

Generic Lab Manual:

This being a generic lab manual is not a complete description or tutorial on everything that the test equipment is capable of measuring. But rather a quick guide on how each piece of equipment is used and how they might be used in a lab. For further information, read the instruction or owners manual for that particular piece of equipment.

An overview on the major functionalities of the equipment.

		Can measure						Mode operation	
		Current		Frequency		voltage		resistance	
Equipment									
Oscilloscope		NO		YES		YES		NO	Input only
Power Supply		NO		NO		NO		NO	Output only
Multimeter		Yes		YES *		YES		YES	Input only
Frequency counter		NO		YES		NO		NO	Input only
Signal Generator		NO		NO		NO		NO	Output only
* depending on how advance the multimeter is, it might have functions to measure Frequency, inductance and capacitance									

Multimeter.

Most basic multimeters perform 4 basic tasks;

They measure voltage, resistance, current and diode functionality.

Some advanced meters, measure frequency, capacitance, temperature.

For this course you only need to obtain an accurate voltage and resistance meter.

You can derive the capacitance and current measurements from those readings.

Read the instruction meter that came with your meter to understand its functions and limitations.

Caveat

Most Multimeters measure in RMS (Root Mean Square) the average voltage, when dealing with high frequencies the multimeter might not react fast enough to obtain an accurate reading. The sampling rate of the meter should be at least twice as the highest frequency being measured.

Peak voltage = $\sqrt{2}$ * RMS

RMS = $\frac{1}{\sqrt{2}}$ * Peak voltage

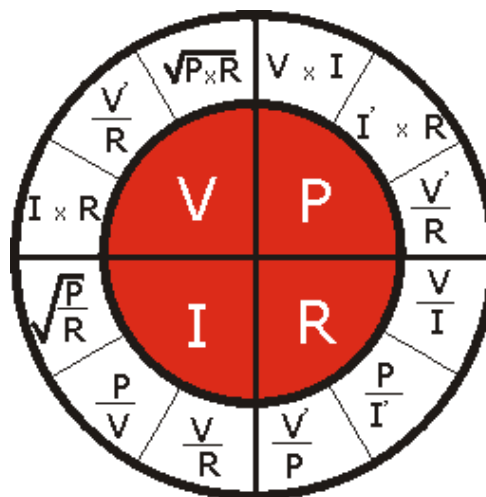
The rms conversion of $\frac{1}{\sqrt{2}}$ times peak (half of peak to peak) voltage is dependent on the waveform. The $\frac{1}{\sqrt{2}}$ works for a sine wave waveform. Anything other than a sine wave and the true rms and calculated rms will be off.

If the waveform is sinusoidal then the rms value is $\frac{1}{\sqrt{2}}$ times the amplitude (when oscillating about zero).



Reference Equations

Ohm's Law/Power Wheel



Pk, Pk-Pk, Rms, Avg

$$V_p = \left(\frac{1}{0.707} \right) \times V_{rms}$$

$$V_p = \sqrt{2} V_{rms} \cong 1.414 V_{rms} \text{ or } I_p = \sqrt{2} I_{rms} \cong 1.414 I_{rms}$$

$$V_{pp} = 2V_p \text{ or } I_{pp} = 2I_p$$

$$V_{rms} = \sqrt{0.5} V_p \cong 0.707 V_p \text{ or } I_{rms} = \sqrt{0.5} I_p \cong 0.707 I_p$$

$$V_{avg} = \left(\frac{2}{\pi}\right) V_p \cong 0.637V_p \quad \text{or} \quad I_{avg} = \left(\frac{2}{\pi}\right) I_p \cong 0.637I_p$$

Line Regulation & Load Regulation

Line Regulation:

V line (max) to V line (min)

$$\frac{V_o(FL), V_{Line(max)} - V_o(FL), V_{Line(min)}}{V_o(FL)_{nom}} \times 100\%$$

Load Regulation:

$$\begin{array}{l} \text{FullLoad} \\ \text{to No-Load} \end{array} = \frac{V_o(NL) - V_o(FL)}{V_o(FL)} \times 100\%$$

RC Filters & LC Filters

RC Filters

$$f = \frac{1}{2\pi RC} \quad \text{or} \quad f_c = \frac{1}{2\pi RC} \quad \text{or} \quad f_c = \frac{1}{2\pi R \parallel RLC}$$

(unloaded) (loaded)

LC Filters

$$f_c = \frac{1}{2\pi \sqrt{LC}}$$

Frequency & Time

$$f = \frac{1}{T}$$

$$T = \frac{1}{f}$$

Duty Cycle

$$\text{Duty Cycle} = \frac{\text{Pulse Width}}{\text{Cycle Time}} \times 100$$

Reactance of Capacitors & Inductors

$$X_C = \frac{1}{2\pi FC} \quad X_L = 2\pi FL$$

Power & Efficiency

Power Factor is the ratio of true power to apparent power.

$$P_f = \frac{P_t}{P_a} = \cos(\varphi)$$

True Power is the power actually used.

$$P_t = V_{rms} \times I_{rms} \cos(\varphi)$$

$$\text{Efficiency} = \eta = \frac{P_{out}}{P_{in}} \quad \text{or} \quad \text{Efficiency}(\%) = \frac{\text{Output Power}}{\text{Input Power}} \times 100$$

Metric to English Units

To Convert

<u>From</u>	<u>To:</u>	<u>Multiply By:</u>
<u>To:</u>	<u>From:</u>	<u>Divide By:</u>
um	mils	.03937
mm	in	.03937
cm	in	.39370
m	ft	3.2808
km	ft	3280.8
km	mi	.62137

dB

$$\text{dB} = -20 \text{ Log } V_o/V_{in}$$

Thermal Characteristics

$$\text{LFPM} = \frac{\text{CFM}}{\text{Area}}$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \div 1.8$$

$$^{\circ}\text{F} = 1.8 \times ^{\circ}\text{C} + 32$$

The practical work supporting Chapter 2 introduces you to using a multimeter to make measurements from circuits. Once you are able to test circuits, you will understand better how they work and be able to locate and correct faults.

Navigation

[!\[\]\(feabb98897b440bc8695a03336a6e2df_img.jpg\) What do meters measure?](#)

[!\[\]\(9dfdaff1d86ba3c1f8353b4d1b61b8c5_img.jpg\) Analogue multimeters](#)

[!\[\]\(83f22ed94ec5517769dd76d702c6bfd8_img.jpg\) Digital multimeters](#)

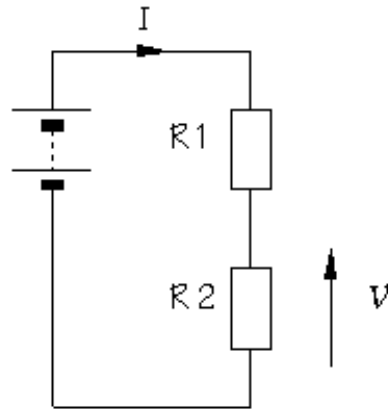
[!\[\]\(8d0f0e0fe25b320c33272c52aec1fbca_img.jpg\) Making measurements](#)

What do meters measure?

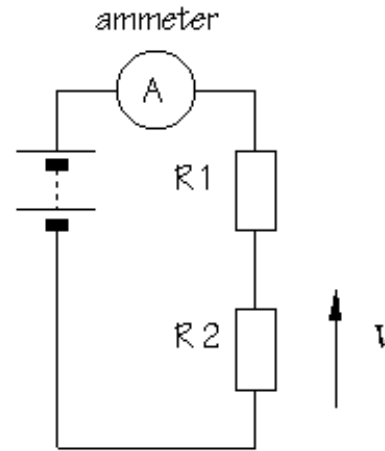
A meter is a measuring instrument. An **ammeter** measures current, a **voltmeter** measures the potential difference (voltage) between two points, and an **ohmmeter** measures resistance. A **multimeter** combines these functions, and possibly some additional ones as well, into a single instrument.

