Name	
Reg. No	
Marks / Grade	

EXPERIMENT NO. 1

INTRODUCTION TO LAB INSTRUMENTS

Objective:

To get a comprehensive understanding of various laboratory instruments.

Equipment:

Oscilloscope, Digital Multi-meter, Function Generator, DC Power Supply.

General Laboratory Operating Procedures:

Listed below are the operating procedures that you are expected to follow in the laboratory.

1. Please treat the instruments with care as they are very expensive.
2. Read the laboratory documentation prior to each lab meeting.
3. Follow the instructions carefully.
4. Return the components to the correct bin when you are finished with them.
5. Before leaving the lab place the stools under the lab bench.
6. Before leaving the lab, turn off the power to all instruments.

OSCILLOSCOPE

We should be familiar to the following four things about oscilloscope.

1. What does an oscilloscope do?
2. How does it work?
3. Setting Up
4. Other Controls

What does an oscilloscope do?

An oscilloscope is easily the most useful instrument available for testing circuits because it allows you to *see* the signals at different points in the circuit. The best way of investigating an electronic system is to monitor signals at the input and output of each system block, checking that each block is operating as expected and is correctly linked to the next.

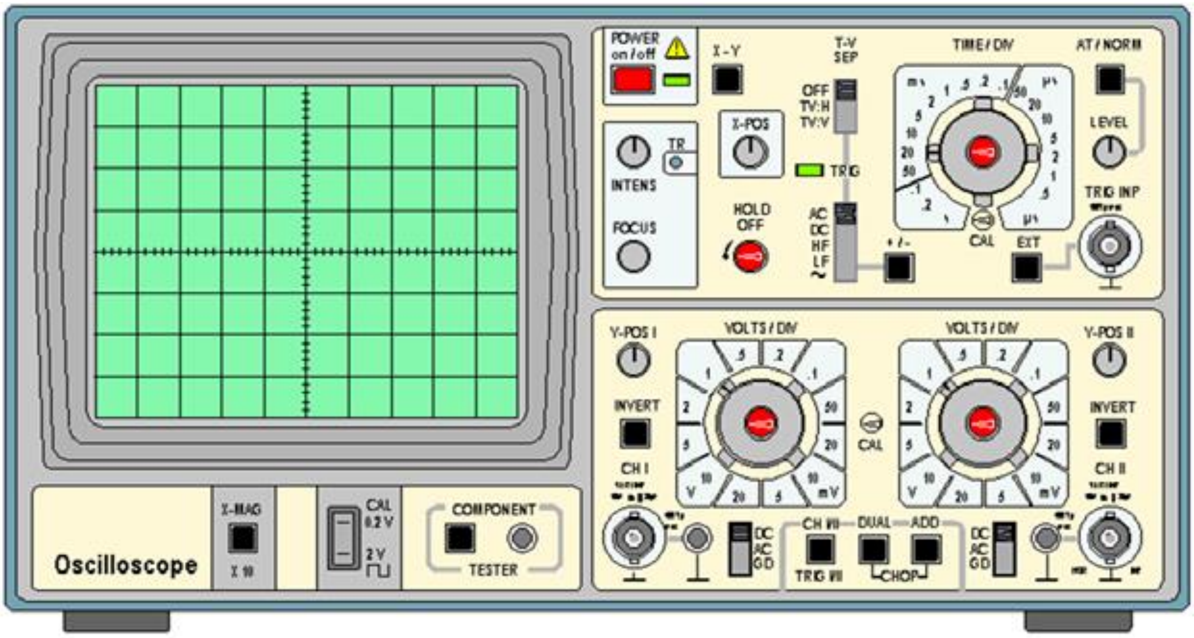


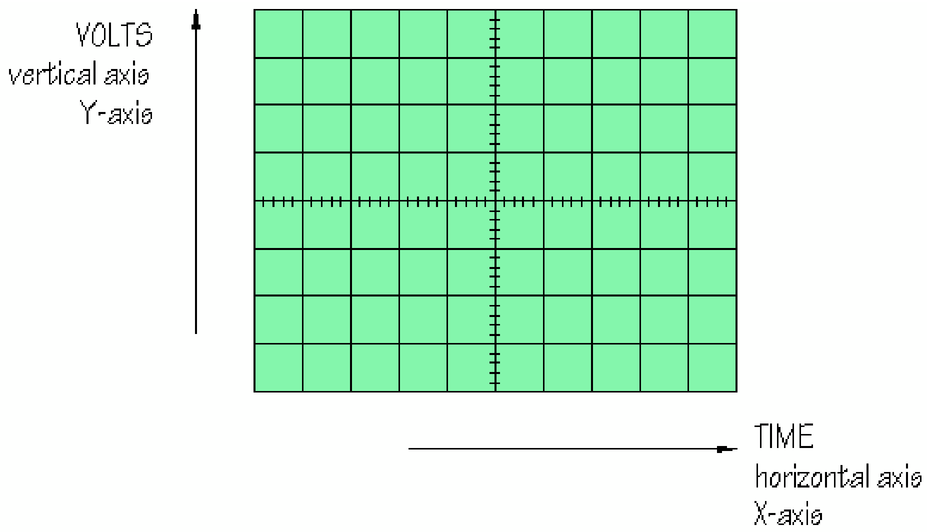
Figure 1.1: An Oscilloscope

The diagram shows an oscilloscope, a popular instrument in UK schools. Your oscilloscope may look different but will have similar controls.

Faced with an instrument like this, students typically respond either by twiddling every knob and pressing every button in sight, or by adopting a glazed expression. Neither approach is especially helpful. Following the systematic description below will give you a clear idea of what an oscilloscope is and what it can do.

The function of an oscilloscope is extremely simple: it draws a *V*/*t* graph, a graph of voltage against time, voltage on the vertical or Y-axis, and time on the horizontal or X-axis.

As you can see, the **screen** of this oscilloscope has 8 squares or divisions on the vertical axis, and 10 squares or divisions on the horizontal axis. Usually, these squares are 1 cm in each direction:

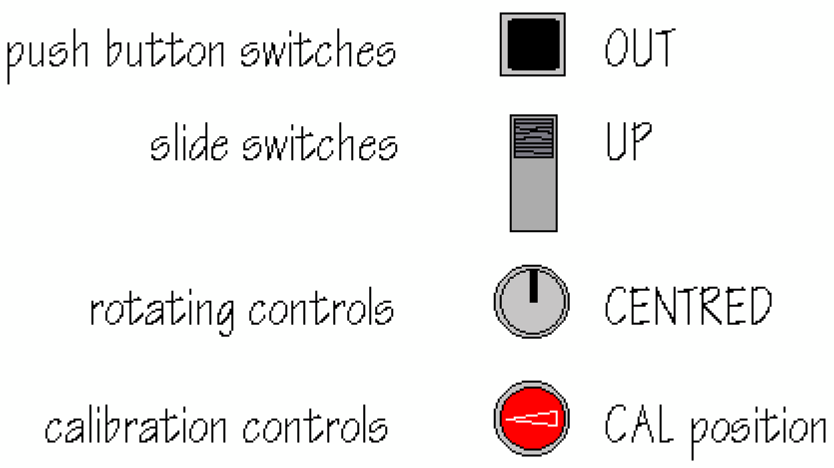


Many of the controls of the oscilloscope allow you to change the vertical or horizontal scales of the *V/t* graph, so that you can display a clear picture of the signal you want to investigate. 'Dual trace' oscilloscopes display two *V/t* graphs at the same time, so that simultaneous signals from different parts of an electronic system can be compared.

