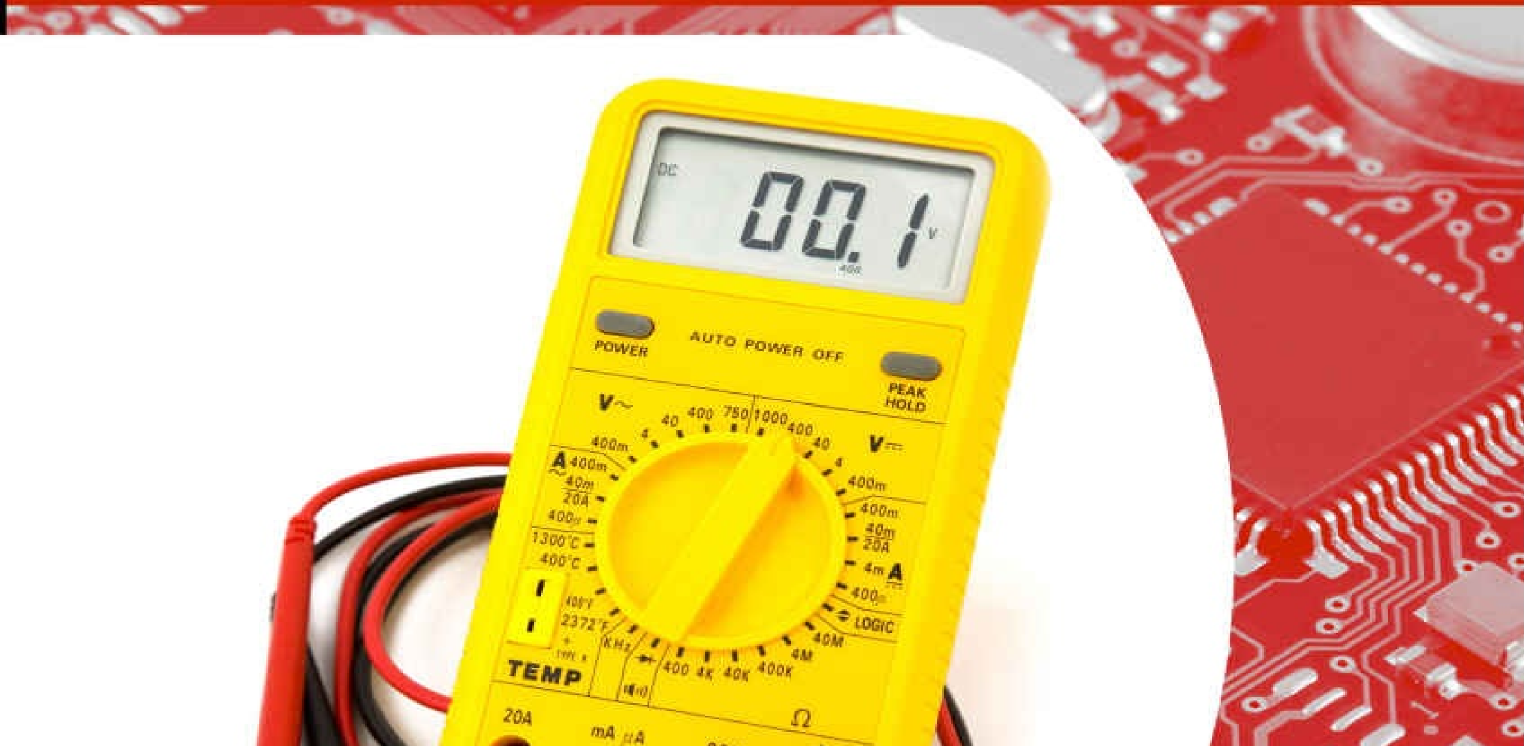
A GUIDE TO

DIGITAL AND ANALOGUE MULTIMETERS



IAN POOLE

A Guide To

Digital & Analogue Multimeters

By Ian Poole

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About this Book

The multimeter has been available in a variety of forms for very many years. It forms the mainstay of many test workshops and development laboratories. Measuring the basic quantities of voltage (AC & DC), current (AC & DC) and resistance the multimeter is able to make the main measurements required for many tests.

Nowadays with integrated circuit technology digital multimeters are able to make many more types of measurement from capacitance and inductance to frequency, time, temperature and much more.

In order to make the best use of the multimeter, it is necessary to know how one works and what its limitations are. In this way, it is possible to utilise it more effectively, and in ways that are able to extend its use.

This book aims to provide an approachable grounding into both analogue and digital multimeter technology, explaining how these instruments work,, what their specifications mean, their limitations, and most important of all how to use them. Some tricks of the trade are also revealed, enabling the reader to use these instruments in many new, interesting and useful ways.

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About the author

Chapter 1: Introduction to Multimeters

The multimeter is an instrument that has been in use for many decades and they are widely used today as much as ever. They have found considerable use because they are easily able to make many of the basic measurements required in all forms of electrical and electronic testing.

Today, it is possible to buy a multimeter with a high level of performance for a relatively low sum. Having moved from analogue meters where precision meters and components were required, to digital instruments where many of the functions can be accurately incorporated into integrated circuits, these instruments are often cheaper to make. Also, their widespread use means that they are manufactured in large quantities enabling the savings of scale to be made.

Multimeters have been available for many years. Over the years the technologies used in them have changed, taking them from large expensive instruments to the portable accurate items they are today.

Multimeter History

In the very early days when the first experiments were being made into the conduction of electrical currents, one of the main challenges that held back development was the ability to measure the current.

Only when it was realised that a current passing through a conductor created a magnetic field could any form of measuring device be made.

It was not until 1820 that the first basic galvanometer was made. These instruments were used within a Wheatstone bridge and were able to detect null points and as a result they could measure resistance and voltage. However these bridges were slow and cumbersome to use.

The next development was that of a meter with a fine coiled spring that enabled proportional measurements to be made. Using fixed magnets and a current carrying coil the deflection of the meter pointer was proportional to the current being passed and hence these instruments could be calibrated. Known as the D'Arsonval/Weston meter these instruments enabled direct measurements to be made. Also by adding a series or shunt resistor the meter was able to measure voltage and current over several ranges.

The next step was to combine the capability of making several different measurements into one instrument. The concept of the first analogue multimeter was born when an engineer working for the British Post Office who dealt with the telecommunications infrastructure in the UK became dissatisfied with having to use several instruments to measure voltage, current and resistance.

The engineer, named MacAdie developed an idea for a multifunctional instrument and took it to a small company named the Automatic Coil Winder and Electrical Equipment Company. The instrument was converted from a concept into a real instrument and named the AVO; standing for Amps, Volts and Ohms.

The first instrument, which as a DC only instrument was launched in 1923, but contained many of the features which were maintained in the AVO right up until the last analogue AVOs were sold in June 2008. At this time it was reputed to be the last professional analogue multimeter being manufactured in the world, making it the first and last.

An AVO 8 Mk III

The success of the AVO meant that many other companies designed and developed their own versions of the AVO. They became so widely used that the generic name multimeter was adopted although some used names such as VOA standing for Volts, Amps and Ohms or VOM standing for Volt Ohm Meter.

The analogue multimeters came in a variety of form factors from small and often very cheap instruments right up to robust professional instruments such as the AVO.

One of the drawbacks of the analogue multimeter was that it needed to draw a finite current for the meter to operate and the needle or pointer to deflect. This gave rise to a class of instruments that used valve or vacuum tubes to provide a much higher input level. These meters using valve / vacuum tube technology were known as either Vacuum Tube Voltmeters, VTVM, or Valve Voltmeters, VTM. Using the very high input impedance of the valve / vacuum tube they were able to provide very high levels of input impedance - levels of 1 MΩ.

Later as semiconductor technology became more widespread, transistors and in particular FETs were used to provide similar capabilities.

Technology proceeded still further as integrated circuit technology allowed for high levels of integration to be achieved. A different approach was adopted, converting the voltage into a digital format which could be processed and then displayed. These digital multimeters, DMMs became very popular, often falling in price below that of their analogue counterparts.

A typical Digital Multimeter

The use of digital technology enabled far more functionality to be incorporated in these test meters. Additional scales like decibels and True RMS could be used as well as including new measurement functions. DMMs with capabilities including capacitance, transistor gain, frequency, duty cycle, temperature (with the use of an external thermocouple, inductance, display hold, and buzzers which sound continuity measurements.

All these developments have considerably improved the functionality of these instruments increasing the number of measurements that can be made and making them truly multi-meters.

Multimeter applications today

Although some analogue multimeters can still be bought, the majority of meters sold and used today are digital types. These digital multimeters or DMMs can be obtained cheaply, although more robust and higher specification models obviously cost more. DMMs are not only easy to use but they also provide a very high level of performance and accuracy for their cost.