Before going in to detail about multimeters, 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:

A



B



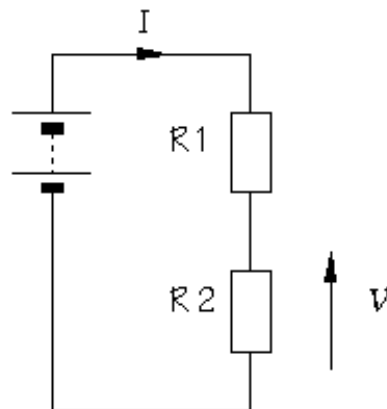
to measure current, the circuit must be broken to allow the ammeter to be connected in series

ammeters must have a LOW resistance

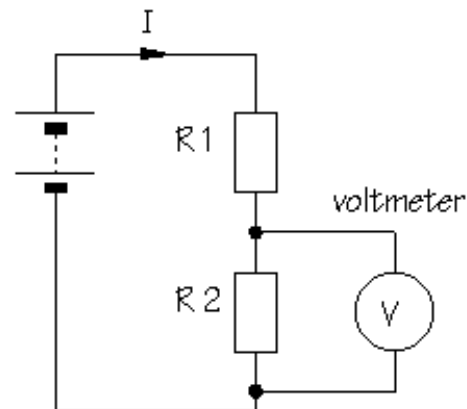
Think about the changes you would have to make to a practical circuit in order to include the ammeter. To start with, you need to *break the circuit* so that the ammeter can be connected in series. All the current flowing in the circuit must pass through the ammeter. Meters are not supposed to alter the behaviour 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:

A



C



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

voltmeters must have a HIGH resistance

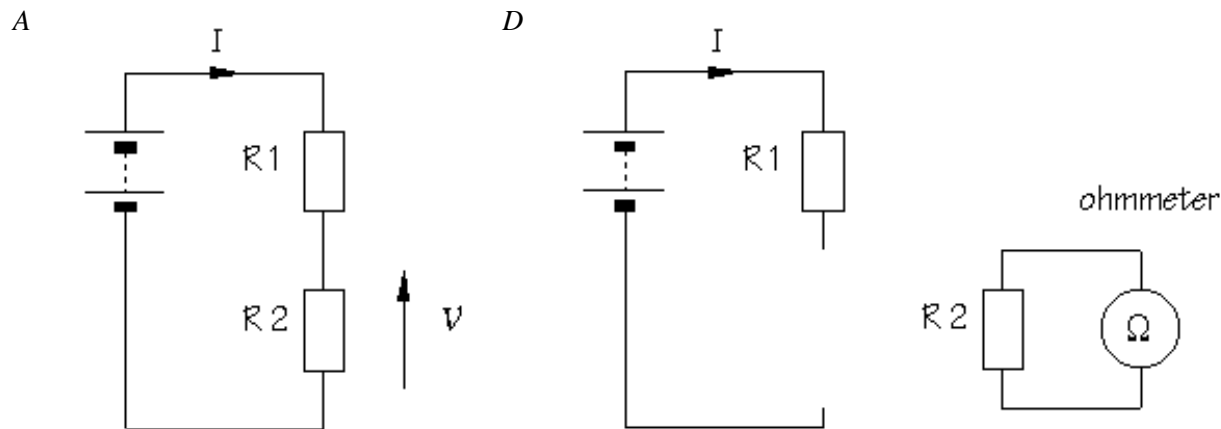
This time, you do not need to break the circuit. The voltmeter is connected in parallel between the two points where the measurement is to be made. Since the voltmeter provides a parallel pathway, it should take as little current as possible.

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 multimeters have a fuse to help protect against misuse.

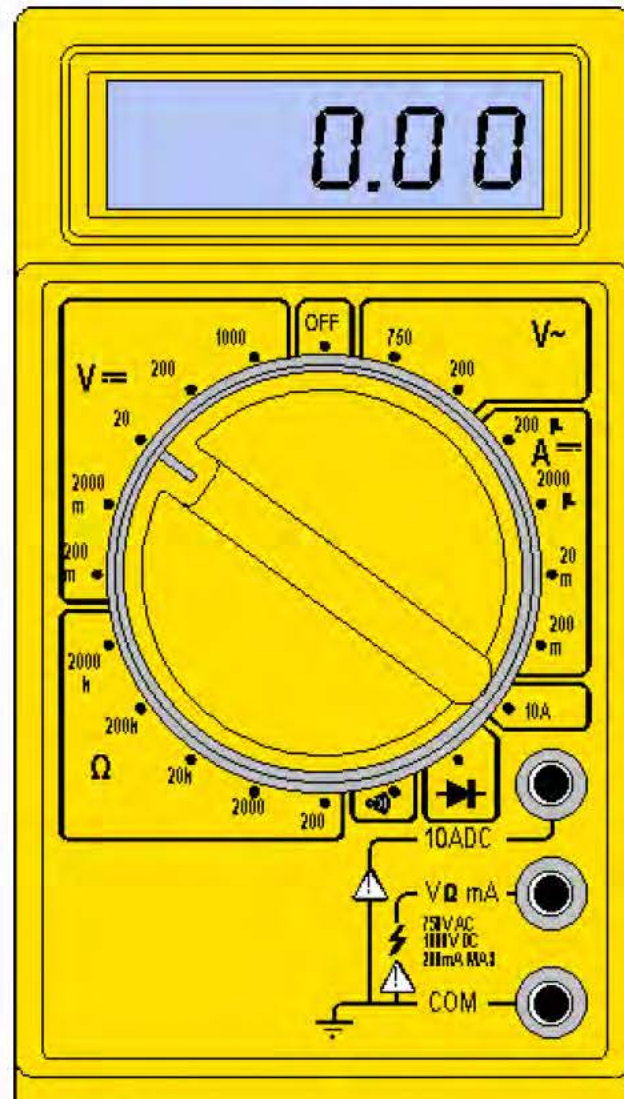


Up

Digital multimeters

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**:





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.

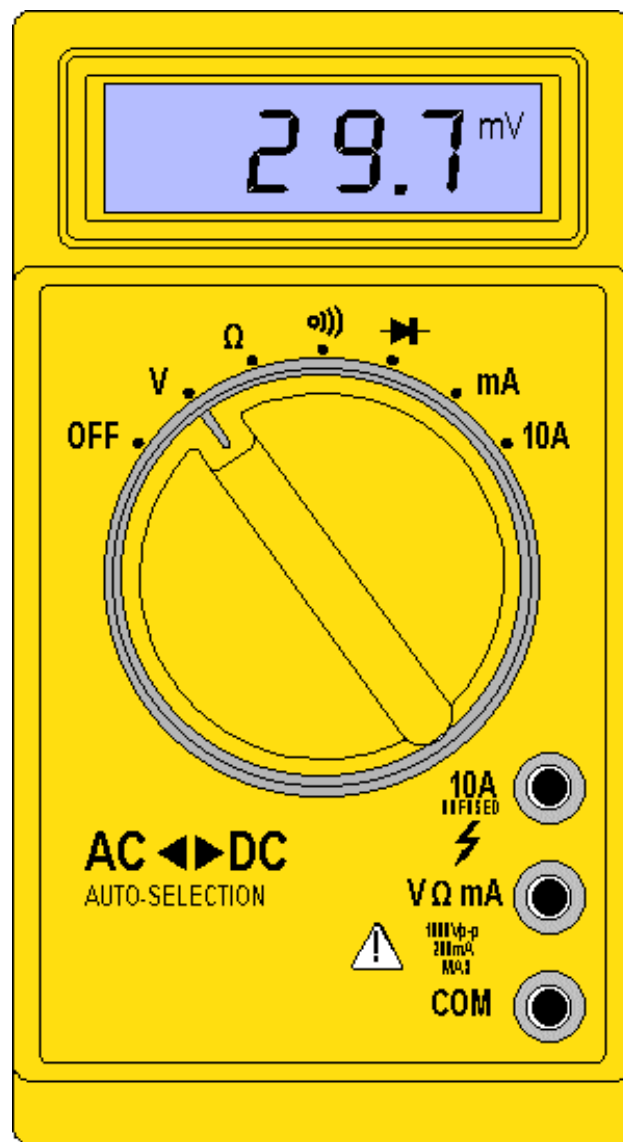
What does DC mean? DC means **direct current**. In any circuit which operates from a steady voltage source, such as a battery, current flow is always in the same direction. Every constructional project described in Design Electronics works in this way.

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.

An alternative style of multimeter is the **autoranging** multimeter:



Autoranging 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 labelled V Ω mA. The 10A socket is very rarely used.



Up

Analogue multimeters

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, $1\text{ M}\Omega$ or $10\text{ M}\Omega$, compared to $200\text{ k}\Omega$ for an 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 $50\text{ }\mu\text{A}$. More expensive digital multimeters can equal or better this performance.

