PRACTICAL ELECTRONICS

The multimeter and how it's used

Many electronics hobbyists only ever buy one item of test equipment — a multimeter. This is the most versatile, cost-effective piece of test gear ever devised for electronics, and should be considered as an essential item. So let's find out what a multimeter is, and see how it is used.

by GREG SWAIN

Many people think that to get involved in electronics you have to buy a lot of expensive test gear. That, fortunately is not true. There's just one essential item of test gear for most hobbyists, and that's a good multimeter.

Even if you never buy or make another item of test equipment, you really must have a multimeter. It's an essential item for carrying out all the basic checks required in building and, if necessary, troubleshooting electronic equipment.

These various checks include making continuity tests, checking resistor values, and performing voltage measurements. You can check the voltage of a power supply rail, for example, to make sure that its value is correct. And, of course, if an assembled project does not work properly, a multimeter will prove invaluable in tracking down the cause of the trouble.

What's a multimeter?

Let's back up a little and find out what a multimeter is.

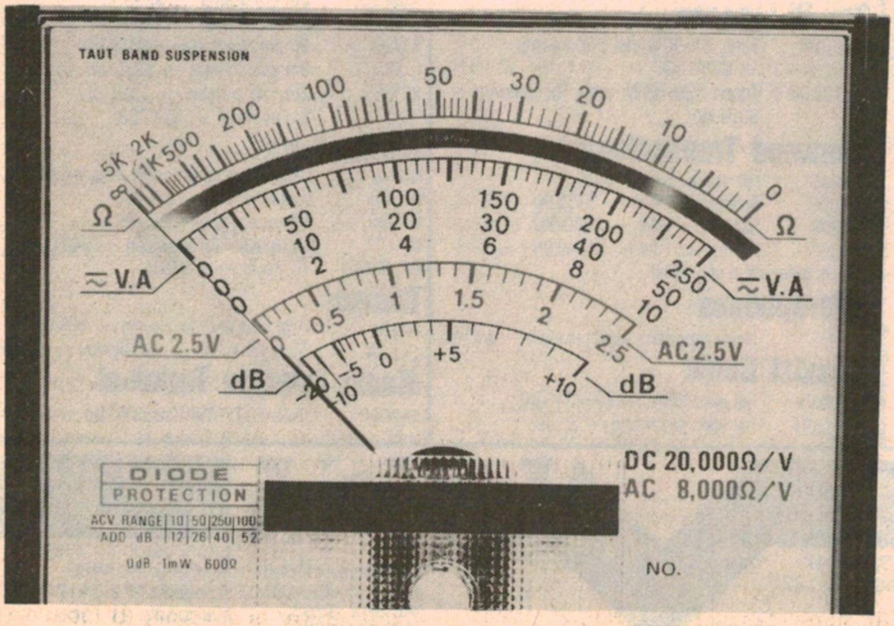
A multimeter is a multi-purpose test instrument that can measure AC and DC voltages, direct current (at least) and electrical resistance, in several overlapping ranges. For this reason, it is often also called a volt-ohm-milliammeter, or VOM for short.

In its most common form, a multimeter consists of a sensitive moving-coil meter movement fitted to a moulded plastic case. The face of the meter is covered with several different voltage, current and resistance scales, arranged in a series of concentric arcs and suitably calibrated. These are sometimes printed in different colours to make it easier to tell which scale is which.

Situated below the meter is a multi-position switch, together with various minor controls and a number of input terminals into which the test leads are plugged. The purpose of the multi-position switch is to allow the user to select the operating mode and the measurement range he or she requires. A typical multimeter has between 15 and 30 different ranges to choose from.

OK, so how does a meter that indicates current flow also indicate AC and DC voltages and measure resistance?

The answer is that inside the multimeter are some cleverly contrived circuits that convert voltage and resistance values into tiny electrical currents that the meter can measure. When you select a specific voltage, current or resistance range by means



This close-up view clearly shows the scale markings on a typical multimeter. The mirror strip is provided to eliminate parallax errors when reading the meter.