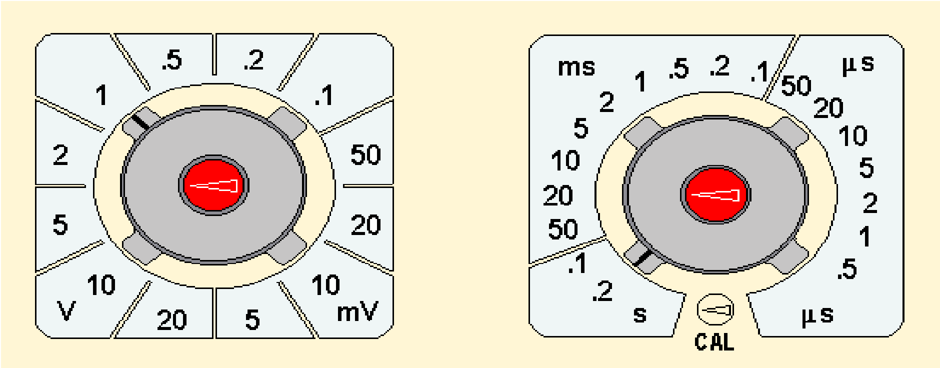
Setting up the Oscilloscope:

1. Someone else may have been twiddling knobs and pressing buttons before you. Before you switch the oscilloscope on, check that all the controls are in their 'normal' positions. This means that:
   - all push button switches are in the OUT position
   - all slide switches are in the UP position
   - all rotating controls are CENTRED
   - the central TIME/DIV and VOLTS/DIV and the HOLD OFF controls are in the calibrated, or CAL position

   Check through all the controls and put them in these positions:



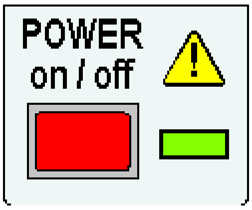
2. Set both VOLTS/DIV controls to 1 V/DIV and the TIME/DIV control to 2 s/DIV, its slowest setting:



VOLTS/DIV TIME/DIV

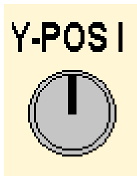
3. Switch ON, red button, top centre:

The green LED illuminates and, after a few moments, you should see a small bright spot, or **trace**, moving fairly slowly across the screen.



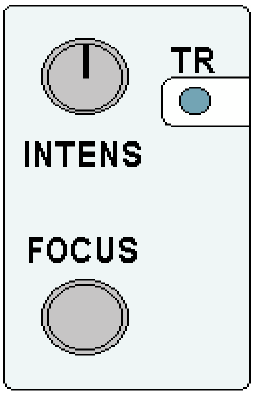
4. Find the Y-POS 1 control:

What happens when you twiddle this?
The Y-POS 1 allows you to move the spot up and down the screen. For the present, adjust the trace so that it runs horizontally across the centre of the screen.



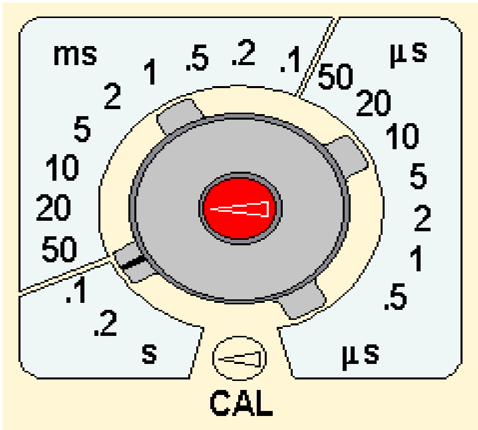
5. Now investigate the INTENSITY and FOCUS controls:

When these are correctly set, the spot will be reasonably bright but not glaring, and as sharply focused as possible. (The TR control is screwdriver adjusted. It is only needed if the spot moves at an angle rather than horizontally across the screen with no signal connected.)



6. The TIME/DIV control determines the horizontal scale of the graph which appears on the oscilloscope screen.

With 10 squares across the screen and the spot moving at 0.2 s/DIV, how long does it take for the spot to cross the screen? The answer is 0.2 x 10 = 2 s. Count seconds. Does the spot take 2 seconds to cross the screen?

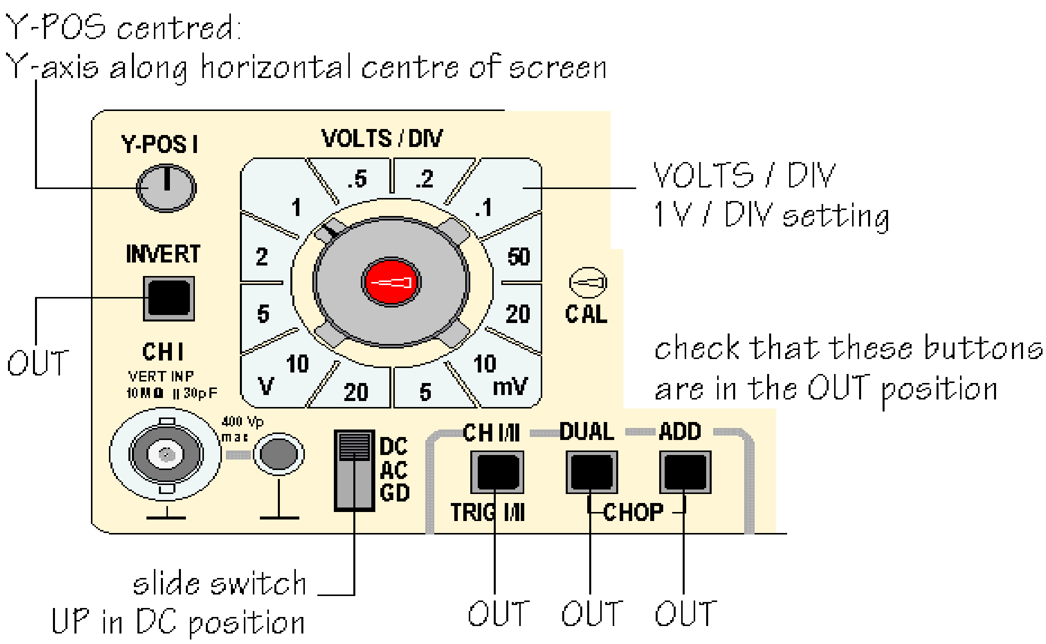


Now rotate the TIME/DIV control clockwise: With the spot moving at 0.1 s/DIV, it will take 1 second to cross the screen.

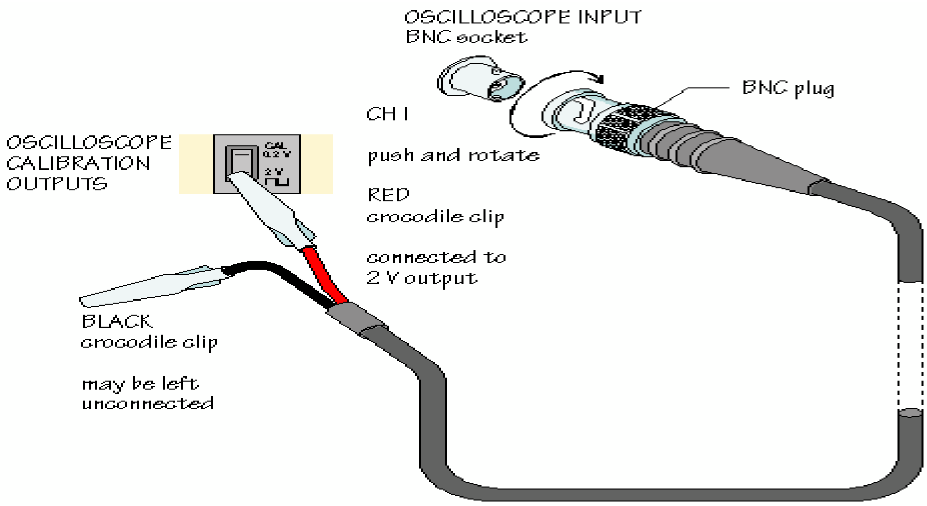
Continue to rotate TIME/DIV clockwise. With each new setting, the spot moves faster. At around 10 ms/DIV, the spot is no longer separately visible. Instead, there is a bright line across the screen. This happens because the screen remains bright for a short time after the spot has passed an effect which is known as the **persistence** of the screen. It is useful to think of the spot as still there, just moving too fast to be seen.

