit. Read the value of current passing through the meter, and hence through the circuit. If the reading is too low to be sensible, switch the circuit off and transfer the red test lead back to the normal $V\Omega mA$ socket and select the highest DC current range, 200m (200 milliAmps) and re-activate the circuit. If the display shows a minus sign then the meter is connected to the circuit the wrong way round. You can assume this unless you know conclusively which way the current should flow in the circuit in which case it could indicate a fault condition.

Once all tests have been made, disconnect the meter and reconnect the circuit at the point where the “break in” was made before re-activating the circuit.

There are some small panel meters available which can be used to measure current. These devices use a “shunt resistor” in the circuit through which the current will pass and the panel meter is then connected across the shunt. The panel meter then actually measures the voltage drop across the shunt. It is then arranged that the panel meter displays this small voltage but it is calibrated and labelled as current (Amps).

Other measurements and settings.

There might be some times when other types of measurements, no matter how unlikely are needed, for instance checking a DC voltage on a circuit for residual AC, such as could be the case with a faulty alternator. Testing the circuit with the meter set to 20 volts DC might show for arguments sake 14 volts, then setting the switch to an AC volts position shown by a “V” followed by a ~, the display should show a very low reading, if anything at all. Should the display show a higher reading then it could indicate that there is a residual AC voltage combined with the DC voltage which could be a result of a fault condition. When a low AC volts selection is set on the multimeter there might be random numbers showing on the display. This is quite normal and not an indication of a fault condition.

Continuity “Beep”

A small “loudspeaker” symbol on the function switch is the setting for the audible continuity tester. This is useful where the operator can’t see the display when making a continuity check. When the circuit is continuous then the meter will beep.

hfe

The switch setting “hfe” is unlikely to ever be used, particularly in a garage setting. It is the setting for measuring the “amplification factor” of a transistor.

Hold button

An example of where the “Hold” button might be useful in the garage setting could be for making voltage measurement where a maximum reading needs to be displayed. For instance when trying to determine the maximum charging voltage on a vehicle battery. Set the meter as if measuring DC volts and set the range to 20 volts and connect to the battery. At tick-over the display might show something in the range of 12-14 volts DC. Press the “Hold” button once and then increase the engine revs to say 2000 rpm when the voltage could rise to 15 volts or more, depending on what load is present on the circuit, headlights, etc. Reduce the engine speed to tick-over once again and observe the display. It should now hold and display the maximum voltage that was measured during the test, even after disconnecting the meter from the circuit. Pressing the “Hold” button a second time should return the meter to normal operation.

3. The Clamp meter.

This type of meter is often a digital multimeter with a clamp like device at one end. Analogue clamp meters are available but they tend to be very much more expensive to purchase.



A typical low cost clamp meter

The digital multimeter functions are the same as almost any other DMM, select the function and range and the using two test leads make the measurement and read the result on the digital display.

The unique function provided by this type of meter is that it can “sense” rather than actually measure the current flowing in a wire without disconnecting or breaking into the circuit. Operation relies on the same magnetic induction principles as those found in a transformer.

In the example shown above the current ranges are 0-40 Amps and 0-600 Amps. Earlier versions of the clamp meter would only measure AC using the clamp but later types utilise some internal electronics to enable the operator to measure DC current using the clamp also. Exactly how this is done is unknown and anyway how is of no interest to the operator.

40 Amps and 600 Amps may not be particularly useful in the required application so the measuring ranges can be changed to 0-20 Amps and 0-300 amps by looping the wire under test and passing it twice through the clamp and making the necessary conversion in the display using mental arithmetic. For instance, if the wire is looped twice then the actual current sensed by the clamp is doubled for display. So a display of 40 Amps would mean that there is 20 Amps flowing in the wire.

The clamp meter could be of use in the garage setting for measuring the current being drawn by high current circuits such as the starter motor while it's cranking, usually a current too large to be measured using an ordinary meter. In the case of the DC clamp meter, it is important that the current in the wire under test flows in the correct direction. This is normally shown on the side of the clamp in some way, check the user's manual for full information on this use.

Errors of measurement.