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

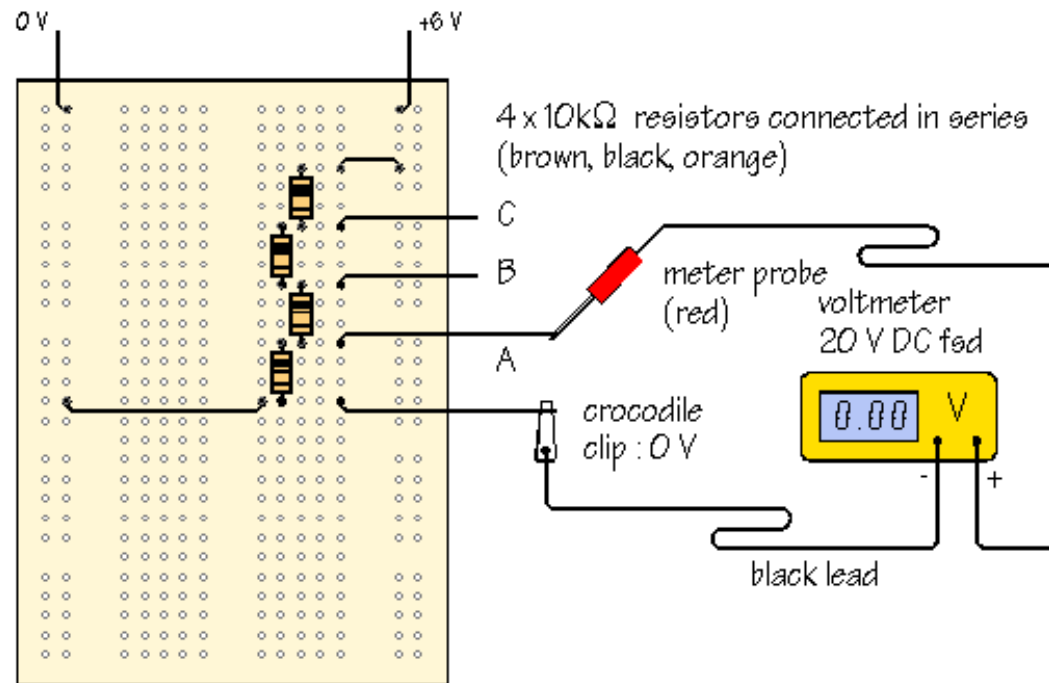


Up

Making measurements

1. *Voltage measurements:*

Build the circuit shown below using prototype board and four $10\text{ k}\Omega$ resistors:



Using the multimeter as a voltmeter, measure the power supply voltage and then measure the voltages at points A, B and C.

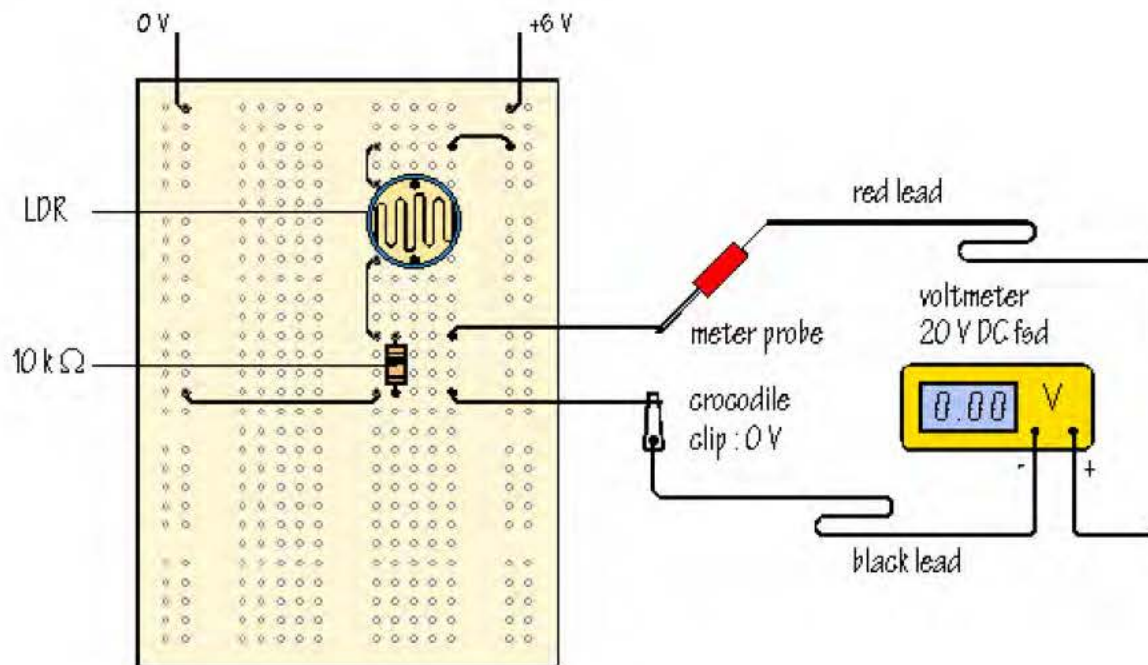
What do you notice about your results?



The four resistors are connected in series, making a chain known as a **potential divider**, or **voltage divider**. The total voltage is shared between the four resistors and, allowing for tolerance, each resistor receives an equal share. (You will find out a lot more about potential dividers in the next Chapter.)

Modify the circuit, replacing one or more of the $10\text{k}\Omega$ resistors with $1\text{k}\Omega$ or $100\text{k}\Omega$ values. Are the results as you expect?

The diagram below shows a **light sensor** circuit built in a similar way:



▲ *Up to previous stage*

The circuit uses an **LDR**, or **light dependent resistor**. The resistance of the LDR changes with illumination. In the dark, the resistance is high, up to $1\text{ M}\Omega$ or more. When light shines on the LDR, the light energy increases the number of charge carriers available to transfer current, and the resistance falls. In bright light, the resistance can be as little as $100\ \Omega$.

What happens to the output voltage of the light sensor circuit when you cover the LDR with you hand?

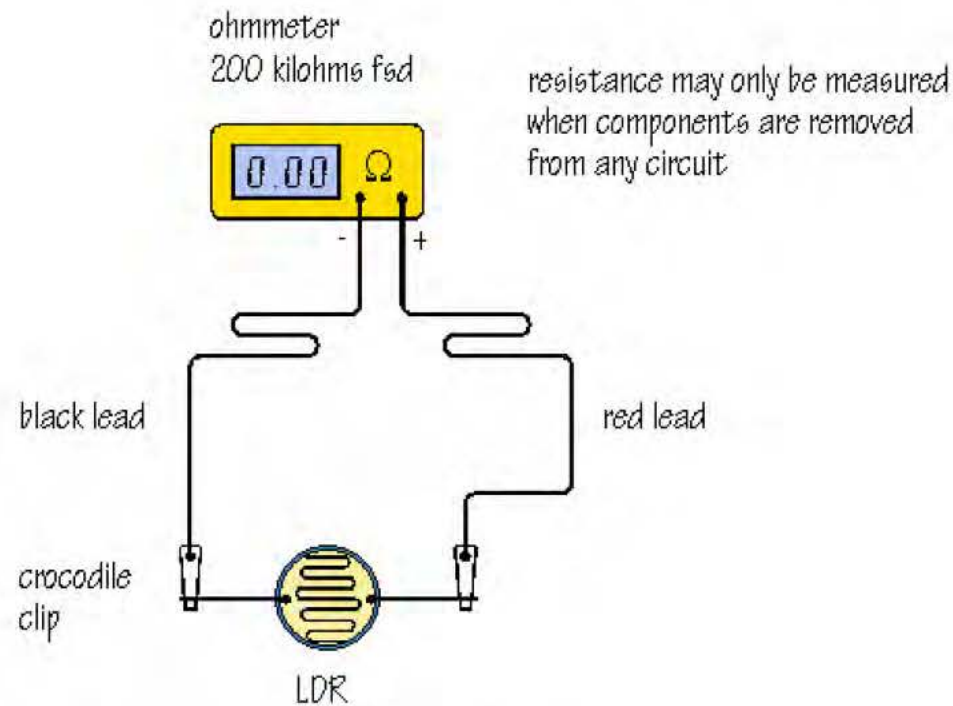


Is the output voltage HIGH or LOW in the dark?