Keep rotating TIME/DIV. At faster settings, the line becomes fainter because the spot is moving very quickly indeed. At a setting of 10 μs/DIV how long does it take for the spot to cross the screen?

7. The VOLTS/DIV controls determine the vertical scale of the graph drawn on the oscilloscope screen. Check that VOLTS/DIV 1 is set at 1 V/DIV and that the adjacent controls are set correctly:

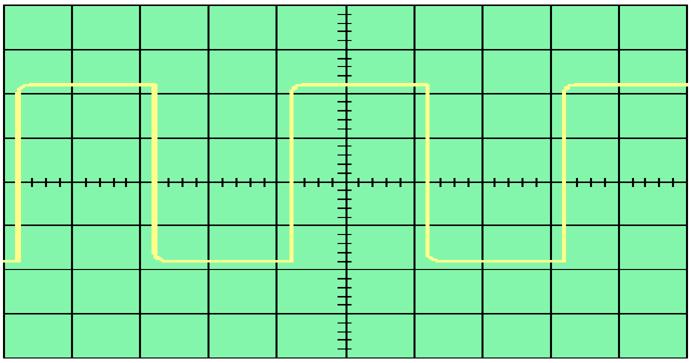


The *oscilloscope* has a built in source of signals which allow you to check that the oscilloscope is working properly. A connection to the input of channel 1, CH 1, of the oscilloscope can be made using a special connector called a BNC plug, as shown below:

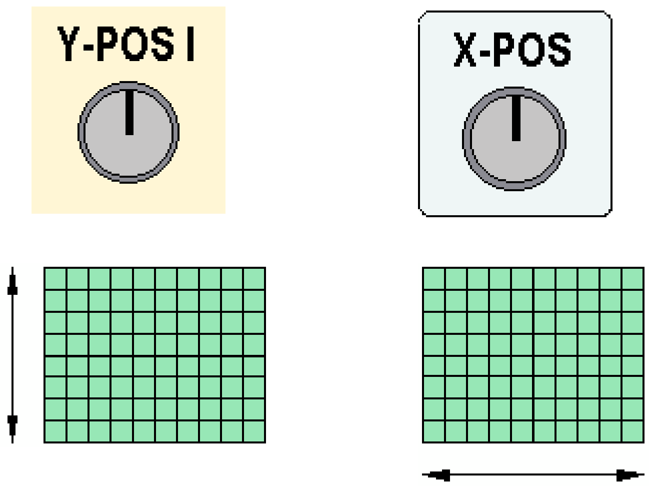


The diagram shows a lead with a BNC plug at one end and crocodile clips at the other. When the crocodile clip from the red wire is clipped to the lower metal terminal, a 2 V square wave is connected to the input of CH 1.

Adjust VOLTS/DIV and TIME/DIV until you obtain a clear picture of a 2V signal, which should look like this:



Check on the effect of Y-POS 1 and X-POS:

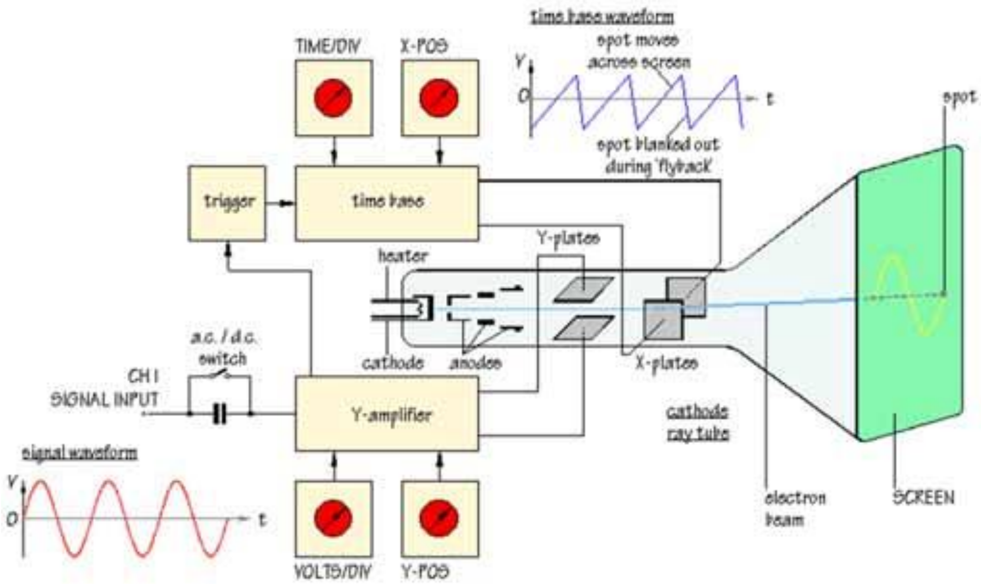


What do these controls do? Y-POS 1 moves the whole trace vertically up and down on the screen, while X-POS moves the whole trace from side to side on the screen. These controls are useful because the trace can be moved so that more of the picture appears on the screen, or to make measurements easier using the grid which covers the screen.

You have now learned about and used the most important controls on the oscilloscope. You know that the function of an oscilloscope is to draw a *V*/*t* graph. You know how to put all the controls into their 'normal' positions, so that a trace should appear when the oscilloscope is switched on. You know how the change the horizontal scale of the *V*/*t* graph, how to change the vertical scale, and how to connect and display a signal.

How does an oscilloscope work?

An outline explanation of how an oscilloscope works can be given using the block diagram shown below:



Like a television screen, the screen of an oscilloscope consists of a **cathode ray tube**. Although the size and shape are different, the operating principle is the same. Inside the tube is a vacuum. The electron beam emitted by the heated cathode at the rear end of the tube is accelerated and focused by one or more anodes, and strikes the front of the tube, producing a bright spot on the phosphorescent screen.

The electron beam is bent, or deflected, by voltages applied to two sets of plates fixed in the tube. The horizontal deflection plates or **X-plates** produce side to side movement. As you can see, they are linked to a system block called the **time base**. This produces a saw tooth waveform. During the rising phase of the saw tooth, the spot is driven at a uniform rate from left to right across the front of the screen. During the falling phase, the electron beam returns rapidly from right or left, but the spot is 'blanked out' so that nothing appears on the screen.

In this way, the time base generates the X-axis of the *V*/*t* graph. The slope of the rising phase varies with the frequency of the saw tooth and can be adjusted, using the TIME/DIV control, to change the scale of the X-axis. Dividing the oscilloscope screen into squares allows the horizontal scale to be expressed in seconds, milliseconds or microseconds per division (s/DIV, ms/DIV, µs/DIV). Alternatively, if the squares are 1 cm apart, the scale may be given as s/cm, ms/cm or µs/cm.

The signal to be displayed is connected to the **input**. The AC/DC switch is usually kept in the DC position (switch closed) so that there is a direct connection to the **Y-amplifier**. In the AC position (switch open) a capacitor is placed in the signal path.