Typical multimeters for the hobbyist

Featuring almost identical specifications, the Dick Smith Q-1024 (left) and the University Model CTN-500MP are ideal multimeters for the hobbyist. Both offer 20,000 ohms per volt sensitivity on the DC voltage ranges, are supplied complete with batteries and test leads, and cost less than $30.

The Dick Smith Q-1024 has 21 measuring ranges as follows: DC voltage 0.1, 0.5, 2.5, 10, 250 and 1000V; AC voltage 2.5, 10, 50, 250 and 1000V; direct current 50uA, 0.25mA, 2.5mA, 25mA and 500mA; resistance (ohms) R x 1, R x 10, R x 100 and R x 1000.

The University Model CTN-500MP has 19 measuring ranges and an "OFF" position which applies damping to the meter movement when the unit is not being used. The ranges are: DC voltage 2.5, 10, 50, 250, 500 and 5000V; AC voltage 10, 50, 250, 500 and 1000V; direct current 50uA, 5mA, 50mA and 500mA; resistance R x 1, R x 10, R x 100, R x 1000.

The Dick Smith Q-1024 is available from Dick Smith Electronics, PO Box 747, Crows Nest 2065; the University Model CTN-500MP from Radio Despatch Service, 869 George St, Sydney 2000.

of the multi-position switch, you actually connect a specific circuit between the multimeter's test leads and the meter movement.

The circuits themselves are surprisingly simple, and consist mainly of various fixed-value resistor networks. These resistor circuits are connected both directly across the meter terminals and in series with the meter to allow the various measurements to be made. A rectifier circuit, made up from a pair of diodes, is also included to allow AC voltage measurements.

The input terminals

The input terminals of a multimeter are usually recessed "banana" sockets. These accept the banana plugs connected to the ends of the test leads, and allow the test leads to be easily connected to the multimeter. The banana sockets are recessed into plastic moulding for a good reason — to stop you from inadvertently receiving a shock when measuring high voltages.

Typical multimeters have between three and five terminals on the front panel, but only two are used for most measurements. One is usually marked "—COM", and accepts the black test lead. The second is usually marked "+V. Ω .A" (or "+INPUT"), and accepts the red test lead.

The remaining input terminals are high voltage and/or high current input terminals. They are always clearly marked with the voltage (or current) range they measure, and should be used whenever measurements are likely to exceed the ranges normally selected by the multi-position switch.

Note that for voltages up to about 500V, the red test lead supplied with the multimeter can be used. Voltages above this figure generally require the use of a special high voltage test probe.

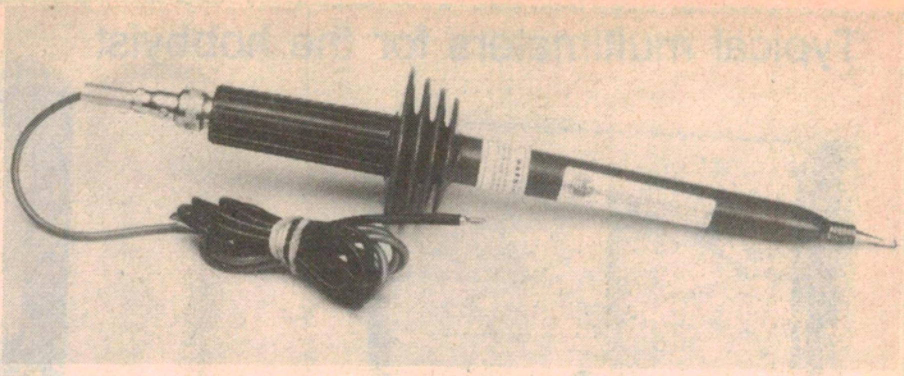
You will seldom, if ever, use the high voltage input terminals — at least not for hobby work. The average hobbyist, in fact, rarely encounters DC voltages above 50V!

Ohms adjust control

All multimeters have an "Ohms Adjust" (or "Ohms Calibrate") control. Its purpose is to compensate for slight variations in the output voltage of the multimeter's internal batteries, and is used only when making resistance measurements.