2. Resistance measurements:

Remove the LDR from the circuit and measure its resistance, as follows:



▲ *Up to previous stage*

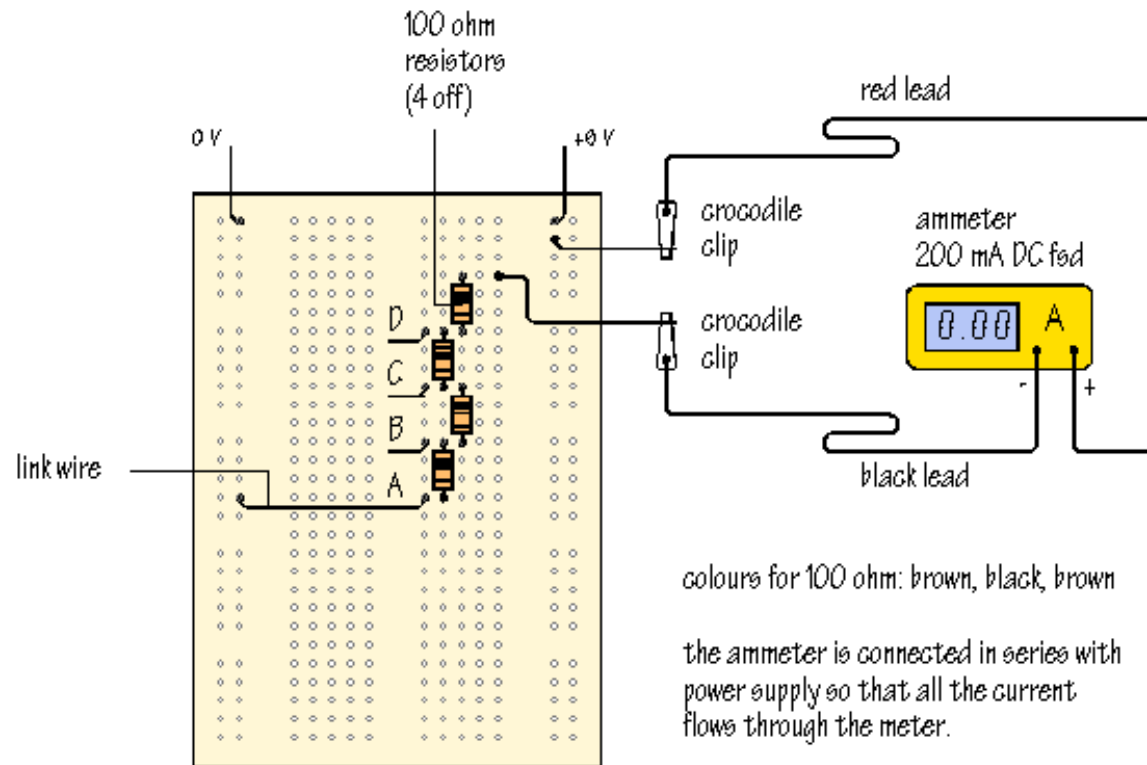
To get the multimeter to function as an ohmmeter, you will need to select a resistance range. With a switched range meter, the 200 k position is usually suitable. You will see the resistance measurement change as the light level changes. Covering the LDR with your hand increases the resistance of the LDR.

If the meter reads } this means that the resistance is more than the maximum which can be measured on this range and you may need to switch to a new position, 2000 k, to take a reading. (How many megohms is 2000 k?)

You can check the value of any fixed value resistor in the same way, and confirm that you have worked out the color code correctly. Don't forget that the [colour code convertor](#) program is available to help you.

3. Current measurements:

The diagram below shows a prototype board set up for the measurement of current:



Using a Multimeter

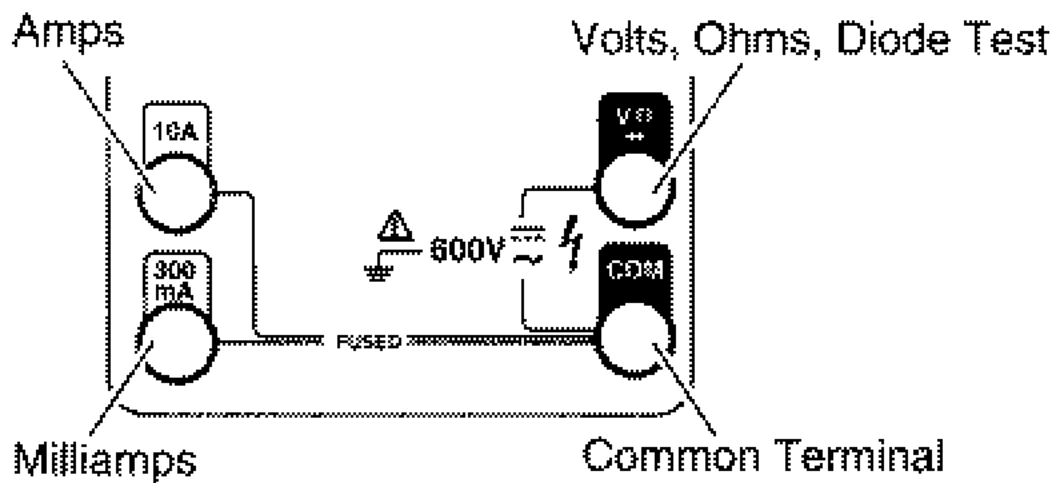
A multimeter is used to make various electrical measurements, such as AC and DC voltage, AC and DC current, and resistance. It is called a *multimeter* because it combines the functions of a voltmeter, ammeter, and ohmmeter. Multimeters may also have other functions, such as diode and continuity tests. The descriptions and pictures that follow are specific to the Fluke 73 Series III Multimeter, but other multimeters are similar.

Important note: The most common mistake when using a multimeter is not switching the test leads when switching between current sensing and any other type of sensing (voltage, resistance). It is critical that the test leads be in the proper jacks for the measurement you are making.

Safety Information

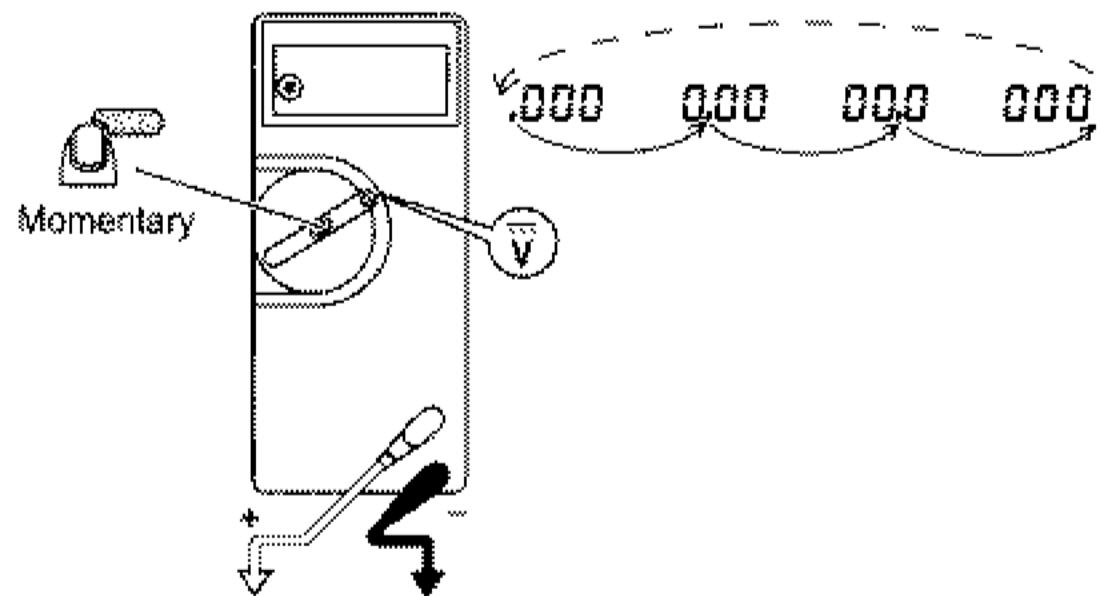
- Be sure the test leads and rotary switch are in the correct position for the desired measurement.
- Never use the meter if the meter or the test leads look damaged.
- Never measure resistance in a circuit when power is applied.
- Never touch the probes to a voltage source when a test lead is plugged into the 10 A or 300 mA input jack.
- To avoid damage or injury, never use the meter on circuits that exceed 4800 watts.
- Never apply more than the rated voltage between any input jack and earth ground (600 V for the Fluke 73).
- Be careful when working with voltages above 60 V DC or 30 V AC rms. Such voltages pose a shock hazard.
- Keep your fingers behind the finger guards on the test probes when making measurements.
- To avoid false readings, which could lead to possible electric shock or personal injury, replace the battery as soon as the battery indicator appears.