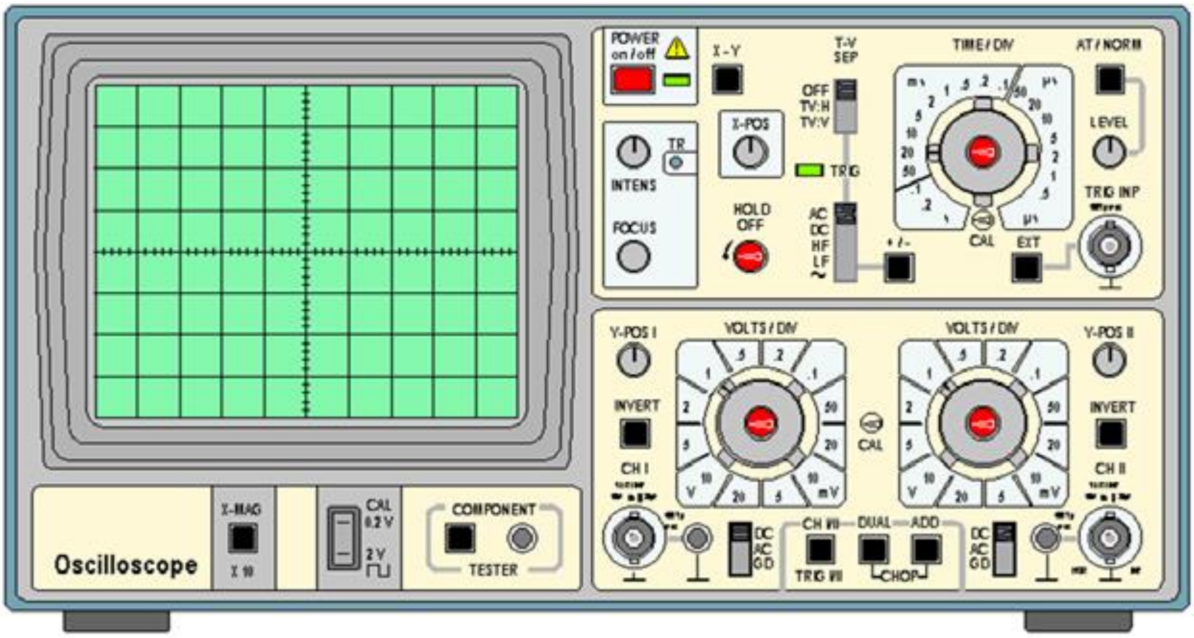
The Y-amplifier is linked in turn to a pair of **Y-plates** so that it provides the Y- axis of the *V*/*t* graph. The overall gain of the Y-amplifier can be adjusted, using the VOLTS/DIV control, so that the resulting display is neither too small nor too large, but fits the screen and can be seen clearly. The vertical scale is usually given in V/DIV or mV/DIV.

The **trigger** circuit is used to delay the time base waveform so that the same section of the input signal is displayed on the screen each time the spot moves across. The effect of this is to give a stable picture on the oscilloscope screen, making it easier to measure and interpret the signal.

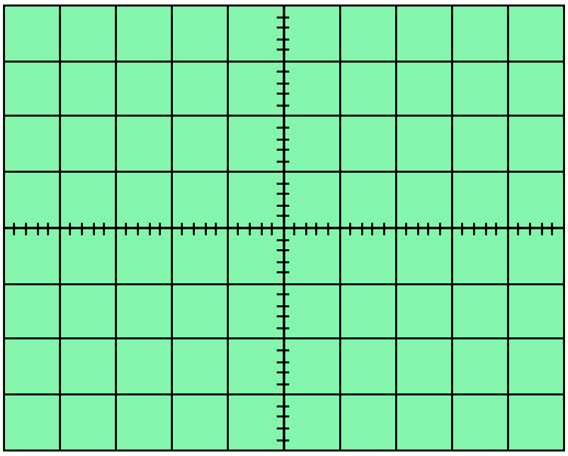
Changing the scales of the X-axis and Y-axis allows many different signals to be displayed. Sometimes, it is also useful to be able to change the *positions* of the axes. This is possible using the **X-POS** and **Y-POS** controls. For example, with no signal applied, the normal trace is a straight line across the centre of the screen. Adjusting Y-POS allows the zero level on the Y-axis to be changed, moving the whole trace up or down on the screen to give an effective display of signals like pulse waveforms which do not alternate between positive and negative values.

Other oscilloscope controls:

The diagram below is a image map of an oscilloscope. Some controls are more useful than others and one or two are rarely if ever used in an introductory electronics course.



Screen: usually displays a *V*/*t* graph, with voltage *V* on the vertical axis and time *t* on the horizontal axis. The scales of both axes can be changed to display a huge variety of signals.



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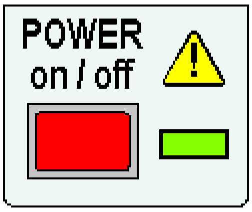
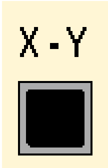
On/off switch: pushed in to switch the oscilloscope on. The green LED illuminates.



X-Y control: normally in the OUT position.

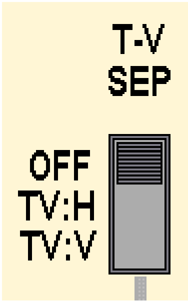
When the X-Y button is pressed IN, the oscilloscope does not display a *V/t* graph. Instead, the vertical axis is controlled by the input signal to CH II. This allows the oscilloscope to be used to display a *V/V* voltage/voltage graph. The X-Y control is used when you want to display component characteristic curves.



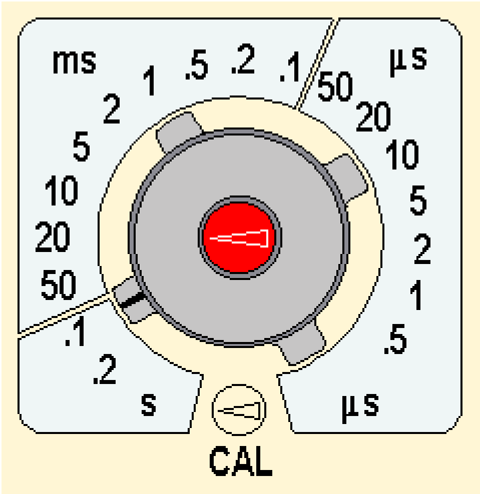
TV-separation: Oscilloscopes are often used to investigate waveforms inside television systems. This control allows the display to be synchronized with the television system so that the signals from different points can be compared.

☠MAINS VOLTAGE☠

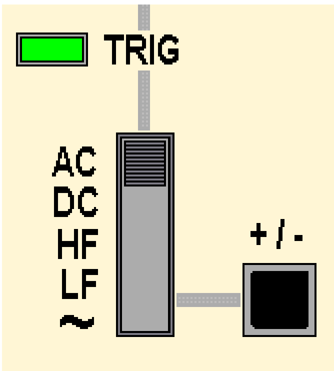
You must **not** try to investigate television systems because of the dangerously high voltages inside. The correct position for this control is OFF.

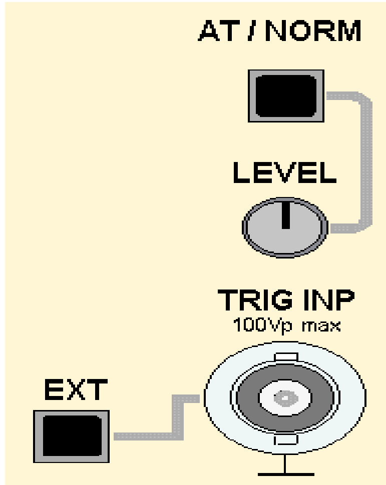


TIME / DIV: Allows the horizontal scale of the *V/t* graph to be changed.