Chapter 2: Analogue Multimeter

The analog or analogue multimeter has been one of the mainstays used for electronics test.

Although digital multimeters have become the option of choice these days as their costs have fallen and they are still used in some areas because they are extremely flexible and can be used to locate faults, and be used for general electrical and electronic measurements in many areas.

Analogue multimeters are still able to provide some functions that are not quite so easy when using digital multimeters. This is particularly true when monitoring voltages that may be fluctuating. Also analogue meters can give a good indication of a measurement. Often when using a meter it is only necessary to see whether a voltage is present or not. In these circumstances it can often be faster to see where the meter needle is on an analogue meter than read the exact measurement on a digital one.

ANALOGUE MULTIMETER METER BASICS

The analogue VOA meter or VOM is based around the moving coil galvanometer - the basic analogue meters that can be found in many applications today.

Typical analogue multimeter / VOA

The meters will have a full scale deflection, FSD, i.e. the maximum reading calibrated on the scale of a certain current. Typically this might be a value of 50µA. The functionality of the basic meter is then extended by adding series and shunt resistors to enable voltage and current to be measured.

Extending range of a meter for current measurements: To extend the current ranges of a basic analogue meter, a resistor is placed in parallel with the meter. The same voltage is present across both the meter and the shunt, and the value of the shunt resistance can be arranged to take the majority of the current. In this way the range of the meter can be extended.

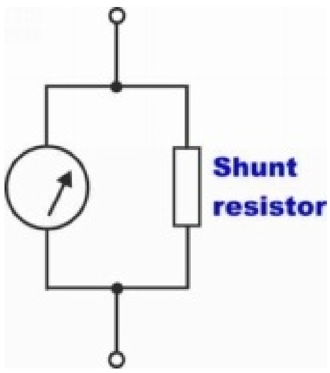


Figure 2.1 Analogue meter using a shunt a shunt resistor for higher current capability

The value of the shunt resistor is easy to calculate using Ohm’s law. Using this it can be determined that the proportion of the current flowing in each leg is inversely proportional to the resistance. This if the moving coil meter has a full scale deflection of 50 µA and a resistance of 2 kΩ for a 1mA FSD, 0.95 mA needs to flow in the shunt resistor for the same voltage across the shunt resistor and the meter itself. Therefore the resistance of the shunt resistor needs to be: 5 / 95 x 2 kΩ = 105.3Ω.

Extending the range for voltage measurements: For voltage measurements, resistors are placed in series with the meter.

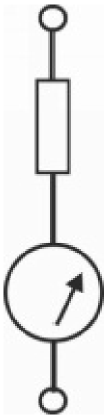


Figure 2.2 Analogue voltmeter using a moving coil meter

It is easy to calculate the value for the resistor. Knowing the resistance of the moving coil meter and its full scale deflection, it is possible to use Ohm's law to calculate the required values.

For example take a moving coil meter with a 50 µA FSD and a coil resistance of 2kΩ. For a voltage of 10 volts to enable 50µA to flow the total resistance must be V/I = R or 10 / 50 x 1-6 = 200 kΩ. Thus the series resistor required is 200 k? - 2 kΩ i.e. 198 kΩ.

Resistance capability for a VOA meter: In order to provide the resistance measurement capability, an additional battery is required. This provides a current source to drive current through the external resistor. The amount of current flowing provides an indication of the resistance.

When making resistance measurements using an analogue multimeter, it is found that the high resistance indications are at the left hand section of the meter, i.e. when less current is flowing, and the low values of resistance are indicated at the right hand end of the meter scale, because a higher current flows. This may be a little confusing at first, but one quickly becomes accustomed to this. When using a resistance measurement on an analogue multimeter or analogue VOA meter, it is first necessary to "zero" the meter. This is needed to calibrate out any variations in the battery voltage. It is achieved simply by sorting out the two analogue multimeter probes and adjusting the control normally labelled "Zero" for zero ohms. Once this has been achieved the meter can be used accurately. A further point to note is that the negative terminal of the analogue multimeter is positive with respect to the positive terminal, i.e. the polarity on the terminals is the opposite of what might normally be expected. For most measurements this is not of any consequence, although for some measurements of semiconductors it will have a bearing as they conduct only in one direction.

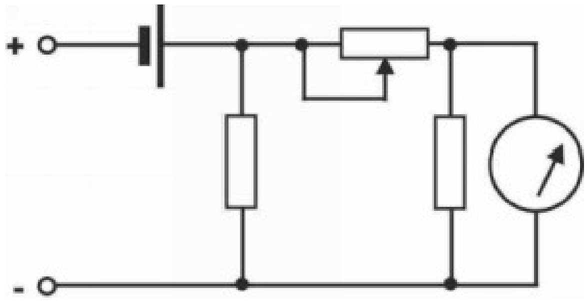


Figure 2.3 Analogue Ohm-meter or resistance meter circuit

It can be seen that by adding the shunt and series resistors as well as a resistor network and battery, for resistance, it is possible to provide a considerable amount of additional capability for the basic analogue moving coil meter.

Analogue multimeter specifications

While there are very many similarities between a digital multimeter and an analogue multimeter, there are some significant differences in the specifications.

The analogue multimeter specifications are different because of the way in which they work. Accordingly some of the analogue multimeter specifications may not be familiar to those who are more used to using digital multimeters.

Analogue multimeter or VOA meter ranges

Analogue multimeters, like digital ones have a variety of ranges. They are described in terms of Full Scale Deflection or FSD. This is the maximum that the range can read. In order to get the best reading, it is necessary to have the scale reading somewhere between about a 25 and 100% of FSD. In this way the optimum accuracy and significant number of figures can be read. As a result of this meters have a variety of ranges, that may appear to be reasonably close to each other - often there are two ranges per decade: 1, 3, 10, … etc.

A typical meter may have the following ranges (note that the figures indicate the FSD):

- DC Voltage: 3.0V, 10V, 30V, 100V, 300V, 1000V
- AC Voltage: 10V, 30V, 100V, 300V, 1000V
- DC Current: 50µA, 1mA 10mA, 100mA , 1A
- AC Current: 100mA, 1A
- Resistance: R, 100R, 10 000R

There are several points to note from these typical analogue multimeter ranges:

The low voltage AC voltage, and in this example the 10V AC range may have a different scale to the others. The reason for this is that at low voltages a bridge rectifier is non-linear and this needs to be taken into consideration. Often as in the above example a 3 volt AC range may not be included. This is because the rectifiers used at these voltages become very non-linear and the measurements are not reliable.

High voltage ranges such as the 1000V or 1kV ranges will often use a different input connection to enable the reading to be taken through a different shunt and kept away from the rotary switch that may not be able to handle a voltage this high.

AC current is often not included in the lower end meters because of the difficulties of undertaking the measurement without a transformer to step up any voltage across a series sensing resistor for rectification.

Batteries inside the multimeter are used to provide a current for the resistance measurements. No other readings require the use of battery power - the meter is passive from that viewpoint.

In this example, the three resistance ranges of varying sensitivity multiply the meter reading by 1, 100, or 10 000 dependent upon the range. This allows for low resistance measurements to be made as well as very high ones. Typically the higher resistance ranges may use a higher voltage battery than the one used for the low resistance ranges.

Analog multimeter sensitivity

One of the specifications for an analogue multimeter or VOA meter is its sensitivity. This comes about because the meter must draw a certain amount of current from the circuit it is measuring in order for the meter to deflect. Accordingly the meter appears as another resistor placed between the points being measured. The way this is specified is in terms of a certain number of Ohms, Ω (or more usually kΩ) per volt. The figure enables the effective resistance to be calculated for any given range.

Thus if an analogue multimeter had a sensitivity of 20 kΩ per volt, then on the range having a full scale deflection of 10 volts, it would appear as a resistance of 10 x 20 kΩ, i.e. 200 kΩ.

When making measurements the resistance of the meter should be at the very least ten times the resistance of the circuit being measured. As a rough guide, this can be taken to be the highest resistor value near where the meter is connected.

Normally the sensitivity of an analogue meter is much less on AC than DC. A meter with a DC sensitivity of 20 kΩ per volt on DC might only have a sensitivity of 1 kΩ per volt on AC.

Although analogue multimeters meters are not as widely used as before, they are still found in many laboratories and areas where a test meter is needed. As analogue multimeters are capable of providing the levels of accuracy needed for most test applications, they will undoubtedly be seen for many years to come.

Chapter 3: Using an analogue multimeter

Like any instrument an analogue multimeter will perform to its best if it is used in the right way and its limitations are understood. When used correctly an analogue test meter can still produce readings that are more than accurate enough for all but the most exacting requirements.

A few simple hints and tips about how to use an analogue multimeter enable it to produce accurate results, and reduce the possibility of damage from overloads, etc.

Analogue meter advantages & disadvantages

One of the key points of knowing how to use an analogue multimeter is understanding the relevant advantages and disadvantages.