Input Jacks



The black lead is always plugged into the common terminal. The red lead is plugged into the 10 A jack when measuring currents greater than 300 mA, the 300 mA jack when measuring currents less than 300 mA, and the remaining jack (V-ohms-diode) for all other measurements.

Range



The meter defaults to autorange when first turned on. You can choose a manual range in V AC, V DC, A AC, and A DC by pressing the button in the middle of the rotary dial. To return to autorange, press the button for one second.

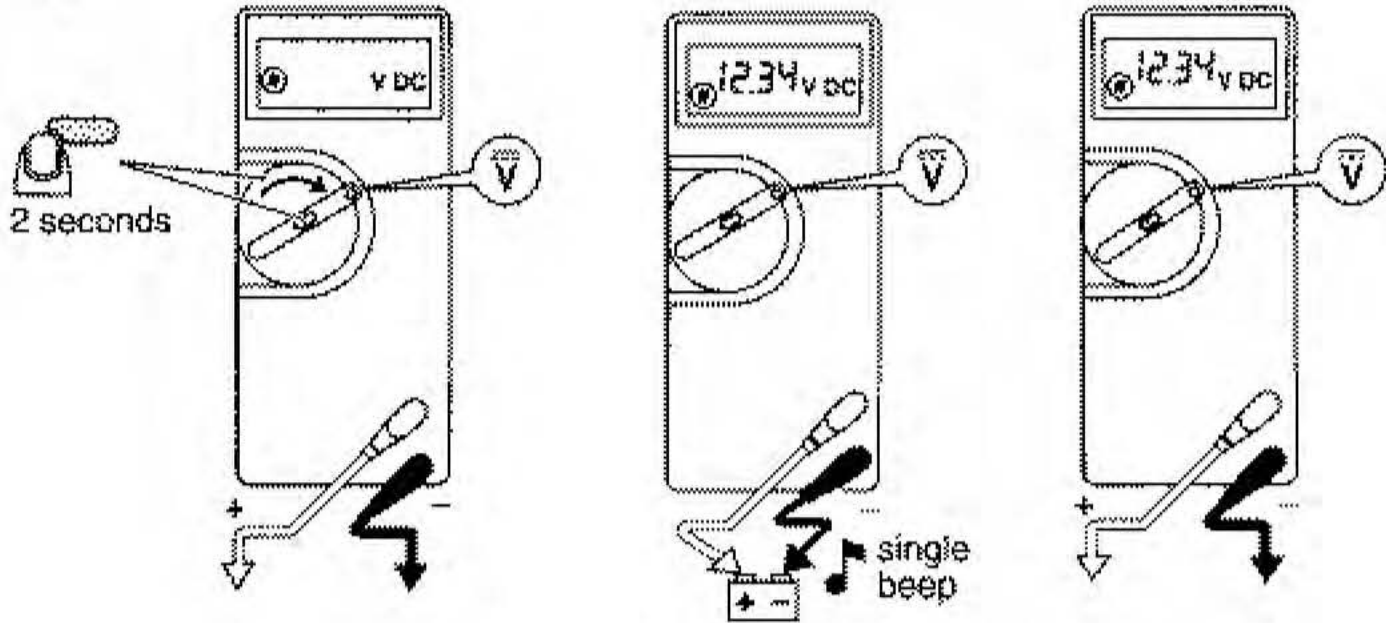
Automatic Touch Hold Mode

The Touch Hold mode automatically captures and displays stable readings. Press the button in the center of the dial for 2 seconds while turning the meter on. When the meter captures a new input, it beeps and a new reading is displayed. To manually force a new measurement to be held, press the center button. To

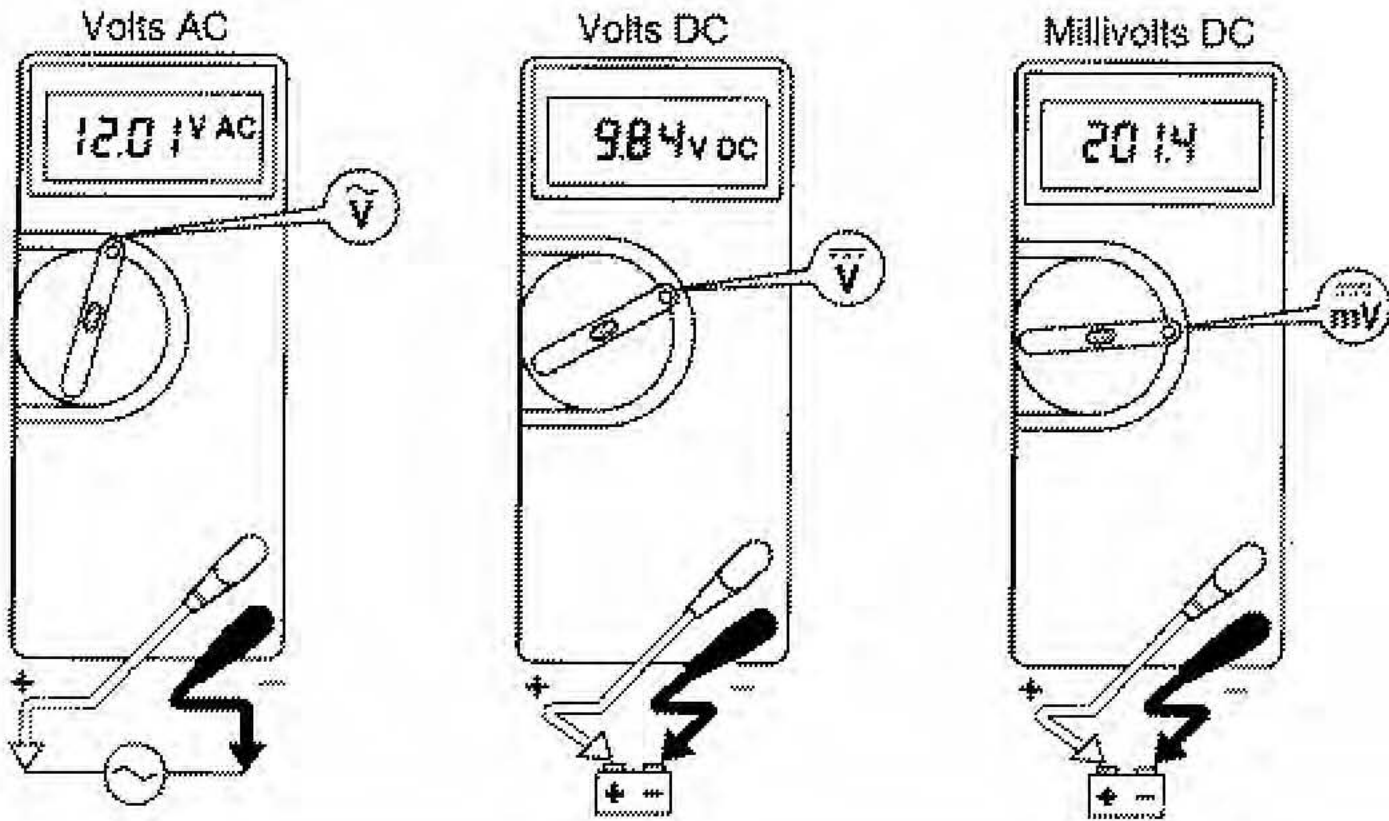
exit the Touch Hold mode, turn the meter off.

Note: stray voltages can produce a new reading.

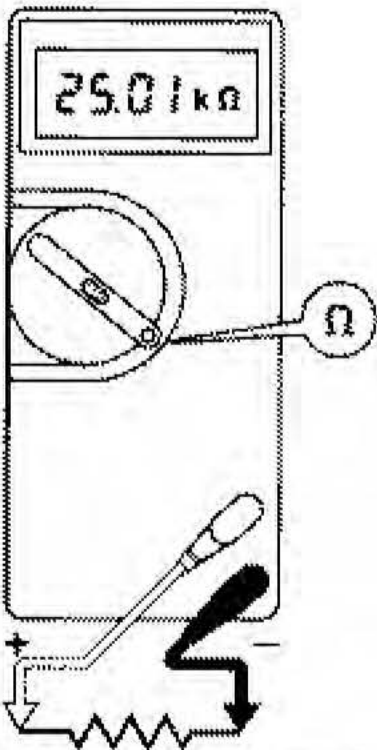
Warning: To avoid electric shock, do not use the Touch Hold to determine if a circuit with high voltage is dead. The Touch Hold mode will not capture unstable or noisy readings.



