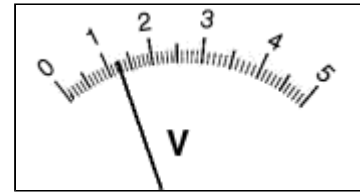


Analogue display

Analogue displays have a pointer which moves over a graduated scale. They can be difficult to read because of the need to work out the value of the smallest scale division. For example the scale in the picture has 10 small divisions between 0 and 1 so each small division represents 0.1. The reading is therefore **1.25V** (the pointer is estimated to be half way between 1.2 and 1.3).

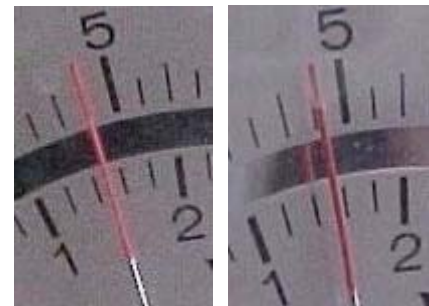


The maximum reading of an analogue meter is called **full-scale deflection** or **FSD** (it is 5V in the example shown).

Analogue meters must be connected the correct way round to prevent them being damaged when the pointer tries to move in the wrong direction. They are useful for monitoring continuously changing values (such as the voltage across a capacitor discharging) and they can be good for quick rough readings because the movement of the pointer can be seen without looking away from the circuit under test.

Taking accurate readings

To take an accurate reading from an analogue scale you must have your eye in line with the pointer. Avoid looking at an angle from the left or right because you will see a reading which is a little too high or too low. Many analogue meters have a small strip of **mirror** along the scale to help you. When your eye is in the correct position the reflection of the pointer is hidden behind the pointer itself. If you can see the reflection you are looking at an angle.



Correct reflection hidden **Wrong** reflection visible

Instead of a mirror, some meters have a **twisted pointer** to aid accurate readings. The end of the pointer is turned through 90° so it appears very thin when viewed correctly. The meter shown in the [galvanometers](#) section has a twisted pointer although it is too small to see in the picture.

Digital display

Values can be read directly from digital displays so they are easy to read accurately. It is normal for the least significant digit (on the right) to continually change between two or three values, this is a feature of the way digital meters work, not an error! Normally you will not need great precision and the least significant digit can be ignored or rounded up.



Digital meters may be connected either way round without damage, they will show a minus sign (-) when connected in reverse. If you exceed the maximum reading most digital meters show an almost blank display with just a 1 on the left-hand side.

All digital meters contain a battery to power the display so they use virtually no power from the circuit under test. This means that digital voltmeters have a very high resistance (usually called input impedance) of 1M Ω or more, usually 10M Ω , and they are very unlikely to affect the circuit under test.

For general use digital meters are the best type. They are easy to read, they may be

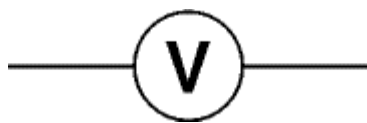
connected in reverse and they are unlikely to affect the circuit under test.

Connecting meters

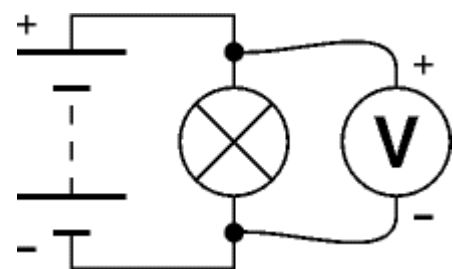
It is important to connect meters the correct way round:

- The **positive terminal** of the meter, marked + or coloured **red** should be connected nearest to + on the battery or power supply.
- The **negative terminal** of the meter, marked - or coloured **black** should be connected nearest to - on the battery or power supply.

Voltmeters



- Voltmeters measure **voltage**.
- Voltage is measured in **volts, V**.
- Voltmeters are connected in **parallel** across components.
- Voltmeters have a **very high resistance**.

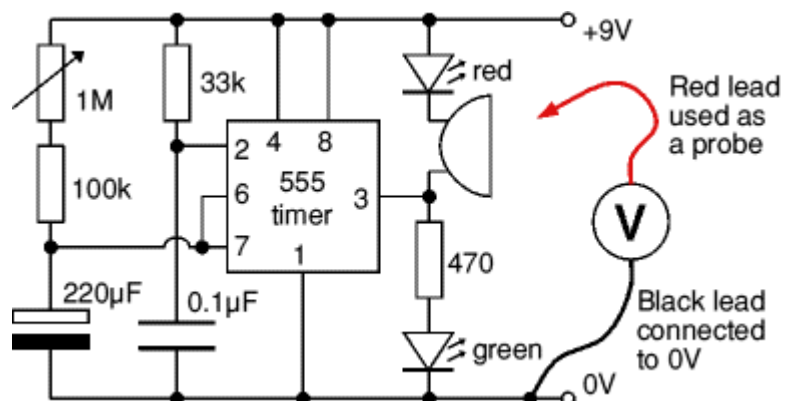


Connecting a voltmeter in parallel

Measuring voltage at a point

When testing circuits you often need to find the voltages at various points, for example the voltage at pin 2 of a 555 timer chip. This can seem confusing - where should you connect the second voltmeter lead?