Like any item of test equipment a multimeter has its limitations. Knowing what they are and how to overcome them is a key stage in understanding how to use an analogue multimeter to its best.

Advantages:

- Analogue movement: The meter needle gives a continuous movement from which it is very easy to gain a fast idea of the order of magnitude, or of trends for slowly moving changes.
- Availability: Analogue test meters may well be available when digital ones are not.

Disadvantages:

- Multiple scales: Any multimeter will have a number of different scales and these can cause confusion. They were often a cause of error.
- Lower input resistance: Using analogue technology, analogue multimeters did not provide such a high input impedance as a digital one. Understanding when this may be an issue is a key element of knowing how to use an analogue multimeter.
- Polarities of test leads: Analogue multimeters do not have an auto-polarity function. Therefore it is necessary to correctly connect the test leads, otherwise the meter could deflect in a negative direction and quickly hit an end stop.

Parallax errors

One common cause of inaccuracy on an analogue multimeter results from parallax issues.

When viewing the meter, the eye should be at right angles to the plane of the meter back markings. In this way there is no error from viewing the needle at an angle.

Some high end professional meters such as the AVO have a mirror in the scale. In this way it is possible to assess whether the eye is directly in front of the scale - when the eye is viewing correctly, it will not be possible to see the reflection of the meter needle as it is masked out by the needle itself. The offset view below indicates this.

The use of the mirror on the scale to reduce parallax errors

In addition to the mirror, often the needle is made thin the same plane as the scale, but much larger in the plane at right angles to the scale. In this way it is possible to see when the needle and the scale are being viewed correctly. It also has the additional advantage that it gives the needle more mechanical strength.

Using the correct range

Another concept in knowing how to use an analogue multimeter is that of knowing which range to use.

In terms of the view of the meter, the best accuracy is gained when the meter is towards the full scale deflection, FSD. In this way a given percentage change in the reading gives the maximum and hence most visible change in meter deflection, and accordingly the most accurate reading.

However care has to be taken not to overload the meter by placing it on a range much too low for the reading to be taken. If this occurs the meter can swiftly move to the end-stop, and damage may occur if it is overloaded too much. It is always best to start well above the range expected to give full scale deflection and switch the range when everything has settled.

Analogue meter zero position adjustment

Analogue multimeters, and in fact any analogue moving coil meter will have a zero adjuster.

This zero adjustment should not normally need to be touched, but it may vary slightly with time and temperature.

Adjustment should be made with the meter not in use and it should be gently adjusted with a screwdriver to ensure the meter is properly zeroed. Care should be taken to ensure that the eye is directly above the meter, and any mirror in the meter should be used to ensure that accuracy is maintained.

The adjustment should be undertaken with the meter level as if the meter is placed horizontally, for example, the zero position will change. There can be a noticeable variation if the meter is changed from the horizontal to vertical plane.

Finishing using multimeter

When the measurements using the analogue multimeter have been completed, it is always wise to return he meter to its “Off” position. This prevents the meter being picked up and connected for a voltage measurement, when, for example it has been left set for a current measurement. In this case excess current could flow through the meter causing damage to the meter and also with the possibility of damage to the circuit under test.

If no specific “Off” position is available, after use the multimeter should be switched to the highest voltage range.

Making measurements using an analogue multimeter

Analogue multimeters are very easy to use to make measurements of voltage, current and resistance.

There are obviously different requirements for each of the different types of test and therefore each type of test is addressed separately.

To illustrate the basic concepts, the very simple circuit below will be used.

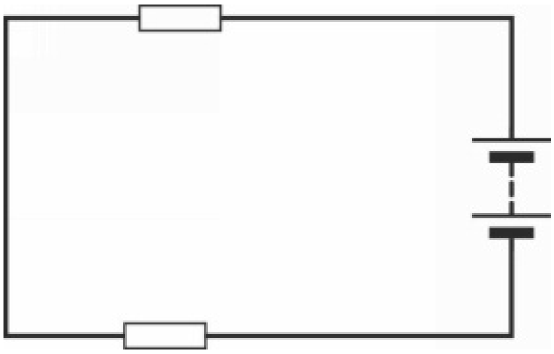


Figure 3.1 Very simple circuit to illustrate test methods

Voltage measurements

The voltage measurement is the easiest form of measurement to make using an analogue multimeter. Essentially it requires the meter to be correctly set and then the meter leads placed across the item under test.

When making the voltage measurement, first the meter needs to be correctly set. Normally it is best to set the meter to a range that is much higher than the voltage expected. In this way, if a surprisingly large voltage is measured, then it will not damage the meter as it could exceed its full scale deflection, FSD. Once the voltage has been measured the range can be reduced.

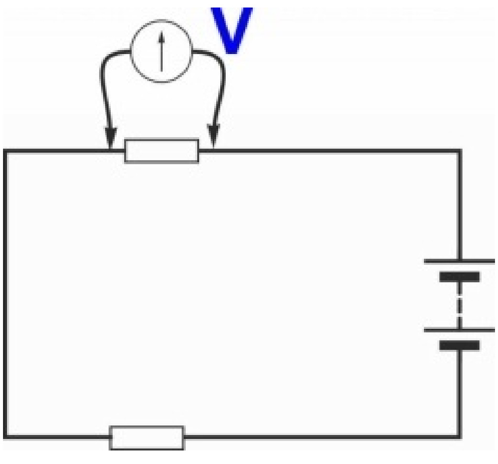


Figure 3.2 Making a simple voltage measurement

The test probes or leads need to be applied to the correct terminals of the meter. Often there are more than two - the additional ones often being used for extended ranges, etc. Typically the “Common” or “COM” connection on the multimeter is used for the negative voltage end of the measurement and the connection marked “Volts” or similar goes to the positive end of the measurement.

Once the relevant settings and connections have been chosen on the multimeter the measurements can be taken. The probes are simply applied across the nodes that are to be measured.

Often voltage measurements are taken between ground and some voltage on the circuit. As a result, many probes have a crocodile clip for the negative probe, and a point for probing a node on the circuit for the positive lead. Care must be taken not to slip, and accidentally cause a short circuit.

Also when making voltage measurement it should be realised that the meter will take a certain amount of current itself. In many instances this will not matter, but where the impedance of the circuit is high, it may actually load the circuit and cause the voltage at the point being measured to change. The actual resistance presented by the meter can be calculated from its sensitivity. If it is 10kΩ/V and it is being used on the 10V range, then the load resistance it presents to the circuit is 10kΩ x 10, i.e. 100kΩ.

Multimeters are normally used for testing low frequency or DC circuits. Sometimes it will be necessary to measure DC or low frequency values on circuits that carry high frequencies like RF. Remember that placing the probe on any point of the circuit will add stray capacitance and also inductance to the circuit. This can considerably alter the operation of the circuit if it uses frequencies above a hundred kHz or so.

Current measurements

Current measurements are a little more difficult to make than voltage ones. The reason for this is that the current needs to flow through the meter and hence the meter needs to be placed in series with the circuit where the current measurement is to be made. This requires the circuit to be broken rather than placing the probes across the points to be measured.

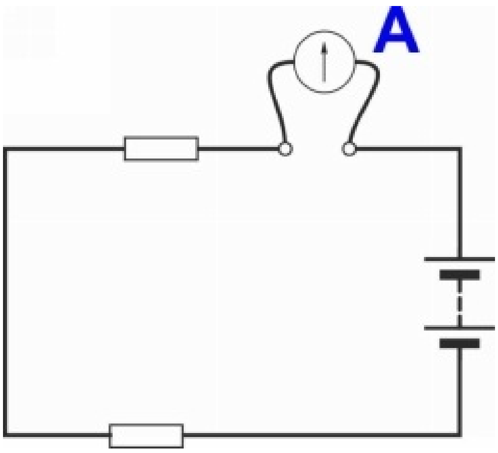


Figure 3.3 Making a simple current measurement

Care must be taken to ensure that he meter stays in circuit for the duration of the test. It is not often convenient to use probes as these are inclined to slip. Instead probes with clips can be used to make a steady contact. It may also be necessary to break the circuit in some way to allow the meter to be placed in circuit.

Once the measurement has been concluded, it is always best to remove the meter and return it to its off position, or at least to a high voltage range, and if necessary move the current connections accordingly on the meter. It is all too easy to forget and use the meter for a voltage measurement and effectively add a short circuit across the points being measured - a current meter has a low resistance.

When making a current measurement, be aware that even though the meter has a low resistance on its current range, this may affect the operation of the circuit. Also the length of the leads may have an effect, especially when high frequencies are present in the circuit.

Resistance measurements

When using a multimeter for resistance measurements, the first step is to make sure that the zero ohm position is correctly adjusted. This is required to compensate for a number of variations from small tolerances in the components in the meter to the state of the battery within the meter that is used to supply the current needed for the measurement.