AC and DC Voltage

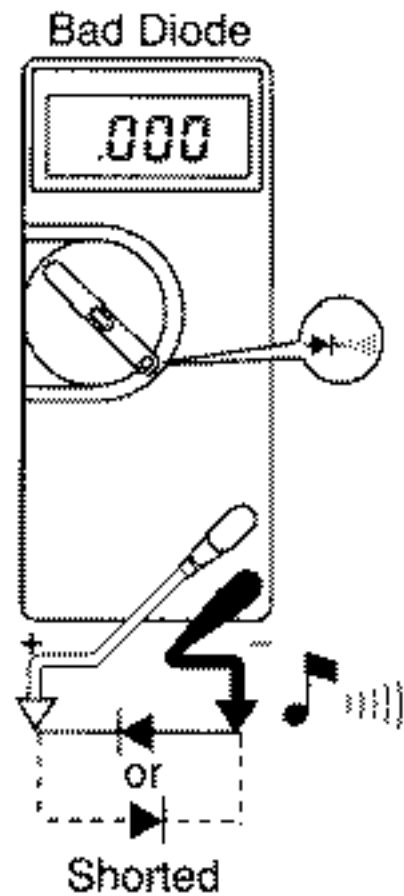
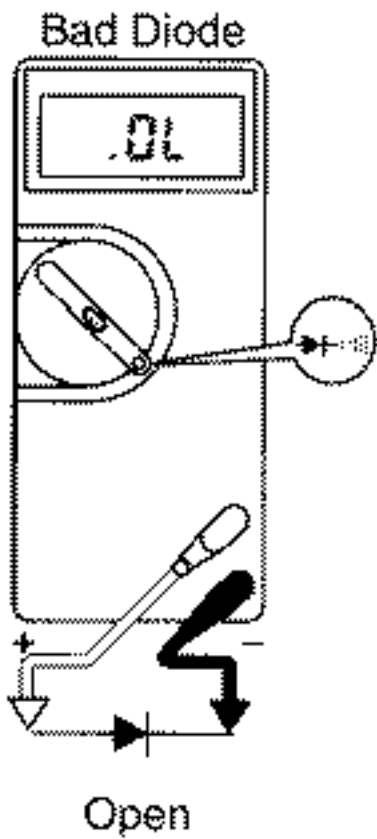
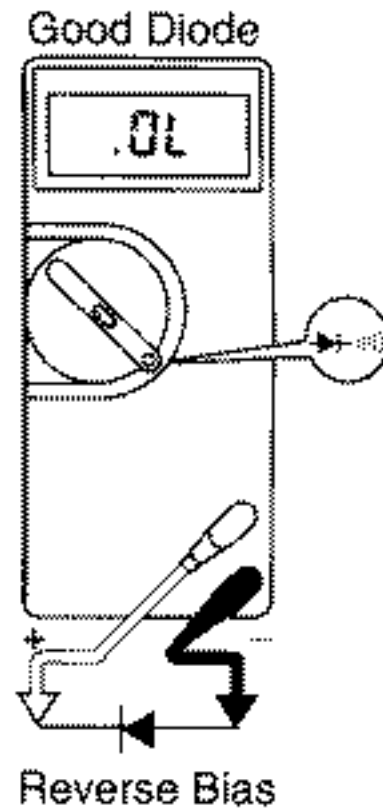
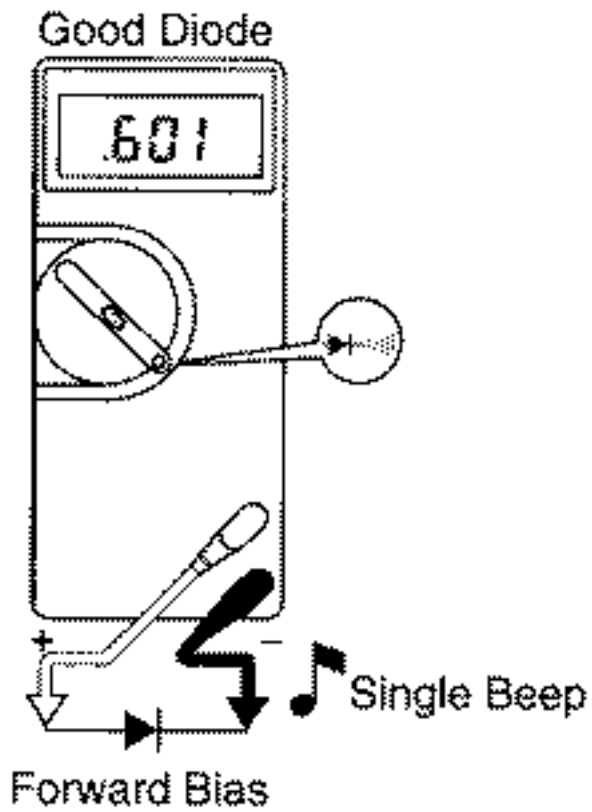


Resistance

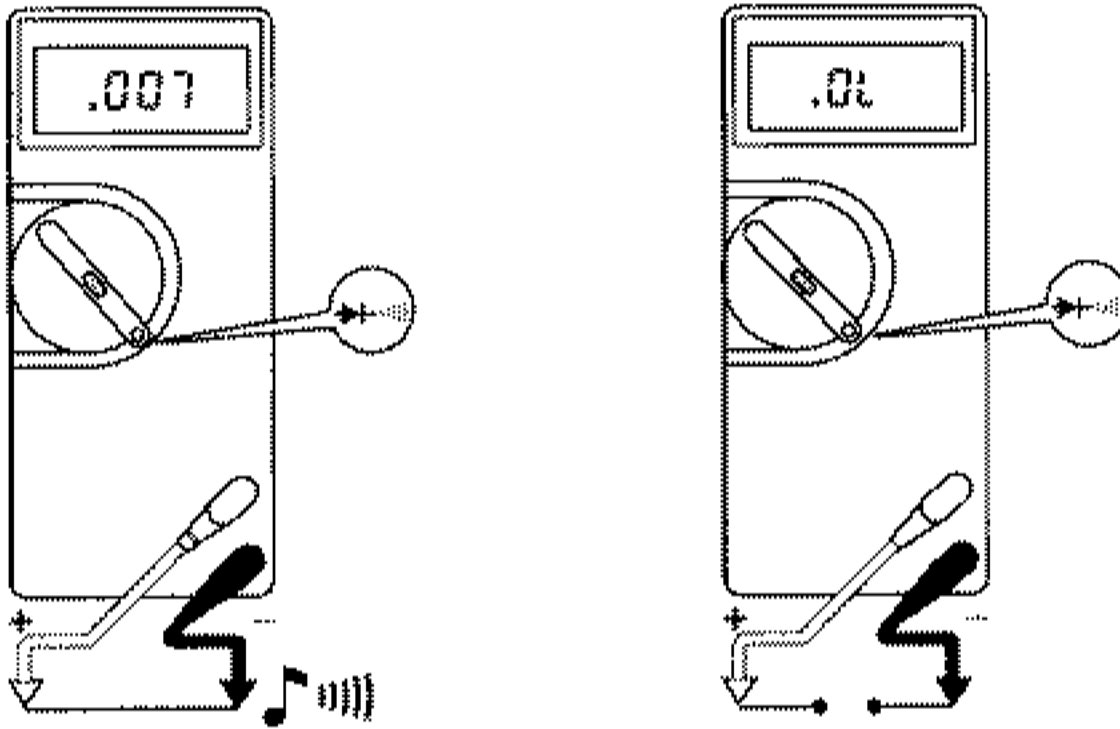


Turn off the power and discharge all capacitors. An external voltage across a component will give invalid resistance readings.