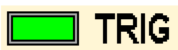
Trigger controls: This group of controls allows the oscilloscope display to be synchronized with the signal you want to investigate.





When the AT/NORM button is in the OUT position, triggering is automatic. This works for most signals. If you change the AT/NORM button to it's IN position, the most likely result is that the signal will disappear and the oscilloscope screen will be blank. However, if you now adjust the LEVEL control, the display will be reinstated. As you adjust the LEVEL control, the display starts from a different point on the signal waveform. This makes it possible for you to look in detail at any particular part of the waveform.

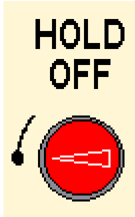
The EXT button should normally be in its OUT position. When it is pushed IN, triggering occurs from a signal connected to the trigger input, TRIG INP, socket. The slide switch to the left of TIME/DIV gives additional triggering options. AC is the normal position and is suitable for most waveforms. In the DC position, you use the LEVEL control to select a particular DC voltage on the signal waveform where triggering will occur. The +/- button gives triggering on the upward slope of the signal waveform in the OUT position, and triggering on the downward slope in the IN position.



The green TRIG LED illuminates when a trigger point is detected. HF gives triggering in response to high frequency parts of the signal; LF gives triggering for low frequency components and  indicates that triggering will occur at 50 Hz, corresponding to UK mains frequency. You are not likely to need any of these slide switch positions.

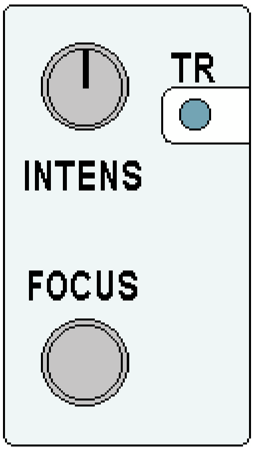
The HOLD OFF control allows you to introduce a delay relative to the trigger point so that a different part of the signal can be seen.

Normally, you will want to leave the HOLD OFF control in its minimum position, as illustrated. With more experience of using the oscilloscope, you will develop a clear understanding of the functions of the important trigger controls and be able to use them effectively.



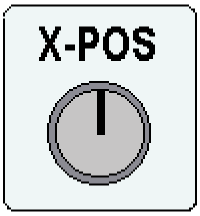
Intensity and Focus: Adjusting the INTENSITY control changes the brightness of the oscilloscope display. The FOCUS should be set to produce a bright clear trace.

If required, TR can be adjusted using a small screwdriver so that the oscilloscope trace is exactly horizontal when no signal is connected.



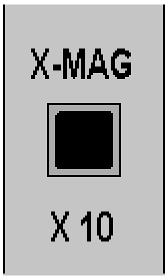
X-POS: Allows the whole *V*/*t* graph to be moved from side to side on the oscilloscope screen.

This is useful when you want to use the grid in front of the screen to make measurements, for example, to measure the period of a waveform.



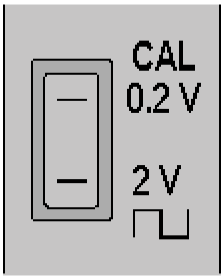
X-MAG: In the IN position, the horizontal scale of the *V*/*t* graph is increased by 10 times.

For example, if TIME/DIV is set for 1 ms per division and X-MAG is pushed IN, the scale is changed to 0.1 ms per division.



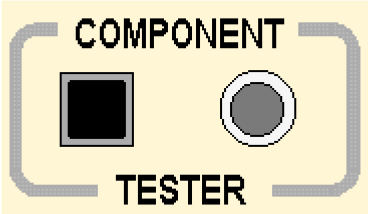
CAL outputs: The top terminal gives a 0.2 V peak to peak square wave, while the lower terminal gives a 2 V peak to peak square wave, both at 50 Hz.

The signals from these outputs are used to confirm that the oscilloscope is correctly calibrated.



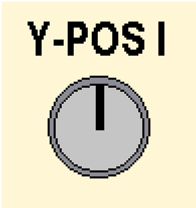
Component tester: The output socket provides a changing voltage which allows component characteristic curves to be displayed on the oscilloscope screen.

When the button is IN, the oscilloscope displays a *V*/*V* graph, with the component tester voltage connected internally to provide the horizontal axis. To get normal *V*/*t* graph operation the component tester button must be in the OUT position.

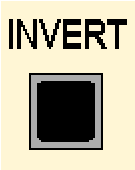


Y-POS I and Y-POS II: These controls allow the corresponding trace to be moved up or down, changing the position representing 0 V on the oscilloscope screen.

To investigate an alternating signal, you adjust Y-POS so that the 0 V level is close to the centre of the screen. For a pulse waveform, it is more useful to have 0 V close to the bottom of the screen. Y-POS I and Y-POS II allow the 0 V levels of the two traces to be adjusted independently.

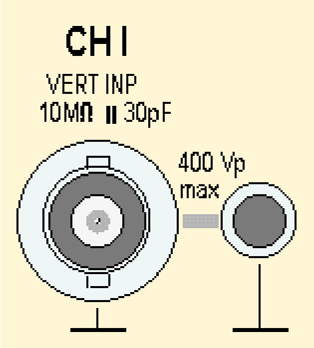


Invert: When the INVERT button is pressed IN, the corresponding signal is turned upside down, or inverted, on the oscilloscope screen. This feature is sometimes useful when comparing signals.

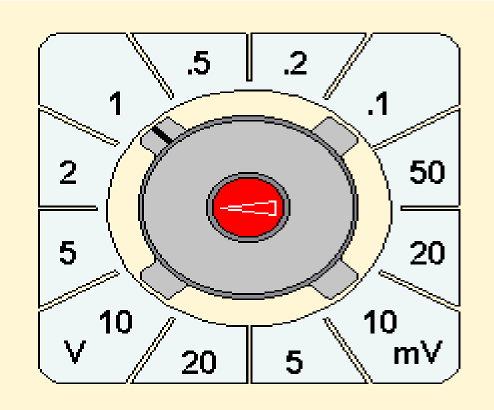


CH I and CH II inputs: Signals are connected to the BNC input sockets using BNC plugs.

The smaller socket next to the BNC input socket provides an additional 0 V, GROUND or EARTH connection.

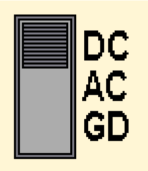


VOLTS / DIV: Adjust the vertical scale of the *V*/*t* graph. The vertical scales for CH I and CH II can be adjusted independently.



DC/AC/GND slide switches: In the DC position, the signal input is connected directly to the Y-amplifier of the corresponding channel, CH I or CH II. In the AC position, a capacitor is connected into the signal pathway so that DC voltages are blocked and only changing AC signals are displayed.

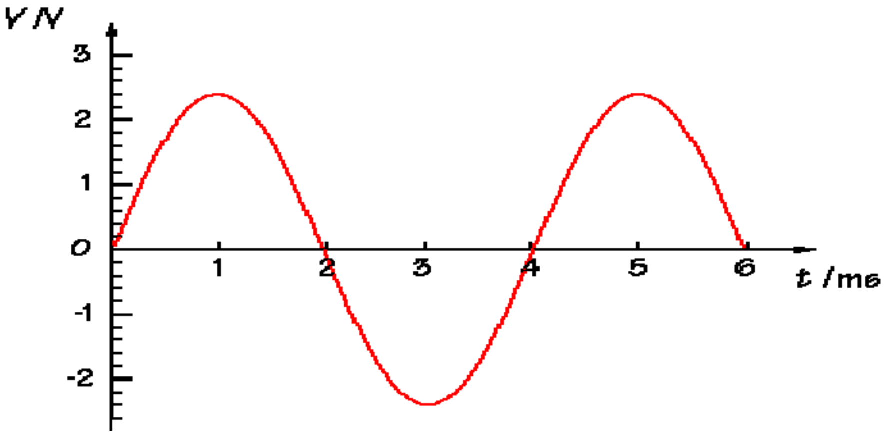
In the GND position, the input of the Y-amplifier is connected to 0 V. This allows you to check the position of 0 V on the oscilloscope screen. The DC position of these switches is correct for most signals.



