Electronics and Electromagnetism

Lab 1: Introduction to basic Electronic devices and Electronic Components Part 1
(The Breadboard, Multimeter and Standard Circuit Components)

Purpose

The aim of this lab is to provide an overview on how to use a breadboard and basic electronic components to build a simple circuit and to be able to test and troubleshoot the design of circuit via Digital Multimeter***(DMM)***. At the end of this lab, you should be able to neatly demonstrate how to build simple circuit and make measurements or identify faults of a circuit using a multimeter!

Bread Board or Proto board

A breadboard is a device used to build a prototype of an electronic circuit. One of the advantages of the board is that soldering is not required hence the wire connections can be changed anytime, making it a perfect tool to build prototype circuits. Breadboards come in different sizes. A typical full-sized breadboard is shown in the figure below

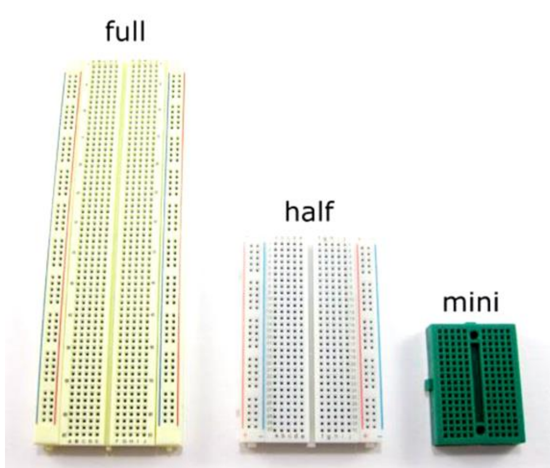


Figure 1: Different size Breadboards

If you look on the back of your breadboard, there is a yellow waxy paper covering some sticky foam. If you were to peel back that foam, you would see dozens of these metal rows.

(it is not advisable to do this as you should keep the yellow paper on your breadboard, we will sacrifice this one for some photos! *For the sake of **SCIENCE*** 😋)

If you pulled the metal parts out with pliers (again, do not do this yourself!) you would see each one is a metal clip with little teeth (see Figure 2). The rows have 5 teeth - one for each hole on the top of the breadboard. These little teeth are great at gripping onto electronic parts. When a part is pushed into the breadboard, the clip pushes open and grabs onto the metal leg. Any other parts that are plugged into the other 4 teeth are thus electrically connected.

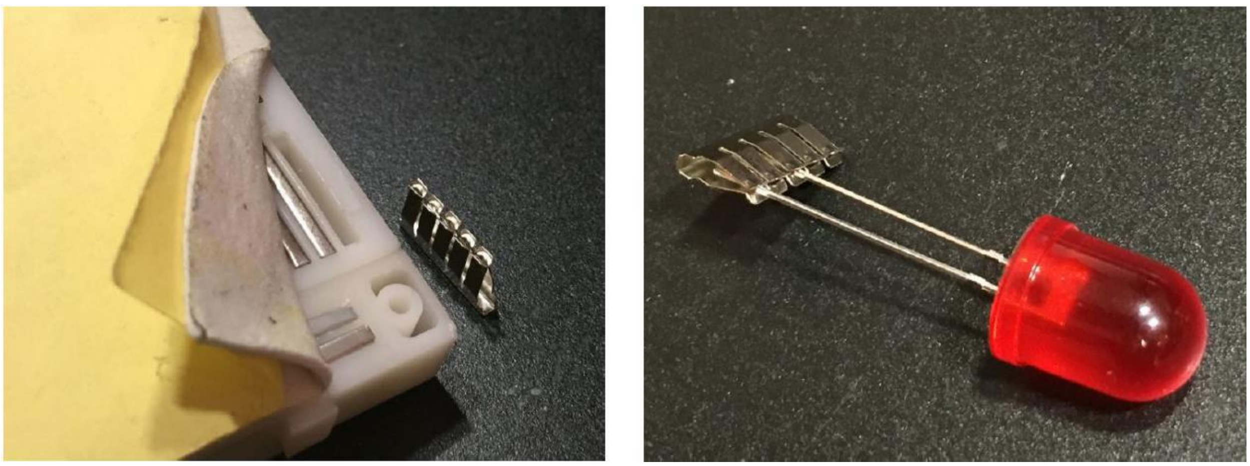
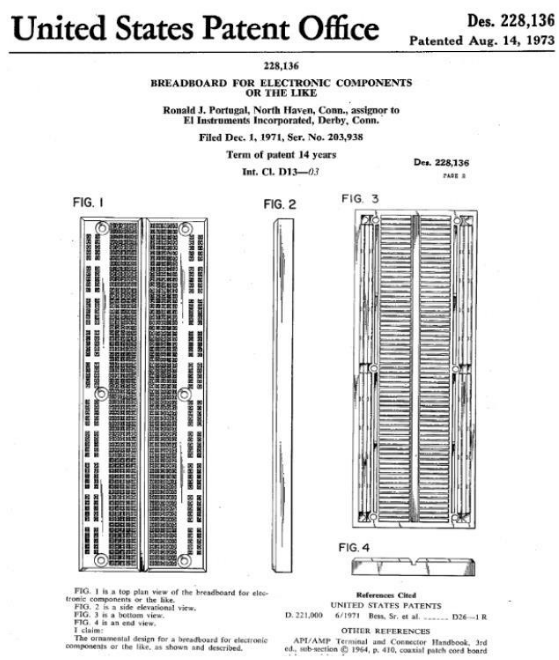