- Connect the **black** (negative -) voltmeter lead to 0V, normally the negative terminal of the battery or power supply.
- Connect the **red** (positive +) voltmeter lead to the point you where you need to measure the voltage.
- The **black** lead can be left permanently connected to 0V while you use the **red** lead as a probe to measure voltages at various points.
- You may wish to use a crocodile clip on the **black** lead to hold it in place.



Voltage at a point really means the voltage difference between that point and 0V (zero volts) which is normally the negative terminal of the battery or power supply. Usually 0V will be labelled on the circuit diagram as a reminder.

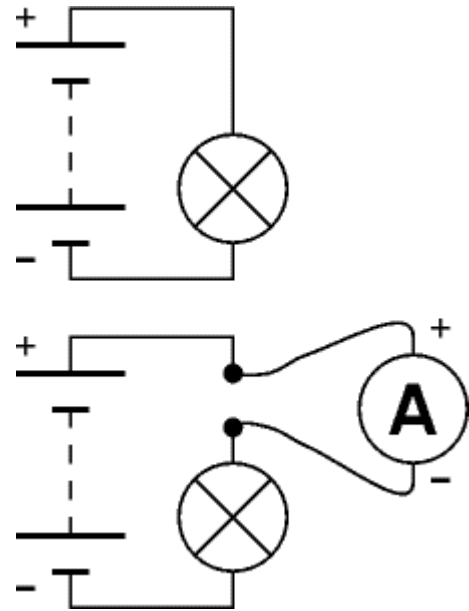
Analogue meters take a little power from the circuit under test to operate their pointer. This may upset the circuit and give an incorrect reading. To avoid this voltmeters should have a resistance of at least 10 times the circuit resistance (take this to be the highest resistor value near where the meter is connected).

Most analogue voltmeters used in school science are not suitable for electronics because their resistance is too low, typically a few $k\Omega$. $100k\Omega$ or more is required for most electronics circuits.

Ammeters



- Ammeters measure **current**.
- Current is measured in **amps (amperes), A**. 1A is quite large, so mA (milliamps) and μA (microamps) are often used. $1000mA = 1A$, $1000\mu A = 1mA$, $1000000\mu A = 1A$.
- Ammeters are connected in **series**.
To connect in series you must break the circuit and put the ammeter across the gap, as shown in the diagram.
- Ammeters have a **very low resistance**.

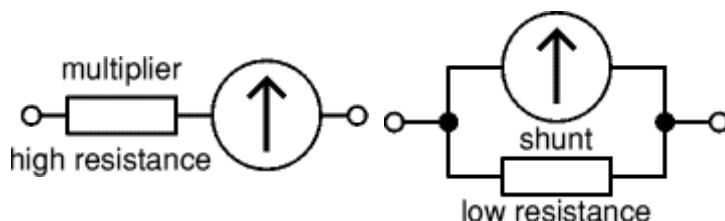


Connecting an ammeter in series

The need to break the circuit to connect in series means that ammeters are difficult to use on soldered circuits. Most testing in electronics is done with voltmeters which can be easily connected without disturbing circuits.

Galvanometers

Galvanometers are very sensitive meters which are used to measure tiny currents, usually 1mA or less. They are used to make all types of analogue meters by adding suitable resistors as shown in the diagrams below. The photograph shows an educational $100\mu A$ galvanometer for which various multipliers and shunts are available.



Making a Voltmeter

A galvanometer with a high resistance **multiplier** in series to make a voltmeter.

Making an Ammeter

A galvanometer with a low resistance **shunt** in parallel to make an ammeter.

Ohmmeters

An ohmmeter is used to measure resistance in ohms (Ω). Ohmmeters are rarely found as separate meters but all standard [multimeters](#) have an ohmmeter setting. 1Ω is quite small so $k\Omega$ and $M\Omega$ are often used.



$1k\Omega = 1000\Omega$, $1M\Omega = 1000k\Omega = 1000000\Omega$.

Multimeters

Multimeters are very useful test instruments. By operating a multi-position switch on the meter they can be quickly and easily set to be a **voltmeter**, an **ammeter** or an **ohmmeter**. They have several settings (called 'ranges') for each type of meter and the choice of AC or DC.

Some multimeters have additional features such as transistor testing and ranges for measuring capacitance and frequency.

Analogue multimeters consist of a [galvanometer](#) with various resistors which can be switched in as multipliers (voltmeter ranges) and shunts (ammeter ranges).



Analogue Multimeter

Digital Multimeter

Multimeter Photographs © [Rapid Electronics](#)