To undertake the ohm-meter zeroing, the test probes for the meter should be shorted together to give a zero ohm resistance between the terminals of the meter, and the small "Ohms Adjustment" control should be used to give full scale deflection on the meter that corresponds to the zero ohms position.

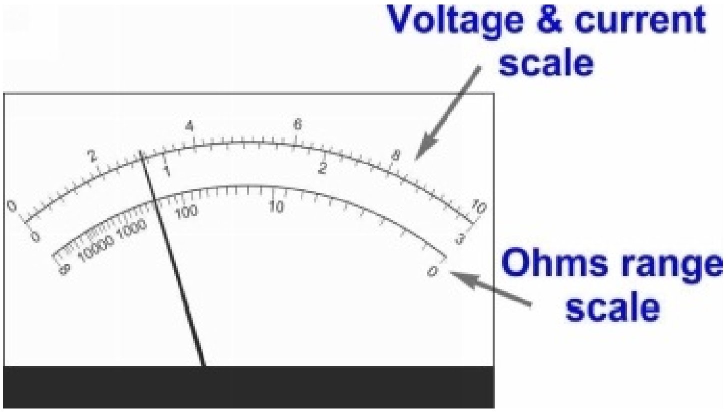


Figure 3.4 Scale on a typical analogue multimeter

On an analogue meter, the zero ohms position corresponds to full scale deflection, and increasing resistance gives a lower level of deflection, i.e. less current flows through the resistor. In this way the meter scale can be considered to be reversed - higher values of resistance are to the left of the scale and lower ones to the right.

For any resistance measurement, the component to be measured should be removed from the circuit as other paths will be present that will distort the reading. Also any power remaining within the circuit will add to the inaccuracies.

Warning: Never measure resistance when the circuit is powered, as power from the circuit will not only distort the reading, but could also seriously damage the meter.

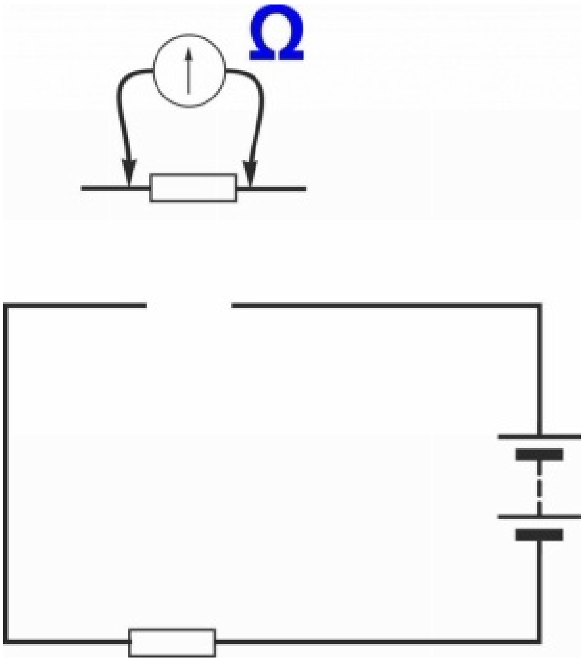


Figure 3.5 Making a resistance measurement

Another point to notice is that measuring capacitors is not always advisable. Charge stored in the capacitor acts as an external power source and this not only distorts the reading, but if reasonable voltages are present on high value capacitors, damage can result to the meter.

However there are occasions when it may be necessary to check the insulation of a capacitor. If this needs to be done, then make sure the capacitor is discharged first. This should be done through a suitable resistor to ensure that sparks are not created.

When measuring a capacitor, the meter will first deflect and then settle to its final value. The reason for this is that the battery in the meter supplies charge to the capacitor and this causes the meter to deflect initially. Only when the charging is complete is the reading valid.

For electrolytic capacitors there will be some leakage shown, and it would be expected that some leakage will be present and indicated as a high resistance. If there is too much leakage indicated then this could indicate a problem.

Never test tantalum capacitors with a meter. Some have very low value working voltages and they do not like reverse voltages and damage could result as a result of the voltage from the internal battery. Although most are low voltage, often, but not always 1.5 volts, some use higher voltage batteries especially for high resistance ranges..

Testing diodes

Analogue multimeter can be used to give a basic test of whether a semiconductor diode is operational or not. It cannot provide any parameters about its performance as most test requirements only need to check basic functionality - it is very much less likely that the performance will degrade over time for most types of diode, and the original performance will be guaranteed by the manufacturer.

Most failures of diodes are catastrophic, rendering the diode completely non-functional. This simple analogue multimeter test is able to detect whether the basic diode function of the component is intact.

The test basically relies on using the meter to test for the resistance of the diode in both directions. In the reverse direction, the diode should not conduct and will indicate a high resistance, whereas in the forward direction, it will conduct and indicate a lower resistance.

When testing a diode with a multimeter in this way, it should be remembered that the terminal used as positive terminal for measuring voltage, etc is actually negative with respect to negative terminal. In other words the polarity on these terminals appears to be the opposite of what might be expected. This is because of the way the analogue multimeter works.

As a result the readings for testing a diode with a multimeter in this way are as given below in the diagram.

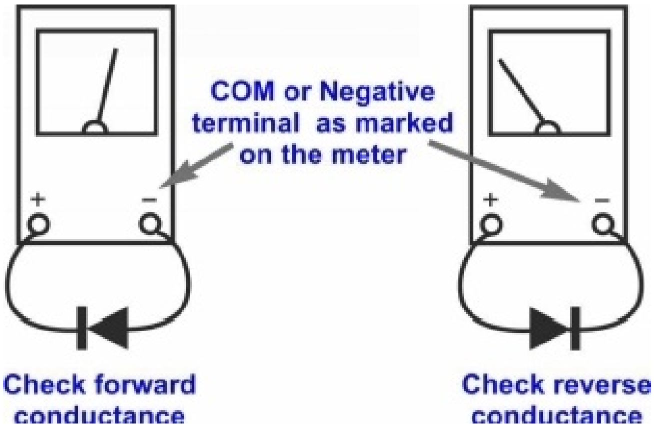


Figure 3.6 Testing a diode with a multimeter

When measuring diodes, the readings taken are only indicative. The reading of the diode in the reverse direction should indicate virtually infinite ohms and show no deflection. Some germanium diodes may show visible current in the reverse direction, but this is often normal. The level of deflection in the forward direction of the diode will vary considerably dependent upon the range and meter in question. Often it will deflect about half way across the scale.

TESTING BIPOLAR TRANSISTORS

It is quite easy to extend the diode testing using a multimeter to provide a simple transistor test. Like the diode test, this will not enable any parameters to be measured - only whether the junctions are intact. Again, this is not normally necessary because most transistor failures are a complete failure of the device when a junction breaks down as a result of a transient or other issue. They seldom, although not always degrade in performance.

The key to the test is to understand the make-up of a bipolar transistor. From the point of view of this test a transistor can be considered as a pair of diodes wired back to back.

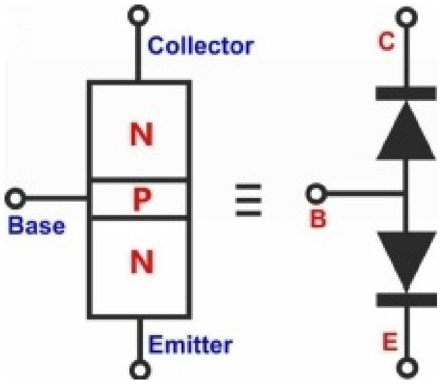


Figure 3.7 Transistor equivalent circuit

The diagram shows an NPN transistor, but the diode directions can be reversed for a PNP transistor.

To perform the test, simply test for the diode functionality between the base and collector and base and emitter.

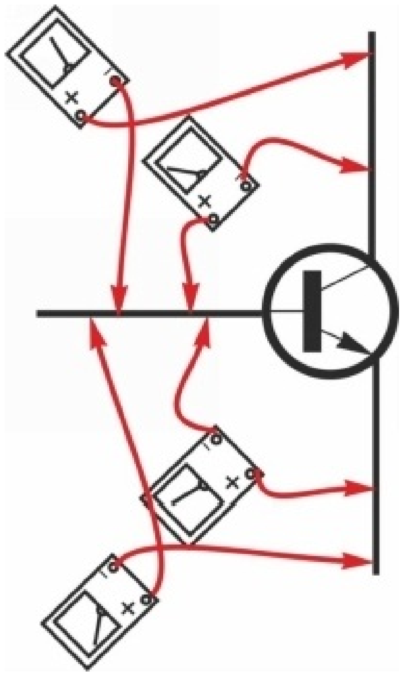


Figure 3.8 Testing a transistor with a multimeter

A final test should be made between the collector and emitter. This should show high resistance in both directions. Sometimes when a large current has been carried by the transistor it is possible for the collector emitter path to punch through the thin emitter region. Often there will still be a diode present between base-emitter and base-collector, but the collector and emitter will show a very low resistance.