Diode Test



Continuity Test



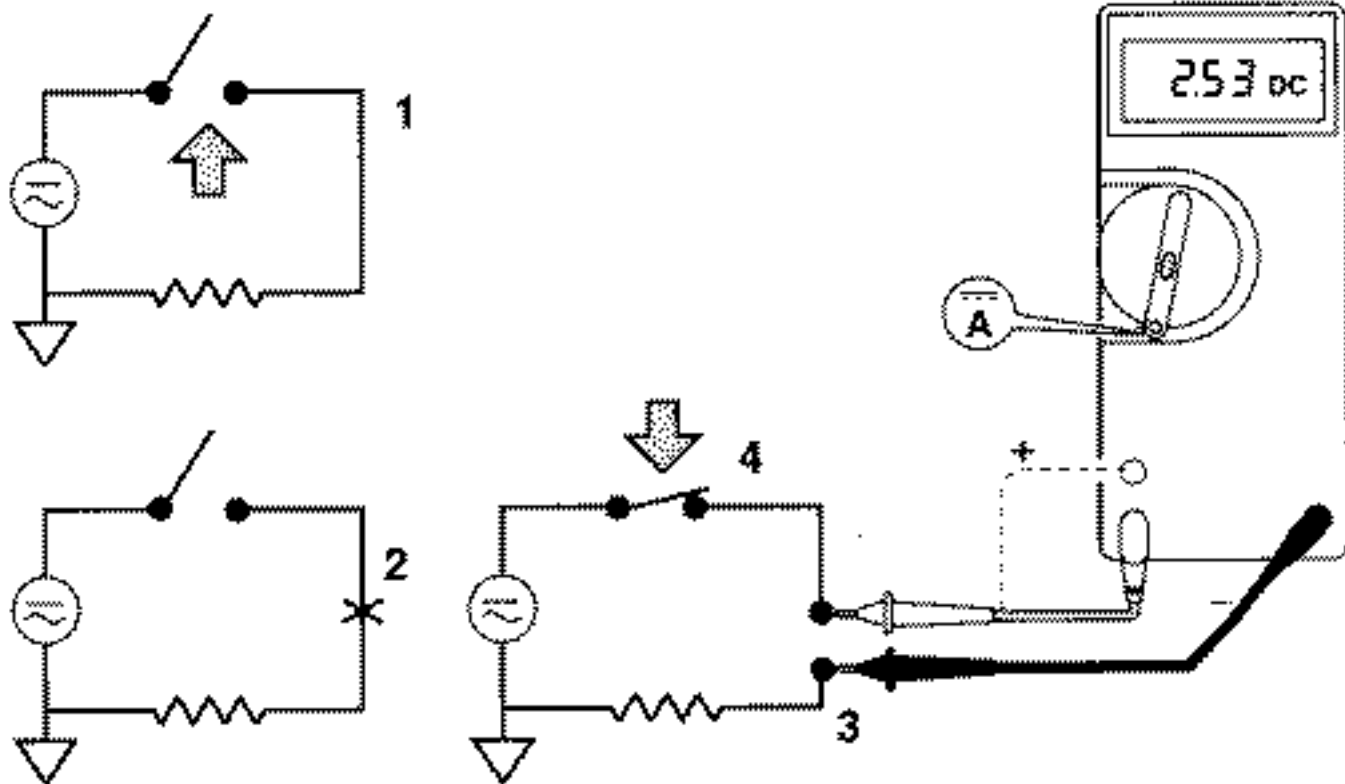
This mode is used to check if two points are electrically connected. It is often used to verify connectors. If continuity exists (resistance less than 210 ohms), the beeper sounds continuously. The meter beeps twice if it is in the Touch Hold mode.

Current

Warning: To avoid injury, do not attempt a current measurement if the open circuit voltage is above the rated voltage of the meter.

To avoid blowing an input fuse, use the 10 A jack until you are sure that the current is less than 300 mA.

Turn off power to the circuit. Break the circuit. (For circuits of more than 10 amps, use a current clamp.) Put the meter in series with the circuit as shown and turn power on.



http://www.allaboutcircuits.com/vol_6/chpt_2/1.html

PARTS AND MATERIALS

- Multimeter, digital or analog
- Assorted batteries
- One light-emitting diode (Radio Shack catalog # 276-026 or equivalent)
- Small "hobby" motor, permanent-magnet type (Radio Shack catalog # 273-223 or equivalent)
- Two jumper wires with "alligator clip" ends (Radio Shack catalog # 278-1156, 278-1157, or equivalent)

A *multimeter* is an electrical instrument capable of measuring voltage, current, and resistance. *Digital* multimeters have numerical displays, like digital clocks, for indicating the quantity of voltage, current, or resistance. *Analog* multimeters indicate these quantities by means of a moving pointer over a printed scale.

Analog multimeters tend to be less expensive than digital multimeters, and more beneficial as learning tools for the first-time student of electricity. I strongly recommend purchasing an analog multimeter before purchasing a digital multimeter, but to eventually have both in your tool kit for these experiments.

CROSS-REFERENCES

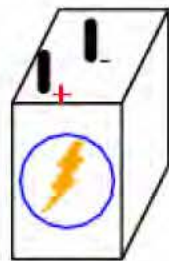
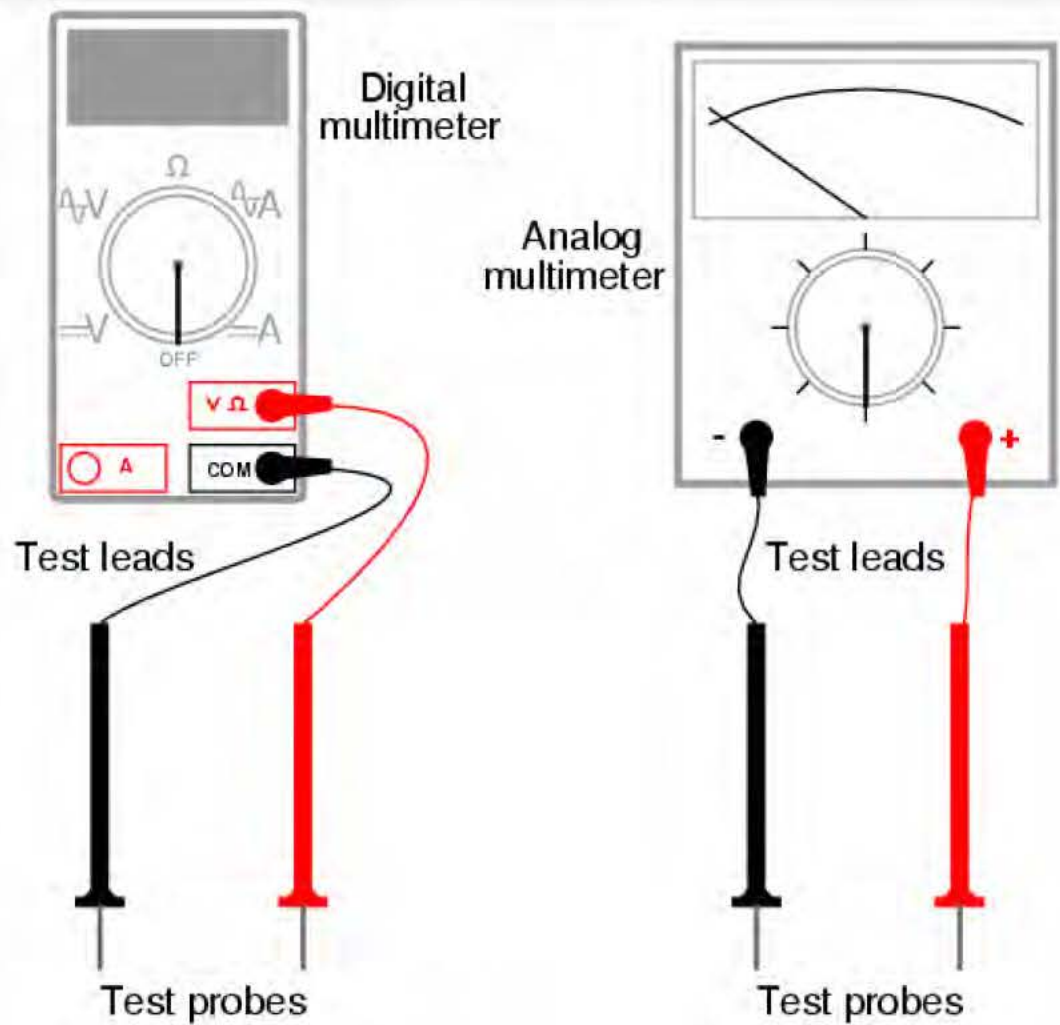
Lessons In Electric Circuits, Volume 1, chapter 1: "Basic Concepts of Electricity"

Lessons In Electric Circuits, Volume 1, chapter 8: "DC Metering Circuits"

LEARNING OBJECTIVES

- How to measure voltage
- Characteristics of voltage: existing *between two points*
- Selection of proper meter range

ILLUSTRATION



6-volt "lantern" battery



Light-emitting diode ("LED")



1.5-volt "D-cell" battery



Permanent-magnet motor

INSTRUCTIONS

In all the experiments in this book, you will be using some sort of test equipment to measure aspects of electricity you cannot directly see, feel, hear, taste, or smell. Electricity -- at least in small, safe quantities -- is insensible by our human bodies. Your most fundamental "eyes" in the world of electricity and electronics will be a device called a *multimeter*. Multimeters indicate the presence of, and measure the quantity of, electrical properties such as *voltage*, *current*, and *resistance*. In this experiment, you will familiarize yourself with the measurement of voltage.