Figure 2 : Metal connections inside the breadboard

You are probably wondering how on earth a piece of plastic that fits in your hand relates to the large slab of wood used to bake or cut bread. A good question! It turns out that many years ago, for engineers working on electronics before 1970 did not know the thing we call a solderless breadboard. Instead, they would build electronics by literally hammering nails into a wooden board - sometimes it was also literally a bread board but usually just a plank purchased from a hardware store.

Figure 3: The REAL "Breadboard"

And then in the early 1970's an awesome thing occurred. **Ronald J Portugal** came up with this brilliant invention, ***"The BREADBOARD FOR ELECTRONIC COMPONENTS OR THE LIKE"***. It was patented 2 years later, and quickly called the "solder-less" Breadboard because no soldering is required to use it, and then shortened to plain Breadboard since nobody uses a "solder-full" breadboard. And that is how the breadboard got its name!



United States Patent Office

Des. 228,136
Patented Aug. 14, 1973

228,136

BREADBOARD FOR ELECTRONIC COMPONENTS OR THE LIKE

Ronald J. Portugal, North Haven, Conn., assignor to El Instruments Incorporated, Derby, Conn.

Filed Dec. 1, 1971, Ser. No. 203,938

Term of patent 14 years

Int. Cl. D13—03

Des. 228,136
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FIG. 1 FIG. 2 FIG. 3 FIG. 4

FIG. 1 is a top plan view of the breadboard for electronic components or the like.
FIG. 2 is a side elevational view.
FIG. 3 is a bottom view.
FIG. 4 is an end view.
I claim:
The ornamental design for a breadboard for electronic components or the like, as shown and described.

References Cited
UNITED STATES PATENTS
D. 221,000 6/1971 Bess, Sr. et al. .... D26—1 R
OTHER REFERENCES
API/AMP Terminal and Connector Handbook, 3rd ed., sub-section © 1964, p. 410, coaxial patch cord board

Figure 4: U.S Patent for the breadboard

Just about every breadboard is made of three sections: Two sets of very long power rails and the large middle section that is full of those 5-hole-long terminal strips. You put the components (buttons, LEDs, resistors, integrated circuits, etc.) in the middle section, with each pin connected to the rows terminal strip.