The Ohms Adjust control is actually a variable resistor in series with the meter movement, and must be adjusted so that the meter reads full scale when the test leads are short-circuited together. It should be used to set the meter for full scale deflection whenever you switch to a resistance range for the first time, and each time you switch to a different resistance range.

In case you're wondering, the multimeter's internal batteries supply power to the meter movement only for resistance measurements. When voltage or current measurements are made, power is supplied to the meter movement by the circuit being measured.



High-voltage probe

A typical high voltage test probe. This particular unit can measure voltages up to 45,000V (45kV), and provides a 1000 to 1 attenuation of input signals to give direct readings in kilovolts.

Meter sensitivity

The DC voltage-measuring circuits in all normal multimeters are based on a simple series resistor/microammeter circuit. When you switch to a different voltage range, you effectively select a different value series resistor to change the meter's full-scale voltage calibration.

When a multimeter is used to measure voltage, its very presence effects the operation of the circuit it is trying to measure. The degree to which the multimeter "loads" (draws power from) the circuit depends mainly on the value of the series resistor in the meter circuit. If loading becomes significant, the operating conditions of the circuit being measured will be greatly altered and any readings taken will be inaccurate.

To minimise loading effects, the value of the series resistor in the multimeter circuit should be as high as possible for each measuring range, and this calls for the use of a highly sensitive meter movement. Most popular multimeters employ a microammeter with a full-scale sensitivity of 50 microamperes (50uA); ie, a current of 50uA must be passed through the meter movement to deflect the pointer full-scale.

The sensitivity of the multimeter itself generally will be specified in terms of an ohms-per-volt value. Assuming the use of a 50uA meter movement, the multimeter will have a sensitivity of 20,000 ohms per volt for its DC voltage ranges. This means that there are 20,000 ohms of resistance in series with the meter movement for every volt of full-scale deflection.

A couple of examples will serve to illustrate what this means: a 0-10V DC range will have 200,000 ohms (200k) of series resistance; a 0-50V DC range will have 1,000,000 ohms (1 megohm, or 1M) of series resistance. And so on.

For most work, a sensitivity of 20,000 ohms per volt will be quite adequate, and the multimeter you buy should have this sort of specification (or better). Don't buy a very cheap multimeter with a 0-1mA meter movement. It will load down the circuits it measures much more than a 20,000 ohms per volt instrument, and will be quite unsuitable for work on modern electronic circuits.

The sensitivity for the AC voltage ranges is also specified in terms of ohms per volt. This is always less than the sensitivity for the DC voltage ranges, a typical figure being 5000 ohms per volt.

A somewhat different situation applies to digital multimeters. These usually have a constant input resistance of around 10 megohms (10,000,000 ohms) for all DC ranges, a figure which is more than adequate for most measurement situations. The main drawback of digital multimeters has to do with their somewhat higher cost when compared to multimeters with conventional meter movements.

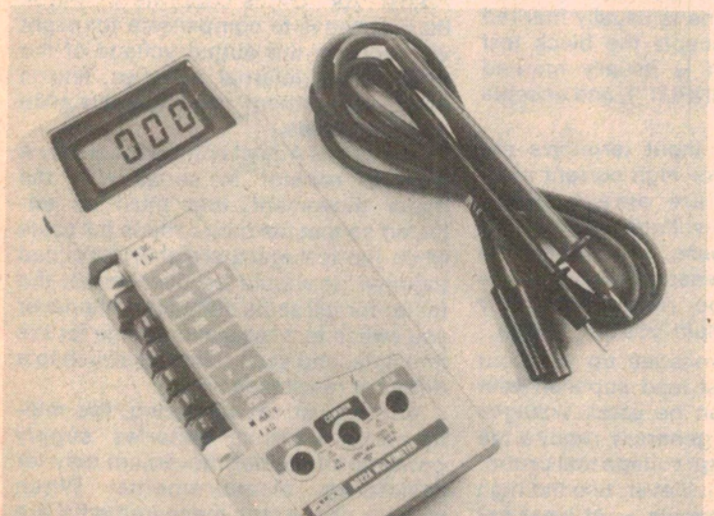
DC voltage measurements

Popular multimeters have anywhere from four to eight overlapping DC voltage ranges. A typical unit, the University Model CTN-500MP, has six ranges for example: 0-2.5V; 0-10V; 0-50V; 0-250V; and 0-500V. The high voltage input terminals must be used for measurements on the last two ranges.