While digital multimeters often have specific diode and transistor test functions, it is still possible to undertake a good test of a diode or transistor with an analogue multimeter.

Chapter 4: Digital Multimeter

Digital multimeters, DMMs have taken over from their analogue counterparts. The use of digital technology has enabled much greater levels of accuracy to be obtained together with more flexibility and the ability to take many more types of measurements.

As a result of this, by far the greatest majority of multimeters sold today are digital ones.

DMMs can be used in very similar ways to their analogue predecessors, although there are a few minor changes in some instances as DMMS are able to incorporate many more facilities.

While DMMs are able to provide improved levels of performance and more capabilities, they are able to achieve this whilst still keeping prices low. As precision mechanical items such as the moving coil meter used in analogue versions are not used, all the capability is within the integrated circuits and a few other precision components. This means that they are much easier and cheaper to produce.

DMM FACILITIES

DMMs are able to make a wide number of measurements. The basic capabilities that almost every DMM will have will include:

- Current (DC)
- Current (AC)
- Voltage (DC)
- Voltage (AC)
- Resistance

However, using integrated circuit technology, most DMMs are able to offer additional test capabilities. These may include some of the following dependent upon the particular DMM:

- Capacitance
- Temperature
- Frequency
- Transistor test - hfe, etc
- Continuity (buzzer)

While some of these additional test features may not be as accurate as those supplied by dedicated test instruments, they are nevertheless very useful, especially where approximate readings only are needed.

In addition to an increase in the number of basic measurements that can be made, refinements of some of the basic measurements are also available on some models. True RMS multimeters are available. In many instances, AC waveforms use forms of average measurements that are then converted to RMS measurements using a form factor. This method of measurement is very dependent upon the shape of the waveform and as a result a true RMS digital multimeter may be required. In addition to the availability of a true RMS meters, similar refinements of the other basic measurements are also available in some instances.

In addition to the additional measurement capabilities, DMMs also offer flexibility in the way measurements are made. Again this is achieved because of the additional capabilities provided by the digital electronics circuitry contained within the digital multimeter. Features including auto-range, auto-polarity, and the like are available.

AUTO-RANGE

This facility enables the correct range of the digital multimeter to be selected so that the most significant digits are shown, i.e. a four-digit DMM would automatically select an appropriate range to display 1.234 mV instead of 0.012 V. Additionally it also prevents overloading, by ensuring that a volts range is selected instead of a millivolts range.

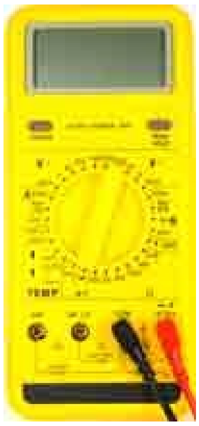
Digital multimeters that incorporate an auto-range facility usually include a facility to ‘freeze’ the meter to a particular range. This prevents a measurement that might be on the border between two ranges causing the meter to frequently change its range which can be very distracting.

Auto-polarity

This is a very convenient facility that comes into action for direct current and voltage readings. It shows if the voltage of current being measured is positive (i.e. it is in the same sense as the meter connections) or negative (i.e. opposite polarity to meter connections). Analogue meters did not have this facility and the meter would deflect backwards and the meter leads would have to be reversed to correctly take the reading.

How a DMM works

The operation of a digital multimeter is relatively straightforward, although there are obviously differences between the actual implementation from different manufacturers.



A typical DMM

The key process that occurs within a digital multimeter for any measurement that takes place is that of voltage measurement. All other measurements are derived from this basic measurement.

Accordingly the key to understanding how a digital multimeter works is in understanding this process.

There are many forms of analogue to digital converter, ADC. However the one that is most widely used in DMMs is known as the successive approximation register or SAR. Some SAR ADCs may only have resolution levels of 12 bits, but those used in test equipment including DMMs generally have 16 bits or possibly more dependent upon the application. Typically resolution levels of 16 bits are used, with speeds of 100k samples per second. These levels of speed are more than adequate for most DMM applications, where high levels of speed are not normally required.

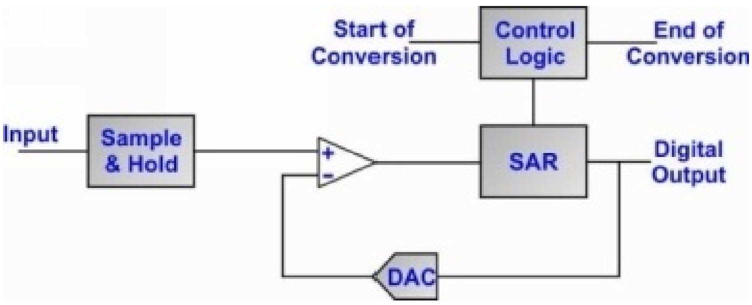


Figure 4.1 Successive approximation register ADC used in most DMMs

As the name implies, the successive approximation register ADC operates by successively homing in on the value of the incoming voltage.

The first stage of the process is for the sample and hold circuit to sample the voltage at the input of the DMM and then to hold it steady.

With a steady input voltage the register starts at half its full scale value. This would typically require the most significant bit, MSB set to “1” and all the remaining ones set to “0”. Assuming that the input voltage could be anywhere in the range, the mid-range means that the ADC is set in the middle of the range and this provides a faster settling time. As it only has to move a maximum of the full scale rather than possibly 100%.

To see how it works take the simple example of a 4-bit SAR. Its output will start at 1000. If the voltage is less than half the maximum capability the comparator output will be low and that will force the register to a level of 0100. If the voltage is above this, the register will move to 0110, and so forth until it homes in on the nearest value.

It can be seen that SAR converters, need one approximating cycle for each output bit, i.e. an n-bit ADC will require n cycles.

DMM Overall Block Diagram

Although the analogue to digital converter forms the key element within the instrument, in order to fully understand how a digital multimeter works, it is necessary to look at some of the other functions around the ADC.

Although the ADC will take very many samples the overall digital multimeter will not display or return every sample taken. Instead the samples are buffered and averaged to achieve high accuracy and resolution. This will overcome the effects of small variations such as noise, etc., noise created by the analogue first stages of the DMM being an important factor that needs to be overcome to achieve the highest accuracy.

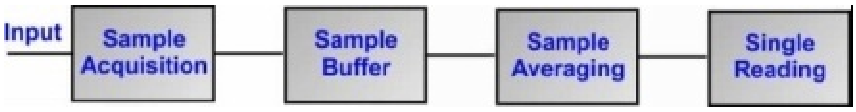


Figure 4.2 Operation flow diagram for operation of a DMM

Measurement time

One of the key areas of understanding how a digital multimeter works is related to the measurement time. Apart from the basic measurement there are a number of other functions that are required and these all take time. Accordingly the measurement time of a digital multimeter, DMM, may not always appear straightforward.

The overall measurement time for a DMM is made up from several phases where different activities occur:

Switch time: The switch time is the time required for the instrument to settle after the input has been switched. This includes the time to settle after a measurement type has been changed, e.g. from voltage to resistance, etc. It also includes time to settle after the range has been changed. If auto-ranging is included the meter will need to settle if a range change is required.

Settling time: Once the value to be measured has been applied to the input, a certain time will be required for it to settle. This will overcome any input capacitance levels when high impedance tests are made, or generally for the circuit and instrument to settle.

Signal measurement time: This is the basic time required to make the measurement itself. For AC measurements, the frequency of operation must be taken into account because the minimum signal measurement time is based on the minimum frequency required of the measurement. For example, for a minimum frequency of 50 Hz, an aperture of four times the period is required, i.e. 80 ms for a 50Hz signal, or 67ms for a 60Hz signal, etc.

Auto-zero time: When auto-range is selected, or range changes are made, it is necessary to zero the meter to ensure accuracy. Once the correct range is selected, the auto-zero is performance for that range.

ADC calibration time: In some DMMs a calibration is periodically performed. This must be accounted for, especially where measurements are taken under automatic or computer control.

It is always useful to know how a digital multimeter works in order to be able to make the best use of it and the most accurate measurements. However it should be remembered that different multimeters from different manufacturers may work in different ways. It is therefore always helpful to consult the manufacturer’s instructions to understand how a particular digital multimeter works.

DMM SPECIFICATIONS

Understanding the multimeter specifications and capabilities is of great importance when selecting an item to buy or when choosing a particular instrument to be included in a test schedule for an electronics test for a particular module or complete unit. It is important to know a variety of aspects of the performance of the digital multimeter, the exact parameters required depending upon the need for the data.

Manufacturers issue specifications for their products and these give all the important parameters relating to the performance of the digital multimeter, DMM. This can be used where buying the equipment as new, or as used test equipment, or even for test equipment rental. The supplier will be able to provide the specification, or often it can be viewed on the Internet.