Voltage is the measure of electrical "push" ready to motivate electrons to move through a conductor. In scientific terms, it is the specific energy per unit charge, mathematically defined as joules per coulomb. It is analogous to *pressure* in a fluid system: the force that moves fluid through a pipe, and is measured in the unit of the Volt (V).

Your multimeter should come with some basic instructions. Read them well! If your multimeter is digital, it will require a small battery to operate. If it is analog, it does not need a battery to measure voltage.

Some digital multimeters are *autoranging*. An autoranging meter has only a few selector switch (dial) positions. Manual-ranging meters have several different selector positions for each basic quantity: several for voltage, several for current, and several for resistance. Autoranging is usually found on only the more expensive digital meters, and is to manual ranging as an automatic transmission is to a manual transmission in a car. An autoranging meter "shifts gears" automatically to find the best measurement range to display the particular quantity being measured.

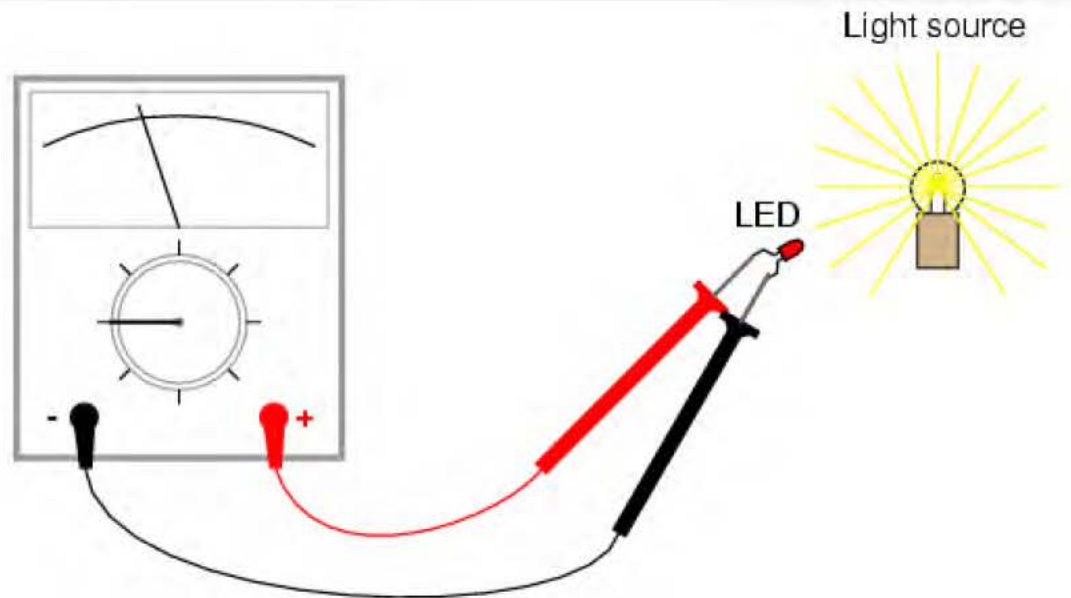
Set your multimeter's selector switch to the highest-value "DC volt" position available. Autoranging multimeters may only have a single position for DC voltage, in which case you need to set the switch to that one position. Touch the red test probe to the positive (+) side of a battery, and the black test probe to the negative (-) side of the same battery. The meter should now provide you with some sort of indication. Reverse the test probe connections to the battery if the meter's indication is negative (on an analog meter, a negative value is indicated by the pointer deflecting left instead of right).

If your meter is a manual-range type, and the selector switch has been set to a high-range position, the indication will be small. Move the selector switch to the next lower DC voltage range setting and reconnect to the battery. The indication should be stronger now, as indicated by a greater deflection of the analog meter pointer (*needle*), or more active digits on the digital meter display. For the best results, move the selector switch to the lowest-range setting that does not "over-range" the meter. An over-ranged analog meter is said to be "pegged," as the needle will be forced all the way to the right-hand side of the scale, past the full-range scale value. An over-ranged digital meter sometimes displays the letters "OL", or a series of dashed lines. This indication is manufacturer-specific.

What happens if you only touch one meter test probe to one end of a battery? How does the meter have to connect to the battery in order to provide an indication? What does this tell us about voltmeter use and the nature of voltage? Is there such a thing as voltage "at" a single point?

Be sure to measure more than one size of battery, and learn how to select the best voltage range on the multimeter to give you maximum indication without over-ranging.

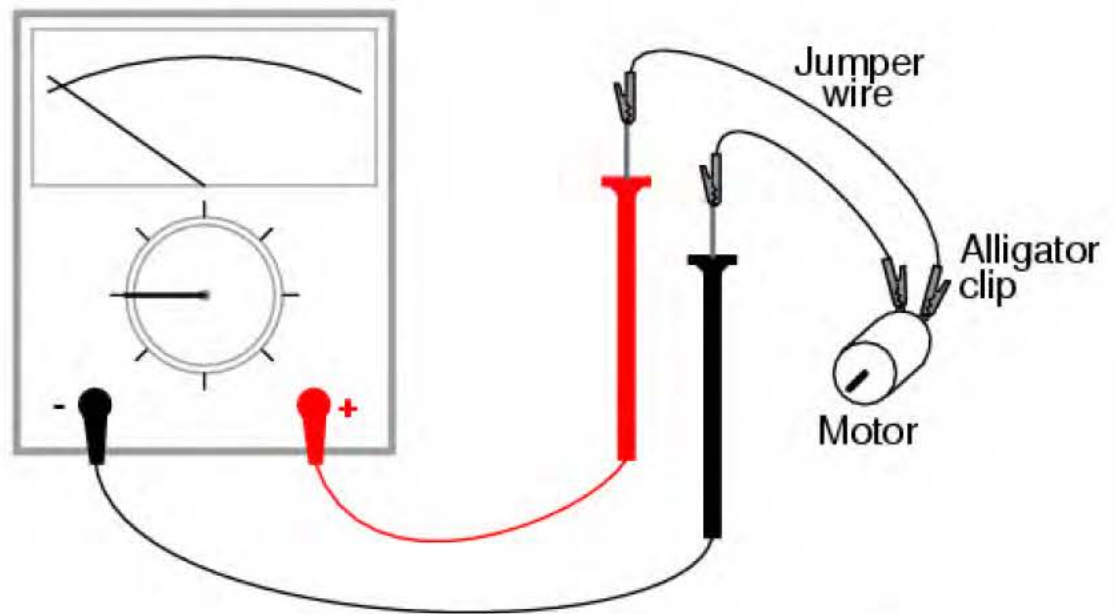
Now switch your multimeter to the lowest DC voltage range available, and touch the meter's test probes to the terminals (wire leads) of the light-emitting diode (LED). An LED is designed to produce light when powered by a small amount of electricity, but LEDs also happen to *generate* DC voltage when exposed to light, somewhat like a solar cell. Point the LED toward a bright source of light with your multimeter connected to it, and note the meter's indication:



Batteries develop electrical voltage through chemical reactions. When a battery "dies," it has exhausted its original store of chemical "fuel." The LED, however, does not rely on an internal "fuel" to generate voltage; rather, it *converts* optical energy into electrical energy. So long as there is light to illuminate the LED, it will produce voltage.

Another source of voltage through energy conversion is a *generator*. The small electric motor specified in the "Parts and Materials" list functions as an electrical generator if its shaft is turned by a mechanical force. Connect your voltmeter (your multimeter, set to the "volt" function) to the motor's terminals just as you connected it to the LED's terminals, and spin the shaft with your fingers. The meter should indicate voltage by means of needle deflection (analog) or numerical readout (digital).

If you find it difficult to maintain both meter test probes in connection with the motor's terminals while simultaneously spinning the shaft with your fingers, you may use *alligator clip* "jumper" wires like this:



Determine the relationship between voltage and generator shaft speed? Reverse the generator's direction of rotation and note the change in meter indication. When you reverse shaft rotation, you change the *polarity* of the voltage created by the generator. The voltmeter indicates polarity by *direction* of needle direction (analog) or *sign* of numerical indication (digital). When the red test lead is positive (+) and the black test lead negative (-), the meter will register voltage in the normal direction. If the applied voltage is of the reverse polarity (negative on red and positive on black), the meter will indicate "backwards."