Why so many different ranges? The answer is that you will have an appropriate measuring scale at your disposal for any of the widely ranging voltages found in electronic equipment. It's obvious that you can't use a low voltage range to measure a high DC voltage — the meter will "slam" full scale, and could even be damaged, if you try. On the other hand, you shouldn't use a high voltage range to measure a low DC voltage — you will not be able to read the scale accurately enough.

Added to this is the problem of the meter's inherent accuracy. The voltage and current ranges of most popular multimeters are only accurate to within ±1% or ±2% of the meter's full scale reading. If we select the 0-to-250V range, for example, the voltage measurement will only be accurate to ±5V (assuming a meter accuracy of ±2%).

So you can see that it doesn't make much sense to try to measure a 1.5V



The Fluke 8022A from John Fluke Manufacturing Company Inc., USA, features a 3½-digit LCD readout, has 24 ranges, and measures DC volts, AC volts, DC and AC current, and resistance. Enquiries to Elmeasco Instruments Pty Ltd, PO Box 30, Concord, NSW 2137.

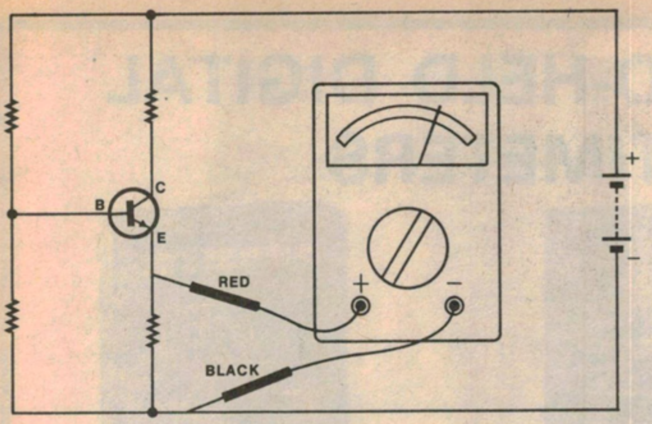


FIG. 1

How a multimeter is used to measure voltage. The red test lead connects to the more positive side of the circuit.

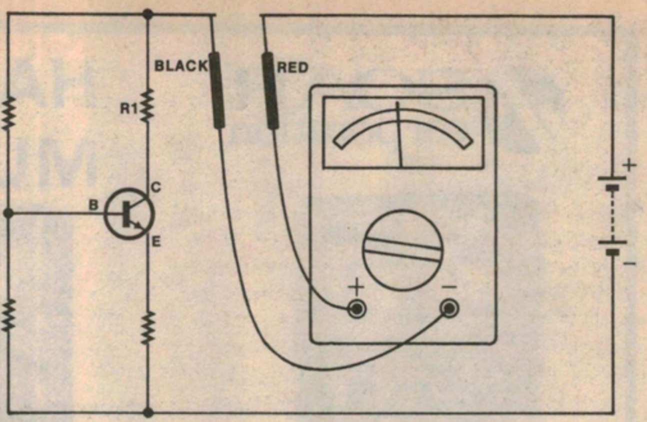


FIG. 2

Current measurements are made by breaking the circuit and connecting the multimeter in series across the break.

battery on the 0-to-250V range — the meter's allowable accuracy would be greater than the voltage you are trying to measure!

The best range for voltage measurement is the one which comes closest to giving a full scale reading, without the meter going off scale (or overloading). The correct technique is to first set the range switch to a voltage range which is known to be higher than the voltage to be measured. The test leads are then connected to the circuit under test, and the best range selected by switching down.

If you have no idea of the value of the voltage you are trying to measure, then initially the highest voltage range should be selected.

What if you inadvertently overload the meter by selecting a voltage range that's too low? Well, most meter movements will withstand a momentary 10-times overload — any more than that and you could damage the meter and/or other components in the multimeter.