For many different types of product, the different manufacturers will specify their products in different ways, making it difficult to compare like for like. Fortunately in the case of digital multimeters, the specifications are normally defined in a way that enables different DMMs from different manufacturers to be compared easily.

A typical DMM used for measuring current, voltage, resistance and many other electronic and electrical parameters

BASIC DIGITAL MULTIMETER FEATURES

One of the key parameters of any digital multimeter, DMM is the types of measurement that can be made by the particular digital multimeter and the ranges over which it will operate. Most DMMs will offer a variety of measurements. The basic measurements will include:

- Current (DC)
- Current (AC)
- Voltage (DC)
- Voltage (AC)
- Resistance

However, using integrated circuit technology, most digital multimeters are able to offer additional test capabilities. These may include some of the following:

- Capacitance
- Temperature
- Frequency
- Transistor test - hfe, etc
- Continuity (buzzer)

It is worth bearing in mind that these additional test capabilities may not offer the same levels of accuracy that a specialised meter for the particular measurement may be able to offer, but normally they are more than adequate for most requirements .

When choosing a particular digital multimeter it is necessary to look at not only the maximum, but also the minimum readings that can be taken.

True RMS vs average

One important element of a digital multimeter specification is whether the DMM is able to measure true RMS values. Today many high end digital multimeters include this facility, although the lower end instruments will typically not incorporate it. True RMS measurements provide a measure of the actual heating effect of the waveform. The reading will therefore take account of the shape of the AC waveform, with any harmonics and distortion, as well as any DC components. It is worth looking carefully at the DMM spec to ascertain whether it does provide a true RMS measurement, and if so whether it is able to incorporate any DC components that may be present.

Those digital multimeters that do not provide a true RMS measurement measure the average of the absolute value of AC voltage and are calibrated so that the readings are corrected to that of the RMS value for a sine wave. This normally works well but errors occur if harmonics are present with the effect becoming progressively worse as the harmonic content increases. For example, if a triangular waveform is measured this will give an error of nearly -4%, while for a square wave signal the error is just over +11%. The presence of any DC will then introduce further errors. Pulse waveforms will also be difficult to measure and the error will depend upon the duty cycle of the signal.

In many instances an average reading calibrated for RMS values is quite satisfactory. However it is necessary to choose the correct DMM to buy new or as used test equipment, or when choosing test equipment rental. It also helps when interpreting the results that are obtained if the limitations of the digital multimeter are fully understood.

Environmental and other external specifications

A digital multimeter will only be able to meet its specifications when it is within a certain environment. Conditions such as temperature, humidity and the like will have impact on the performance. Also conditions such as line voltage can affect the performance. In order to ensure that the digital multimeter is able to operate within its uncertainty specification, it is necessary to ensure that the external conditions are met. Outside this range the errors will increase and the readings can no longer be guaranteed.

A further element to be considered is the calibration period of the digital multimeter. As all circuits will drift with time, the DMM will need to be periodically re-calibrated to ensure that it is operating within its specification. The calibration period will form part of the specification for the DMM. The most usual calibration period is a year, but some digital multimeter specifications may state a 90 day calibration period. The 90 day period will enable a tighter specification to be applied to the digital multimeter, allowing it to be used in more demanding applications. Calibration will be required if the DMM is to be used commercially, although for most domestic / hobby applications it is not required.

When looking at the calibration period of the digital multimeter, it should be remembered that calibration will form a significant element of the cost of ownership and after some years will be significantly above that of any depreciation. A long calibration period for the digital multimeter is normally to be advised, except when particularly demanding testing is required.

Additional DMM features

In addition to the basic measurement features that the digital multimeter, DMM may offer, there are a number of other facilities that enable measurements to be made more easily. With digital multimeters making good use of integrated circuit technology, a variety of features can be included that would not have been possible when using analogue multimeters.

One of the features present on many high end DMMs is auto-ranging. As the name implies, this allows the DMM to choose the correct range for the value appearing at its input. Manual selection of the particular type of measurement to be made is still required.

A further feature that most digital multimeters incorporate is auto-polarity. This enables the DMM to indicate the polarity of the reading with respect to its input connections without the need for the meter leads to be connected the correct way round.

The digital multimeter specification is an important item associated with the DMM. Whether the DMM is to be bought as new or used test equipment, or whether it is to be obtained through a test equipment rental agreement, the DMM specification is a vital element in ensuring that the right digital multimeter is obtained.

DMM accuracy & Resolution

The accuracy of a digital multimeter can be very important in many electronics test applications.

For most service or general electronics test applications, the accuracy will be well in excess of what is needed, but whatever the application it is necessary to understand the accuracy of the test equipment being used.

There are several constituents to what may be loosely termed the accuracy of the digital multimeter. Two of the major components are:

- DMM accuracy
- DMM resolution

Accuracy

The accuracy of the digital multimeter is effectively the uncertainty surrounding the measurement. It is the amount by which the displayed reading can differ from the actual input.

There are a number of ways in which the accuracy may be expressed:

$$\text{DMM Accuracy} = \pm(\text{ppm of reading} + \text{ppm of range})$$

$$\text{DMM Accuracy} = (\%\ \text{Reading}) + (\%\ \text{Range})$$

$$\text{DMM Accuracy} = (\%\ \text{Reading}) + \text{Offset}$$

NB: The abbreviation ppm refers to parts per million.

The way the accuracy is expressed depends upon the exact format for the instrument and also the preferences of the manufacturer. This sometimes makes comparing instruments from different manufacturers more difficult.

To give an example of how this may be calculated for a particular instrument. If 5 volt reading is being made and the specification for the DMM states that for the conditions within the laboratory, the reading will be ± 25ppm, and the 10 volt range is being used for which the accuracy is ± 8ppm. Then:

$$\text{Accuracy} = \pm(25\text{ppm in 5 Volts} + 8\text{ppm in 10 volts})$$

$$\text{Accuracy} = \pm(5 \text{ x } 25/1000000 + 10 \text{ x } 8/1000000)$$

$$\text{Accuracy} = \pm\ 205\mu V$$

Thus the indicated reading should be within 205µV of the actual value.

Effect of temperature on accuracy

As with many other electronic items, temperature can have a significant effect on the measurement accuracy of a DMM.

Many precision or high accuracy instruments have a temperature coefficient contained within the specification.

Although the way in which they may be expressed can vary occasionally the most common way to express them is as ±(ppm of reading + ppm of range)/°C.

AC accuracy

It will be found that the level of AC accuracy for a multimeter is normally less than that for DC measurements. The AC measurements will also be optimised for 50-60 Hz and this means that other frequencies may have poorer degree of accuracy.

As with DC accuracy specifications, a number of counts (often greater than for DC) will be added to the accuracy percentage. Also, for waveforms other than a pure sine wave, additional inaccuracy will be encountered when measured with an average responding DMM.

Even a true RMS responding DMM will have some accuracy limitations for waveforms with high peak amplitude components if measured near full scale.

Resolution

The resolution of a digital multimeter traditionally was specified in terms of the number of digits displayed. Typically this will be a number consisting of an integer and a half, e.g. 3 ½ digits. By convention a half digit can display either a zero or 1.

Thus a four and a half digit meter could display up to 19999. Occasionally a three quarters digit may be used instead of the half. When this is seen, it indicates that the DMM additional numeric can display a number higher than one, but less than nine.

Often the range is extended to 399, 3999, etc. It is worth remembering that increased levels of resolution do not come without penalties. Longer settling times are required for the far right digits to reach their final value. Thus the time between readings is longer.

For many new DMMs the traditional format for quoting the resolution of digits of display may not be appropriate. This is particularly the case for virtual instruments where the display is software controlled and therefore not a limiting factor. Instead the limiting factor is the analogue to digital converter, ADC.

For these instruments the resolution is often expressed in bits. For example a 14 bit ADC would give 2^{14} distinct values, i.e. 16384 values.

It is possible to relate the digits of resolution to the number of the least significant bit.

$$\text{Digits of resolution} = \log(\text{Number of LSB})$$

Where the log is log to the base 10.

This means that for an instrument with a 14 bit ADC the least significant bit is 16384.

$$\text{Digits of resolution} = \log(16384)$$

$$\text{Digits of resolution} = 4.2$$

Digital multimeters are generally able to provide very high degrees of accuracy; certainly they are far more accurate than their analogue counterparts which are normally only to guarantee accuracy levels of between 3 and 5%. A typical handheld or portable DMM should be able to provide accuracy levels of around 0.5% and many bench versions will quote figures of around 0.01%.

Chapter 5: Using a DMM

Digital multimeters are easy to use. They can be used to measure the basic three electrical parameters of current (amps), voltage (volts) and resistance (ohms).