Trace selection switches: The settings of these switches control which traces appear on the oscilloscope screen.

QUESTIONS:

1. Calculate the frequency of waveforms with periods of (a) 10 s, (b) 5 ms, (c) 200 μs.
2. What is the period of waveforms with frequencies of (a) 20 Hz, (b) 150 kHz, (c) 0.5 Hz.
3. Find values for the period, frequency, peak amplitude, peak-to-peak amplitude and rms amplitude for the sine wave shown below:



4. Use graph paper and choose appropriate scales to sketch *V*/*t* graphs for sine waves as follows:
   (a) period 10 ms, peak-to-peak amplitude 5 V.
   (b) frequency 250 Hz, peak amplitude 10 V.
   (c) frequency 4 kHz, rms amplitude 6 V.

DC POWER SUPPLY

DC Power Supply is used to generate either a constant voltage or a constant current. That is, it may be used as either a DC voltage source or a DC current source. You will be primarily as a voltage source. Recall that DC is an acronym for direct current. DC means constant with respect to time.

DC power supply has digital display including 0-30vD C and 0-3A. Adjustable voltage (coarse and fine) and current limiting (2 range meter). The voltage produced by the power supply is controlled by the knob labeled voltage. The current is limited by adjusting the knob labeled current. As long as the circuit does not attempt to draw more current than the value set by the current knob, the voltage will remain constant. Current limiting can prevent damage to equipment and parts which may be unable to handle excessive currents.

FUNCTION GENERATOR

We should know the following things about function generator;

FG-2100A 0.2Hz~2MHz

What is a function generator?

A function generator is a device that can produce various patterns of voltage at a variety of frequencies and amplitudes. It is used to test the response of circuits to common input signals. The electrical leads from the device are attached to the ground and signal input terminals of the device under test.

Features and controls:

Most function generators allow the user to choose the shape of the output from a small number of options.

- Square wave - The signal goes directly from high to low voltage.
- Sine wave - The signal curves like a sinusoid from high to low voltage.
- Triangle wave - The signal goes from high to low voltage at a fixed rate.

The amplitude control on a function generator varies the voltage difference between the high and low voltage of the output signal.

The direct current (DC) offset control on a function generator varies the average voltage of a signal relative to the ground.

The frequency control of a function generator controls the rate at which output signal oscillates. On some function generators, the frequency control is a combination of different controls. One set of controls chooses the broad frequency range (order of magnitude) and the other selects the precise frequency. This allows the function generator to handle the enormous variation in frequency scale needed for signals.

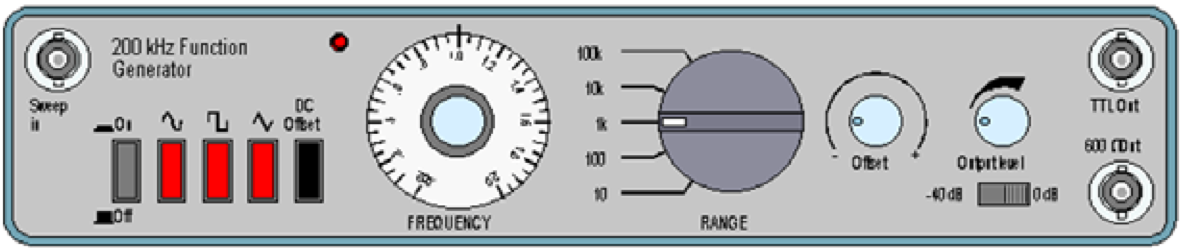
The duty cycle of a signal refers to the ratio of high voltage to low voltage time in a square wave signal.

How to use a function generator?

After powering on the function generator, the output signal needs to be configured to the desired shape. Typically, this means connecting the signal and ground leads to an oscilloscope to check the controls. Adjust the function generator until the output signal is correct, then attach the signal and ground leads from the function generator to the input and ground of the device under test. For some applications, the negative lead of the function generator should attach to a negative input of the device, but usually attaching to ground is sufficient.

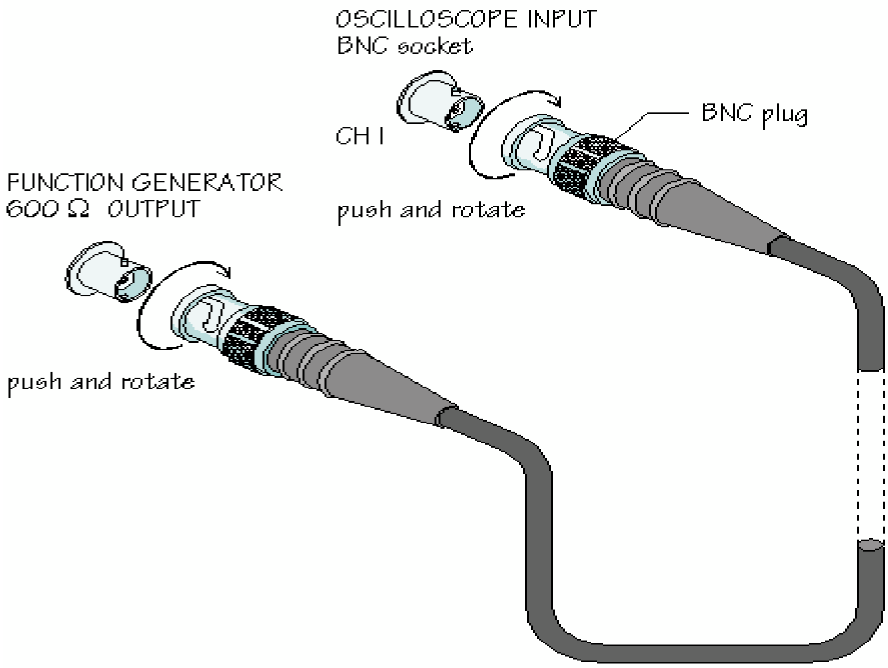
Connecting a function generator to an Oscilloscope:

The diagram shows the appearance of a general function generator.



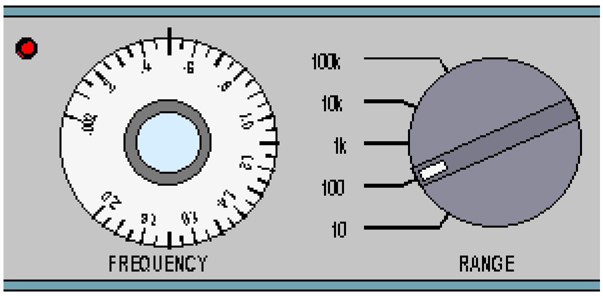
Again, your function generator, or signal generator, may look different but is likely to have similar controls.

The Thandar TG101 has push button controls for On/Off switching and for selecting either sine, square, or triangular wave shapes. Most often the 600 Ω output is used. This can be connected to the CH 1 input of the oscilloscope using a BNC- BNC lead, as follows:



Switch on the function generator and adjust the output level to produce a visible signal on the oscilloscope screen. Adjust TIME/DIV and VOLTS/DIV to obtain a clear display and investigate the effects of pressing the waveform shape buttons.