To explain further, let's say that the multimeter is switched to the 0-to-2.5V range. A voltage of 25V applied to the test leads will not damage the multimeter, provided the overload is removed immediately.

The same comments regarding meter overload apply to the direct current and AC voltage ranges (but not to the resistance ranges). Note, too, that some multimeters include protective diodes across the meter which limit the maximum overload that can be applied to the meter movement. However, this does not prevent the diodes themselves and/or other components from being damaged in cases of gross overload — it merely serves to protect the meter.

Taking a voltage measurement is easy. To measure the voltage between any two points, you simply select the correct voltage range and connect the test leads to those points. The voltage reading is then read directly off the appropriate meter scale.

There's just one proviso — the test leads must be connected to the circuit the right way round. The rule is that the red test lead is always connected to the more positive side of the circuit. If the leads are connected the wrong way round, the meter will attempt to read backwards (this will not damage the meter).

Fig. 1 shows how a multimeter is used in a typical voltage measurement situation — in this case, to measure the voltage between the emitter of a transistor and the negative supply rail. As you can see, all you have to do is connect the test leads directly to the circuit. The red test lead (+) is connected to the emitter, since this is more positive than the negative supply rail.

The power supply voltage for the same circuit is measured in a similar fashion. The only difference is that the red test lead now has to be connected to the positive supply rail. The black test lead is connected to the negative supply rail as before.

What if you wanted to measure the voltage between the collector and emitter of the transistor in Fig. 1? It's quite simple — just connect the multimeter's test leads directly to the transistor leads. The red test lead would be connected to the collector, while the black test lead would go to the emitter.

Other common DC voltage measurements include: measuring voltages across resistors and capacitors, checking transistor base to emitter voltages, checking battery voltages, and checking voltages on an assembled electronic project against those marked on the circuit diagram.

Note that unless otherwise stated, all voltages marked on an electronic circuit are taken with respect to chassis, or the negative supply rail. These voltages are often included on circuit diagrams to guide construction and as an aid to troubleshooting.

AC voltage measurements

AC voltages are measured in much the same way as DC voltages — that is, by connecting the test leads directly to the circuit under test and switching down to the appropriate range. But there's one important difference: it doesn't matter which way round the test leads are connected!

Most popular multimeters have four or five AC voltage ranges, and can measure up to 1000V AC. It may be as well to point out here that a multimeter actually measures a special kind of "average" AC voltage called the RMS (root-mean-square) voltage, rather than the peak AC voltage. In a nutshell,

The Soar ME-523 deigital multimeter is sold by Radio Despatch Service. Like the Fluke 8022A it features a 3½-digit liquid crystal display and has automatic zero adjustment and polarity indication.

Above: a selection of clip-on test probes. They can be clipped directly to the circuit under test, leaving the hands free for other tasks.

Right: the Kamoden 360-TRCX features an input impedance of 100,000 ohms per volt and offers bipolar transistor and capacitor testing. The unit pictured came from Radio Despatch Service; Dick Smith Electronics sell an equivalent model.

the RMS voltage is the numerical value of AC voltage that is as effective in doing work (eg, lighting a light bulb) as the corresponding value DC voltage.

Virtually all AC voltages, including mains voltages, are specified by their RMS value. So when we talk about the mains wiring in our homes as being 240V AC, we really mean 240V RMS.

The AC voltage ranges are most frequently used to measure transformer secondary voltages. Mains voltages may also be checked, but this (and any other high voltage measurement) calls for extreme caution to avoid the possibility of an electric shock.

Current measurements

The majority of direct currents flowing inside electronic equipment range from a few tenths of a milliampere (thousandths of an ampere) to 500 milliamperes (500mA). This means that a four- or five-range instrument capable of measuring up to 500mA is sufficient for most practical electronic work. The University Model CTN-500MP mentioned previously has four current ranges: 0-50uA; 0-5mA; 0-50mA; and 0-500mA.

A few multimeters (generally the more expensive ones) include a 0-10A scale as well. You'll rarely use this range unless you service automotive gear.