Knowing how to use a DMM can enable the best to be gained from them - the most accurate readings and also knowing the limitations of the readings.

Knowing how to use a DMM also enables some tricks of the trade to be used to measure parameters that may not normally be known about, and can be very useful.

Digital Multimeter Measurement Basics

There are a number of initial steps and precautions that should be observed. These guidelines are always best to follow, and if incorporated into a workflow they will help to make measurements more accurate and prevent damage to the instrument or reduce safety risks for the user.

Check battery regularly: DMMs require a power source for their operation. For portable instruments, this is provided by a battery. Regular checks of the battery state are very advisable to ensure that there is sufficient voltage to adequately power the DMM. Also if batteries are left in-situ for long periods they can leak and damage the contacts in the instrument as the contents of the battery are corrosive. To achieve this a sticker such as one indicating the data the battery is due for replacement or a calibration due sticker could be used. This idea is often adopted in many professional organisations.

Return meter to high voltage setting after use: To prevent the possibility of accidental damage by the meter being set to a current or low voltage range, it is always wise to leave the meter set to read a high voltage, even if there is an Off button. It is too easy to automatically connect a DMM to the circuit without thinking about the range. This can lead to damage of both the equipment under test and the meter if it is set to a current range when voltage is to be measured, for example. Although some meters are auto-ranging for voltage, current etc., others are not, and therefore it is always wise to leave the meter set to the highest voltage range possible.

Ensure probes are in good condition: Poor probes may not only result in poor readings, because it is not possible to connect to any test points properly, but also there can be the risk of injury if they are cracked and broken leaving exposed conductive areas when making a high voltage measurement.

Voltage Measurements

One of the primary measurements made by digital multimeters is that of voltage or volts.

Using a digital multimeter to measure voltage is a key function, and one that is particularly easy. However there are a number of precautions, tricks of the trade that can be used to facilitate easier or more accurate operation.

When measuring voltage with a digital multimeter, the process is normally very straightforward, and second nature to many users of this site.

For measuring voltage, the probes are simply placed across the two points where the voltage is to be measured.

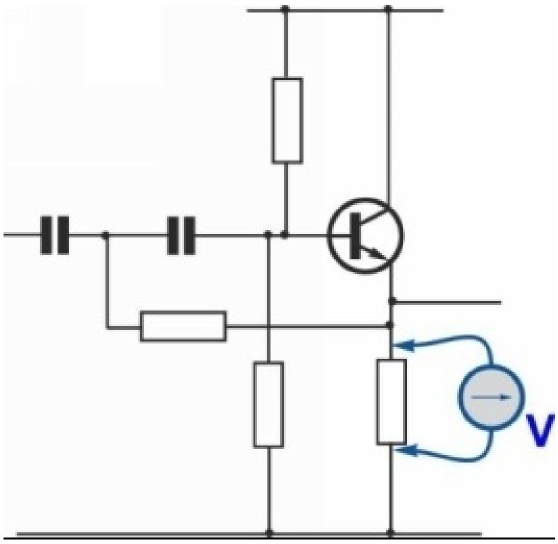


Figure 5.1 A typical digital multimeter voltage measurement

Virtually all digital multimeters have an auto-polarity function, and therefore there is normally no need to worry about which way round the probes are connected. However it is normally best practice to connect the COM or Common connection that is normally the negative connection to the lower voltage or the chassis / zero volt line.

It may even be possible to use a crocodile clip connected to ground and then it is only necessary to probe one point. This is much easier and less likely to result in probes slipping off the required points with the possibility of causing a short circuit.

Whilst many DMMs have an auto-range function which automatically selects the correct range. If the instrument does not have this function, then set it to a range above the maximum anticipated value so that the meter is not overloaded should a larger than expected voltage be present. The range can then be reduced until the most accurate reading is obtained.

AC Voltages

DMMs are able to measure AC voltages as well as DC ones. When measuring AC voltages it is necessary to consider the waveform being measured. Many meters, especially those with higher price tags are able to offer True RMS measurements. As mentioned in the specifications section, those meters that do not have a True RMS function will read the average voltage and then be calibrated for RMS when used with a pure sine wave.

If waveform being measured is not a sine wave, it is necessary to consider the effect of the waveform on the reading.

Precautions when measuring voltage with a DMM

When measuring voltage, there are a few useful pointers that can be employed:

Be aware of impedance: Todays digital multimeters have a very high input impedance. This means that they will place a very negligible load onto the circuit. The main issue will be the levels of stray capacitance from the leads, etc. may be an issue and where higher frequencies are used this may need to be taken into account. The operation of RF circuits, for example, will be altered considerably by the addition of the test leads on many points and this may result in the DC conditions being affected.

Stray pick-up: With very high levels of impedance, stray pickup can be an issue if the source impedance of the circuit is also high. Care may be needed when using a digital multimeter under these circumstances, and the effects of pick-up will need to be born in mind

Beware high voltages: It almost goes without saying when measuring voltage using a digital multimeter, but when dealing with any electronic equipment for repair, extreme care needs to be taken as high voltage points may be accessible.

Frequency effects for AC measurements: Although most meters measure AC waveforms quite satisfactorily, they are only really intended for low frequencies and not for high frequency measurements. If higher frequencies are measured (even above a few kilohertz) then it is necessary to look at the frequency performance of the AC measurements before interpreting he results.

Current Measurements

Current measurements form another key area for DMM measurements.

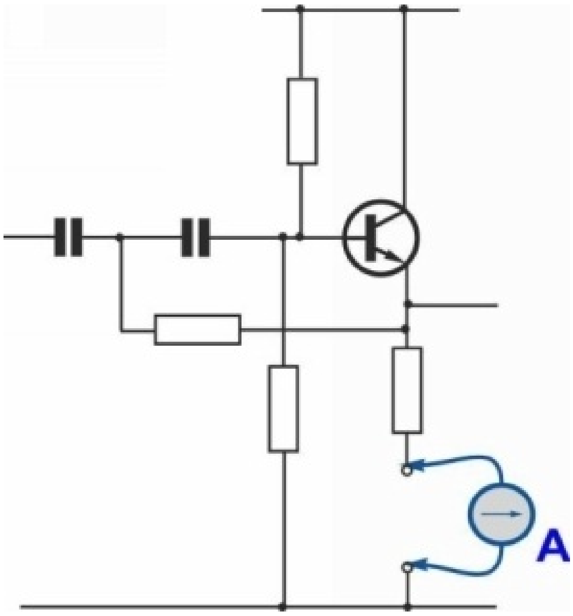


Figure 5.2 Basics of measuring current with a multimeter

Voltage measurements are easy to make with a digital multimeter, but measuring current is slightly more involved, as in the case of an analogue meter.

It is necessary to place the multimeter in series with the circuit so that the current actually flows through the meter.

When making these measurements case must be taken to ensure that the probes are in contact with the two points of the circuit all the time. This can sometimes be difficult to maintain, so it is sometimes better to use a more robust connection. Crocodile clips may provide a possible solution provided there is access to the two points in the circuit. Also be aware that high voltage points should not be exposed otherwise they may present a shock hazard.

Another solution may be to make meter connecting leads that can be soldered to the required points, or connected using a connecting block. Test probes are not normally suitable for this approach.

Test Points and Links

When it is known at the design stage that a current measurement may need to be taken, some designers may insert a link into the design. This link can be removed when a current measurement needs to be taken.

Typically test points would also be provided as shown.

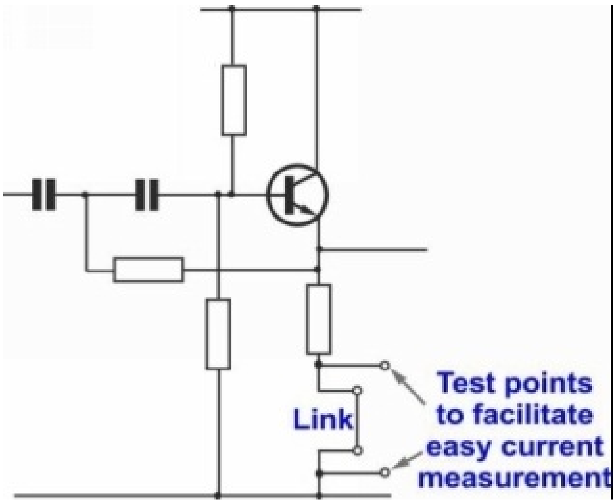


Figure 5.3 Use of a removable link to facilitate current measurement

For designs using surface mount technology, components known as zero ohm links may be used. These are effectively short circuit resistors that can easily be removed from the circuit, enabling current to flow through a meter connected to the circuit.

Another method of facilitating current measurement with a multimeter is to use a small resistor in the circuit.