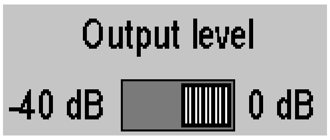
The rotating FREQUENCY control and the RANGE switch are used together to determine the frequency of the output signal. With the settings shown in the diagram above, the output frequency will be 1 kHz. How would you change these setting to obtain an output frequency of 50 Hz? This is done by moving the RANGE switch to '100' and the FREQUENCY control to '.5':



Experiment with these controls to produce other frequencies of output signal, such as 10 Hz, or 15 kHz. Whatever frequency and amplitude of signal you select, you should be able to change the oscilloscope settings to give a clear V/t graph of the signal on the oscilloscope screen.

The remaining features of the function generator are less often used. For example, it is possible to change the output frequency by connecting suitable signals

to the 'Sweep in' input. The DC Offset switch and the Offset control allow you to add a DC voltage component to the output signal producing a complex waveform .
The output level switch is normally set to 0 dB:



This gives an output signal with peak amplitude which can be easily adjusted up to several volts. In the -40 dB position, the amplitude of the output signal is reduced to a few milli-volts. Such small signals are used for testing amplifier circuits. The TTL output produces pulses between 0 V and 5 V at the selected frequency and is
used for testing logic circuits.

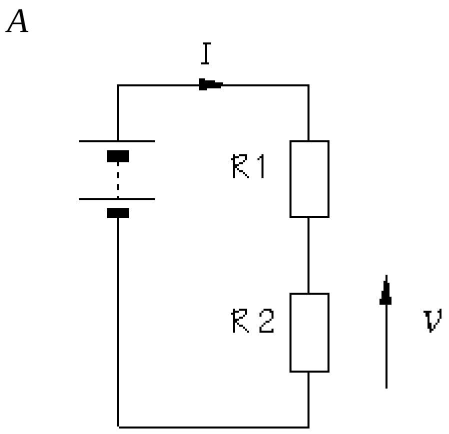
DIGITAL MULTIMETER

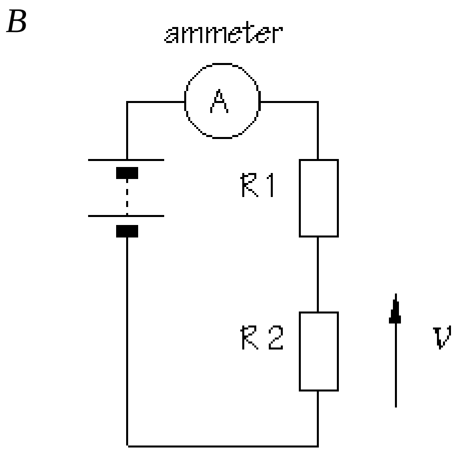
What do meters measure?

A meter is a measuring instrument. An **ammeter** measures current, a **voltmeter** measures the potential difference (voltage) between two points, and an

ohmmeter measures resistance. A **multi-meter** combines these functions and possibly some additional ones as well, into a single instrument.

Before going in to detail about multi-meters, it is important for you to have a clear idea of how meters are connected into circuits. Diagrams *A* and *B* below show a circuit before and after connecting an ammeter:



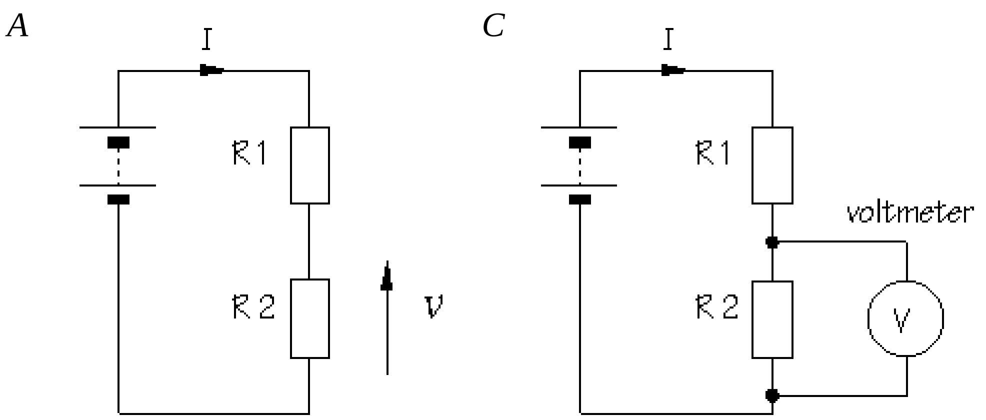


to measure current, the circuit must be broken to allow the ammeter to be connected in series

ammeters must have a LOW resistance

Think about the changes you would have to make to a practical circuit in order to include the ammeter. To start with, you need to *break the circuit* so that the ammeter can be connected in series. All the current flowing in the circuit must pass through the ammeter. Meters are not supposed to alter the behavior of the circuit, or at least not significantly, and it follows that an ammeter must have a very LOW resistance.

Diagram *C* shows the same circuit after connecting a voltmeter:



to measure potential difference (voltage), the circuit is not changed: the voltmeter is connected in parallel

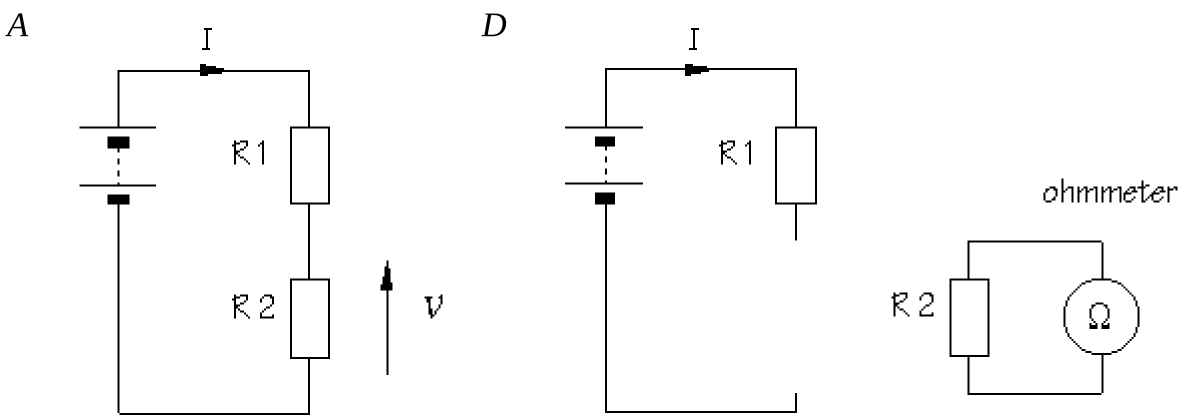
voltmeters must have a HIGH resistance

This time, you do not need to break the circuit. The voltmeter is connected in parallel between the two points where the measurement is to be made. Since the voltmeter provides a parallel pathway, it should take as little current as possible. In other words, a voltmeter should have a very HIGH resistance.

Which measurement technique do you think will be the more useful? In fact, voltage measurements are used much more often than current measurements.

The processing of electronic signals is usually thought of in voltage terms. It is an added advantage that a voltage measurement is easier to make. The original circuit does not need to be changed. Often, the meter probes are connected simply by touching them to the points of interest.