Whilst it isn't absolutely necessary to know about errors of measurement, it can help the user who would like to understand their multimeter a little better.

Calibration error.

As with any measuring system, the results will be subject to given tolerance, although in normal use the calibration error can be discounted. For most low cost digital multimeters the error will be $\pm 2\%$ of the full scale reading for each range. On some meters, the tolerance for the AC ranges could be greater, say $\pm 5\%$ of full scale. A similar error could be expected when using the clamp on a clamp meter. Analogue meters are also subject to similar calibration errors. Refer to the specification sheet attached to the owner's handbook for your multimeter.

Parallax error.

This is an error which applies to the analogue meter only. An error can result from looking at the meter needle from one side or the other instead of directly above it. On better quality analogue meters such as the AVO (above) there is a mirror included on the meter scale to help to position the user's eye in order to reduce the parallax error.

Sensitivity or ohms per volt error.

This is an error again that particularly applies to analogue meters, but when making measurements in high resistance circuits it could also affect digital meters. The meter movement is just a coil of wire which has a resistance value, that value is added to the value of the resistor called the "multiplier" which allows the range of the meter to be extended. A reasonable quality analogue multimeter will have a sensitivity quoted as 20,000 ohms per volt. This effectively works out that if the 10 volt range is being used the meter will add a value of 200,000 ohms ($20,000 \times 10$) across the circuit under test. This 200 k ohms can affect the measured result to quite a large amount.

The sensitivity of most digital multimeters is in the range of 1 to 10 M ohms per volt so the DMM will add a value on the 2 volt range of 2 to 20 M ohms (2 to 20 Million ohms), consequently the presence of the meter in the circuit will have a much reduced effect.

The sensitivity figure will be quoted on the specification sheet in the user's handbook for the multimeter.

Other useful (or maybe not so useful) electrical diagnostic devices which aren't multimeters

While a multimeter could be seen as the best device to reach for when one encounters an electrical problem, not counting problems with ECUs which might require the use of a diagnostic code reader, there are a number of less technical devices on the market which could aid in fault diagnosis. One device gaining in popularity lately, especially since Edd China (Wheeler Dealers) has been seen using one is the voltage or power probe.



A typical "Power Probe"

The Power Probe uses the vehicle power supply instead of an internal battery.

Refer to the user's handbook for full details on using the device.

The probe can be used to detect the presence of a system voltage at the point under test but can also be used to "inject" 12 volts into a circuit, for example to test a relay, motor or bulb.



The "Fusebuddy"

The "Fusebuddy" is a useful device which can be plugged into a standard or mini blade fuseholder to monitor the amount of current being drawn through the circuit, and possibly why a fuse is blowing.

It could be useful to check the current when connecting additional loads to an already fused circuit or as an aid to deciding on the suitable fuse to fit in a new circuit.

Maximum current is 20 Amps.



Automotive relay tester

Whilst not a multimeter, this device is useful to quickly and easily check the operation of an automotive relay out of the circuit or off the vehicle.

Simply plug the relay into the appropriate socket, select whether the relay is a four or five pin device and press the test button.

The relay will be “exercised” ten times and at each operation the switching of the relay contacts are electrically tested. If the tester detects a fault with the contacts it will show a red LED and a green LED if the test was satisfactory.

The case can be modified by using a flat needle file to accommodate high current relays such as the one used to switch the glow plugs on the Td5 engine.

Whether a device such as this represents good value for money when measured against the cost of replacement relays must be a personal decision, but as a diagnostic aid it could have its uses.

If no other tester is available, a simple device which can be used to check for the presence of 12 volts is a bulb and two lengths of wire connected to the appropriate points on the bulb. To test for 12 volts, connect one of the wires to the vehicle earth and the other wire to the point under test. If the bulb lights fully then 12 volts is present, if the bulb doesn’t light up then there’s no volts and if the bulb glows dimly then that’s the time to get your multimeter out. For just a couple of quid an owner can buy a device which looks like a small screwdriver with a lead and crocodile clip on it which does exactly the same as the bulb and wires, it’s just a bit more “professional” looking.