Unlike voltage (and resistance measurements), current measurements require a slight modification to the circuit under test. Basically, to measure the current drawn by a circuit, the power supply rail to the circuit must be broken and the multimeter connected in series across the break.

Fig. 2 shows the basic idea. As with DC voltage measurements, a multimeter is polarity conscious when measuring direct currents. The test leads must be connected the right way round, with the red test lead going to the more positive side of the circuit. As before, the best range is the one that comes closest to giving a full-scale reading, without overloading the meter movement.

Of course, current measurements aren't just limited to the situation shown in Fig. 2. We might, for example, only want to measure the current drawn by a certain circuit stage. A typical situation is where the current drawn by the output stage of an audio amplifier must be monitored in order to make circuit adjustments.

Referring back to Fig. 2, let's say that you want to measure the collector current drawn by the transistor. This simply involves breaking the circuit between the collector of the transistor and resistor R1. The multimeter is then connected across the break, with the red test lead going to the resistor.

Alternatively, you could connect the multimeter between the other end of resistor R1 and the positive supply rail. The reading will be exactly the same as in the previous case.

Resistance measurements

Most multimeters have four or five resistance ranges, each scaled by a factor of 10. A typical unit has four resistance ranges: R x 1, R x 10, R x 100, and R x 1000. The numbers 1, 10, 100 and 1000 are the range multipliers. This means that every marking on the resistance scale is effectively multiplied by 10 when the range switch is set to R x 10; by 100 when set to R x 100; and by 1000 when set to R x 1000.

If you look at the resistance scale on a multimeter, you will notice that it is not linear; the high resistance marks are crammed tightly together near the bottom end of the scale, while the low resistance calibrations are spread out near the top end of the scale. Both ends of this scale should be avoided when taking resistance measurements.

It's no good trying to measure high value resistors with the range switch set to a low resistance range, for example. The readings at the bottom end of the scale are just too closely crowded together for an accurate reading to be taken. At the other extreme, it's no good trying to measure low value resistors with the range switch set to a high resistance range. In this situation, the meter will swing almost full scale and will be quite insensitive to large variations in resistor value.

What you have to try to do, in setting the range switch, is to get the meter to read towards the centre region of the scale. It is only in this region that you will be able to accurately measure resistor values. Of course, if you are measuring very high value or very low value resistors, then you may have no option but to take readings from the ends of the scale.

Fig. 3 shows how a multimeter is used to measure the value of a resistor.

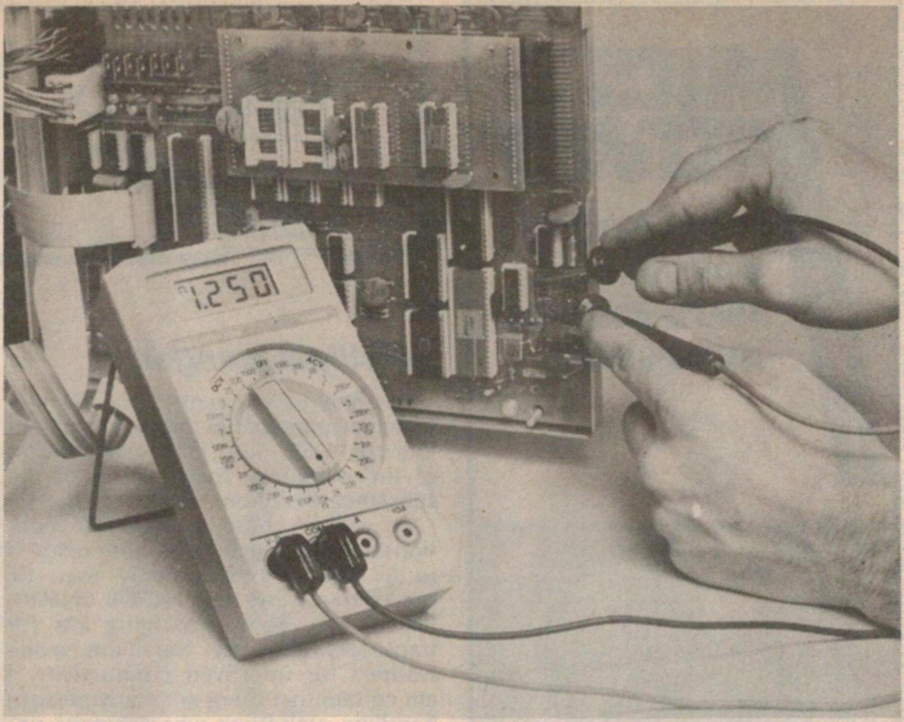
The first step is to set the multi-position switch to the appropriate resistance range, short the test leads, and zero the meter using the Ohms Adjust control, as described previously. The multimeter's test leads are then connected to the resistor, and the indicated value read off the ohms scale of the meter. Multiplying this value by the range multiplier gives the value of the resistor in ohms.