The circuit can be modified so that a resistor carrying current may be split so that it develops a small proportion of the voltage across it. This will be proportional to the current flowing. Thus if a 100Ω resistor (for example) is placed in the emitter circuit, then voltage across the resistor can be measured with a digital multimeter set to the volts range. Using Ohms Law, it is an easy matter to calculate the current.

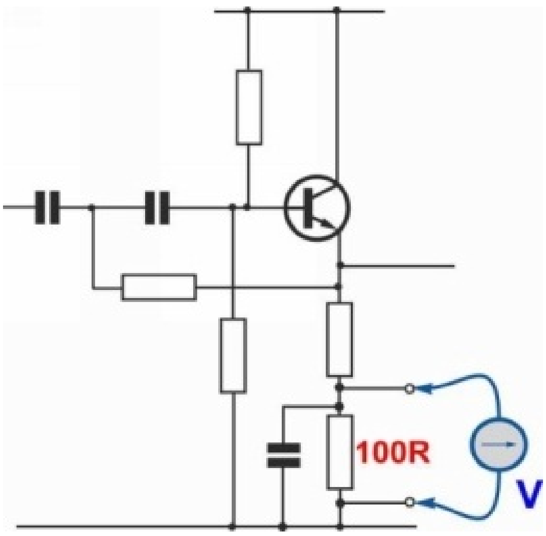


Figure 5.4 Measuring current with a DMM set to measure voltage

In the circuit shown above, the 100Ω resistor would typically be much smaller than the emitter resistor, Re. If 0.10 volt is developed across the measurement resistor, then using Ohms Law it is possible to calculate the current, I, flowing is V/R = 0.10/100, i.e. 1 mA. The value of the resistor used in this type of application will vary dependent upon the circuit and the values within it. Values that are easy to convert into current levels are more convenient, but not essential. Also it is worth remembering that the voltages produced across these current sense resistors are normally relatively low if the operation of the circuit is not to be disturbed, and therefore accuracy may be reduced.

If the circuit is carrying high frequencies it is good practice to decouple the measurement t resistor to ensure that it does not carry any signal, which could be radiated and cause problems .

Current Probes

Another approach that is sometimes adopted is to use a current probe. These are not cheap, but are used particularly in high voltage and high current applications. They consist of clamps that fit around the conductor carrying the current. By sensing the magnetic field they are able to provide a measurement of the current being carried.

Current Measurement Precautions

When measuring current there are a few precautions that can be observed to ensure that the readings are as accurate as possible.

Ensure test leads are secure: It is necessary to ensure that the connections will remain in place for a while when current measurements are being made. It may not be appropriate to use ordinary test probes, because these will only remain in place while they are held. It may be more appropriate to have connections using crocodile / alligator clips or some other method that will keep the connections in place while the circuit is switched on for the test.

Meter resistance: The leads and meter will introduce additional resistance. In most cases this will be very low and can be ignored, bit on some occasions it may be important.

Lead length: The leads used for the multimeter may cause issues with some circuits, especially if they are long. If the circuit is carrying signals above 100kHz or is capable of operating at frequencies above this, the leads may introduce stray capacitance and inductance which can cause the circuit to malfunction. Also radiation of the signal may cause problems.

Some voltage regulator chips are known to oscillate if the lead length to the smoothing capacitor is too long. Local decoupling may therefore be required on some occasions.

Return meter to high voltage test after use: When the current measurements have been completed it is always wise to return the meter to function as a voltage tester after use. In this way, even if the meter is used to make another measurement and the user forgets to set the range, no damage will occur. If the meter is left on a current range and it is accidentally placed across a voltage rail, large amounts of current would be drawn and this could damage both the meter and the circuit under test.

Resistance Measurements

Resistance measurements are one of the common measurements that need to be made in an electronics laboratory or workshop.

Knowing how to measure resistance with a digital multimeter is quite straightforward, although there are a number of precautions and hints and tips that can make the measurements more reliable and accurate.

When making a resistance measurement, the digital multimeter supplies current to the item under test and measures the response. The more current the device is able to draw, the lower the resistance it must have.

Often the digital multimeter will possess several ranges. Typically it is best to opt for the lowest range that does not overflow the display.

For accurate measurements of resistance, the item to be tested should not be affected by other components within the circuit.

In the very basic circuit shown below, other components will affect any readings made.

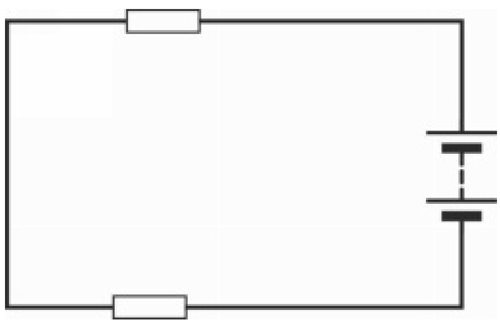


Figure 5.5 Basic resistance measurements

Accordingly the component should be removed from the circuit to enable accurate testing to be undertaken, free from the effects of other components within the circuit.

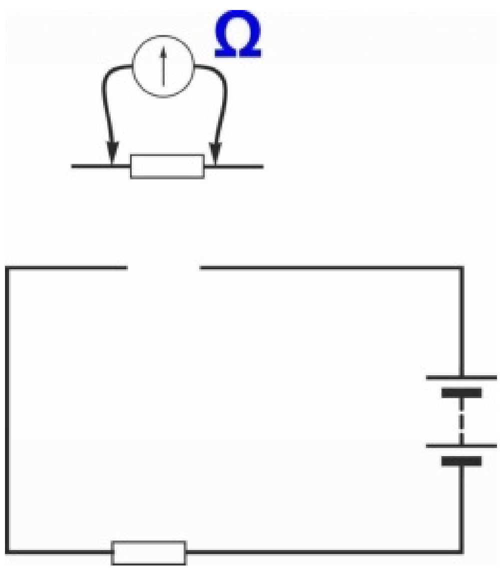


Figure 5.6 Measuring the resistance of the component

Similarly never measure resistance when the circuit is powered, as power from the circuit will not only distort the reading, but could damage the meter.

Continuity testing

It is possible to use many digital multimeters for continuity testing. Often there is a special switch position for this facility. This is one of the most common additions found in a digital multimeter. This capability is sometimes included on a low value Ohms range, or may have its own switch position. The idea is that it is possible to test for continuity and listen for a buzz, rather than having to continually turn away from looking at the unit under test.

The test meter will make an audible tone when resistance below a certain low value is detected. When using the continuity tester, the same precautions for using the ordinary resistance ranges should be observed, especially the unit should not be powered up, or thee should be no voltages on the lines to be tested.

Using a DMM for Other Measurements

In addition to the basic voltage, current and resistance measurements, many digital multimeters offer a range of other measurements that they can make. The actual measurements depend upon the actual DMM being used. However knowing how to use the digital multimeter to make these measurements means that the results can be assessed within the capabilities of the instrument.

Other measurements that may be incorporated into digital multimeters may include:

Frequency : Some digital multimeters can be used to measure frequency. This is one of the less commonly included ranges, but can be used to give a rough indication of frequency up to a few hundred kilohertz. Normally the ranges do not extend very high, and they are not normally nearly as accurate as dedicated frequency counters. However they are useful for some low frequency measurements, where high accuracy levels are not paramount.

Capacitance: With some digital multimeters, it is possible to use them to measure capacitance. Again this facility is not available on all meters, but some have the ability to measure it. Like resistance measurements, capacitance measurements should ideally be undertaken on the component when it is not in circuit. Normally the capacitance ranges are limited, and they are not able to measure small levels of capacitance.

Transistor tester: Occasionally multimeters have the facility to measure transistor parameters. In particular they measure the current gain, i.e. Hfe or β of the transistor. Typically there are three connections for each of the PNP and NPN varieties, so you need to know what sort it is before testing. Values for current gain will be given for DC, and also it is not possible to provide a complete test of the transistor. However if it is working, it is unlikely, although not impossible, that it meets the original specification for that particular type of transistor.

Temperature: Some meters have a temperature measurement capability. To achieve this the meter uses an additional thermocouple (normally provided with the meter). This will have a separate connection point with a polarised for of connection so that the thermocouple is inserted with the correct polarity. The remote end of the wire where two dissimilar metals join is the point at which the temperature is taken. Accuracy of these measurements is generally reasonable, although like other non-standard measurements, they are not as accurate as those obtained with dedicated instruments.

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ABOUT THE AUTHOR

Ian Poole is the editor of Radio-Electronics.com. Having studied at University College London to gain his degree in Electrical and Electronic Engineering, he went on to undertake a career in electronic development working for companies including Racal. He became the hardware development manager at Racal Instruments where he was in responsible for the hardware development activities within the company. Later moving into freelance work as a consultant, he also developed the Radio-Electronics.com website to become one of the leading publications for professional electronics engineers. He is also a Fellow of the Institution of Engineering and Technology and is an author of many books both paper based and in electronic format.