An ohmmeter does not function with a circuit connected to a power supply. If you want to measure the resistance of a particular component, you must take it out of the circuit altogether and test it separately, as shown in diagram *D*:



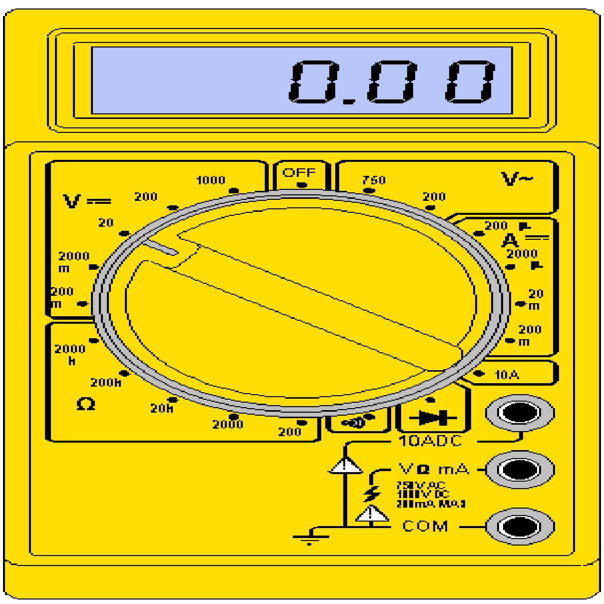
to measure resistance, the component must be removed from the circuit altogether

ohmmeters work by passing a current through the component being tested

Ohmmeters work by passing a small current through the component and measuring the voltage produced. If you try this with the component connected into a circuit with a power supply, the most likely result is that the meter will be damaged. Most multi-meters have a fuse to help protect against misuse.

Digital multi-meters:

Multimeters are designed and mass produced for electronics engineers. Even the simplest and cheapest types may include features which you are not likely to use. Digital meters give an output in numbers, usually on a liquid crystal display. The diagram below shows a **switched range multimeter**:



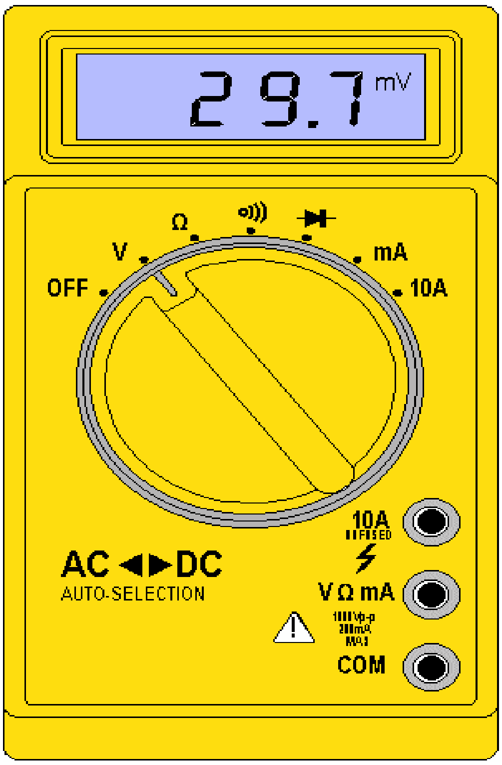
The central knob has lots of positions and you must choose which one is appropriate for the measurement you want to make. If the meter is switched to 20 V DC, for example, then 20 V is the maximum voltage which can be measured, this is sometimes called 20 V **fsd**, where fsd is short for **full scale deflection**.

For circuits with power supplies of up to 20 V, which includes all the circuits you are likely to build, the 20 V DC voltage range is the most useful. DC ranges are indicated by V= on the meter. Sometimes, you will want to measure smaller voltages, and in this case, the 2 V or 200 mV ranges are used. What does DC mean? DC means **direct current**. In any circuit which operates from a steady voltage source, such as a battery, current flow is always in the same direction. Every constructional project described in Design Electronics works in this way. AC means **alternating current**. In an electric lamp connected to the domestic mains electricity, current flows first one way, then the other. That is, the current reverses, or alternates, in direction. With UK mains, the current reverses 50 times per second.

☠MAINS VOLTAGE☠

For safety reasons, you must NEVER connect a multimeter to the mains supply.

You are not at all likely to use the AC ranges, indicated by V~, on your multimeter. An alternative style of multimeter is the **auto-ranging multimeter**:



The central knob has fewer positions and all you need to do is to switch it to the quantity you want to measure. Once switched to V, the meter automatically adjusts its range to give a meaningful reading, and the display includes the unit of measurement, V or mV. This type of meter is more expensive, but obviously much easier to use.

Where are the two meter probes connected? The **black** lead is always connected into the socket marked COM, short for COMMON. The **red** lead is connected into the socket labeled VΩmA. The 10A socket is very rarely used.

Analogue multi-meters:

An analogue meter moves a needle along a scale. Switched range analogue multimeters are very cheap but are difficult for beginners to read accurately, especially on resistance scales. The meter movement is delicate and dropping the meter is likely to damage it!

Each type of meter has its advantages. Used as a voltmeter, a digital meter is usually better because its resistance is much higher, 1 MΩ or 10 MΩ, compared to 200 kΩ for a analogue multimeter on a similar range. On the other hand, it is easier to follow a slowly changing voltage by watching the needle on an analogue display.

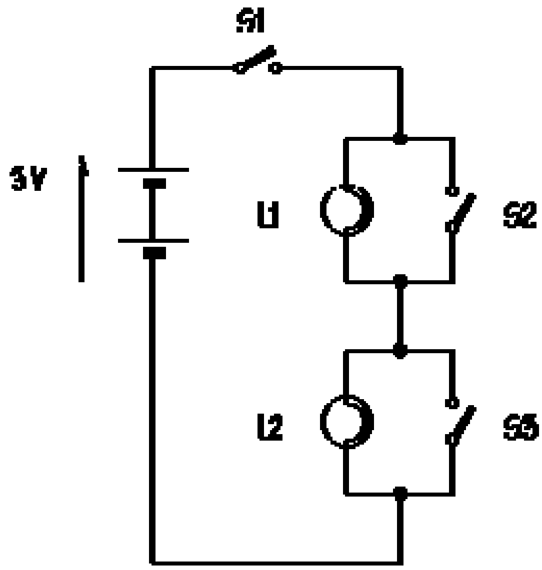
Used as an ammeter, an analogue multimeter has a very low resistance and is very sensitive, with scales down to 50 µA. More expensive digital multimeters can equal or better this performance.

Most modern multimeters are digital and traditional analogue types are destined to become obsolete.

QUESTIONS:

1. What is electric current?
2. What units are used to measure current?
3. Which materials allow current to flow easily?
4. Which materials prevent the flow of electric current?
5. What is a circuit?
6. What is potential difference (voltage)?
7. What is a battery?
8. How is the capacity of a cell measured?
9. What is the direction of flow of conventional current?

10. Can the behavior of electronic circuits be analyzed by assuming current flow in this direction?
11. Which part of the torch limits the flow of current?
12. What units are used to measure resistance?
13. What symbols are used to represent current, potential difference (voltage), and resistance?
14. If the potential difference (voltage) across a wire is constant, reducing the resistance of the wire causes the current to . . . ?
15. If the potential difference (voltage) across a wire is increased, without changing its resistance, the current will . . . ?
16. Calculate the resistance of a lamp filament if 150 mA of current flow when the lamp is connected to 3 cells in series (4.5 V).
17. In the circuit below, which switches should be closed?



(A) to light lamp L1 only?
(B) to light lamp L2 only?
(C) to light lamps L1 and L2?

18. What would happen to lamps L1 and L2 if switches S1, S2 and S3 were *all* closed at the same time? Why should closing all three switches be avoided?
19. What are the important features of ammeters, voltmeters and ohmmeters?
20. Which type of meter is used most often?