That's really not as complicated as it sounds! Let's say, for example, that the resistor we are measuring has a value of 1000 ohms (or 1k). The best range to select in this case is the "R x 10" range, meaning that we have to multiply the reading on the meter scale by 10. The meter will read "100" and 10 x 100 equals, 1000 ohms — the value of our resistor.

The best advice is buy a handful of resistors, work out their values from their colour codes, and check them with your multimeter. You'll soon get the hang of things.

Resistance measurements are not just confined to measuring resistor values, though. You can also use your multimeter to check other components — checking capacitors for short circuits, for example — and to check the resistance between any two points of an assembled circuit. Make sure that no power is applied to the circuit when making these checks, otherwise your readings will be hopelessly inaccurate.

Another thing to remember here is that it is not possible to check accurately the value of a resistor that has been soldered into circuit. The reading will be considerably affected by the presence of other components, both active and passive, shunting the component to be measured. The only way round this problem is to disconnect one lead of the resistor from the circuit. Its value can then be measured in the normal way.



The Beckman Model 3020 3½-digit LCD multimeter features 0.1% accuracy on DC voltage ranges, a 10A current range, and a diode test function. It is fully overload protected up to 1500V DC and 1000V AC. Enquiries to Warburton Franki Pty Ltd, 199 Parramatta Rd, Auburn 2144.

Continuity checks

Switching to one of the low ohms ranges — R x 1 or R x 10 — enables you to use your multimeter as a continuity checker. In fact, you will probably use your multimeter as a continuity checker more often than for any other job.

When you test for continuity, you are simply checking to see whether or not two points are directly connected together by a copper track, a length of hook-up wire, or by some other very low resistance path. If the two points are directly connected, then the meter will read full scale, or zero ohms, the same as when you short the two test leads together. If the two points are open circuit (ie, not connected), then the meter will read infinity.

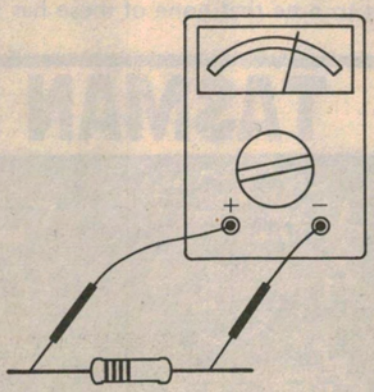


FIG. 3

How to measure resistance. Just connect the test probes across the circuit to be measured and select the best range.

Here are just some of the useful tests that can be performed:

- making sure that a transformer frame is properly connected to earth (chassis);
- tracing wires in a multi-core cable;
- checking wires, cables and copper tracks for breaks;
- checking newly installed mains wiring for inadvertent shorts;
- identifying connector terminals;
- checking that circuits are properly earthed;
- checking switch action; and
- general troubleshooting.

Buying a multimeter

Most multimeters cost somewhere between $20 and $80, although a digital multimeter can cost well over $100. The average hobbyist spends somewhere between $25 and $35 on a multimeter, and a model chosen from this price range will be quite adequate for most hobby work. Specifications for two models chosen from this price range, the University Model CTN-500MP and the Dick Smith Q-1024, are given on the second page of this chapter.

So that's the multimeter — a versatile test instrument that is a voltmeter, an ammeter, and an ohmmeter all rolled into one. Buy one as early as you can and learn how to use it; your money will be well spent.