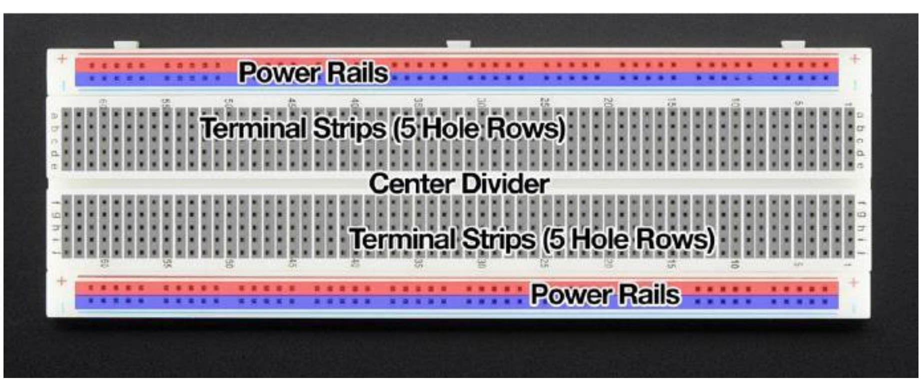
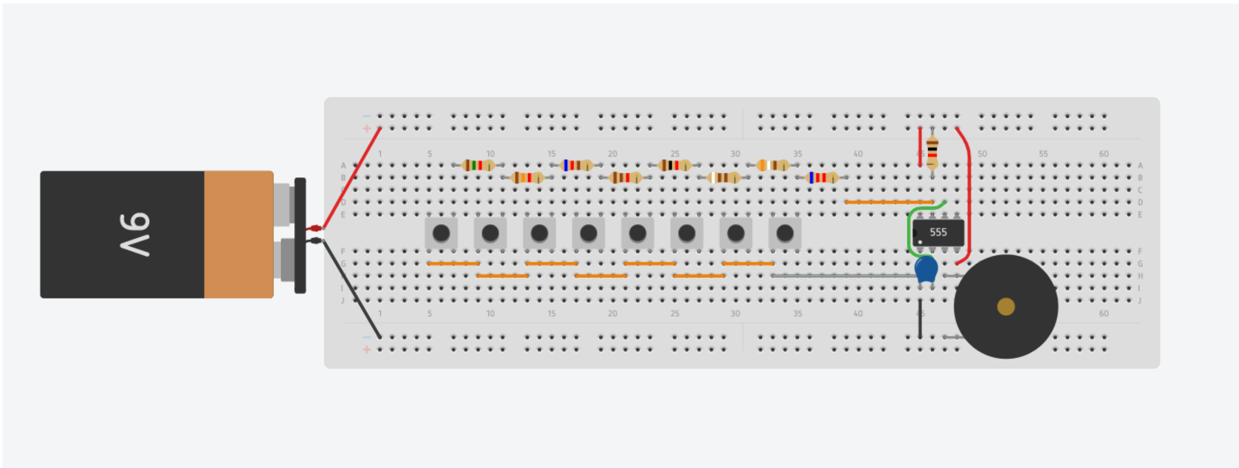


Figure 5: Breadboard connections

Fun Exercise – Let us build a Simple Circuit – Click me

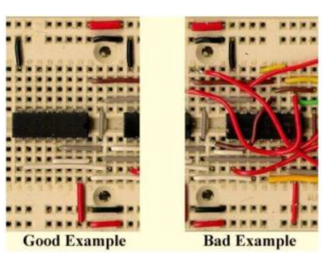


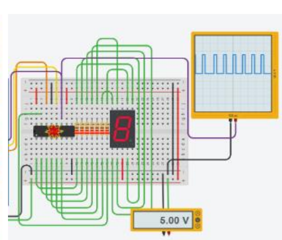
Components

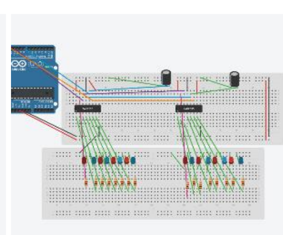
1. 555(NE 555) Timer IC – 1
2. Speaker – 1
3. 100nf Capacitor – 1
4. Push Buttons – 7
5. Resistor 6.2KΩ -1
6. Resistor 1.5KΩ -1
7. Resistor 1.3KΩ -1
8. Resistor 1.1KΩ -1
9. Resistor 1KΩ -2
10. Resistor 910Ω -1
11. Resistor 620Ω -1
12. Resistor 390Ω -1
13. 9V Battery

Hint – *Find out the pin configuration of 555 IC using the DATA sheet*

For your reference







DC Power Supplies and Batteries

A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load. As a result, power supplies are sometimes referred to as electric power converters. DC power supplies use AC mains electricity as an energy source.

Such power supplies will employ a transformer to convert the input voltage to a higher or lower AC voltage. A rectifier is used to convert the transformer output voltage to a varying DC voltage, which in turn is passed through an electronic filter to convert it to an unregulated DC voltage.

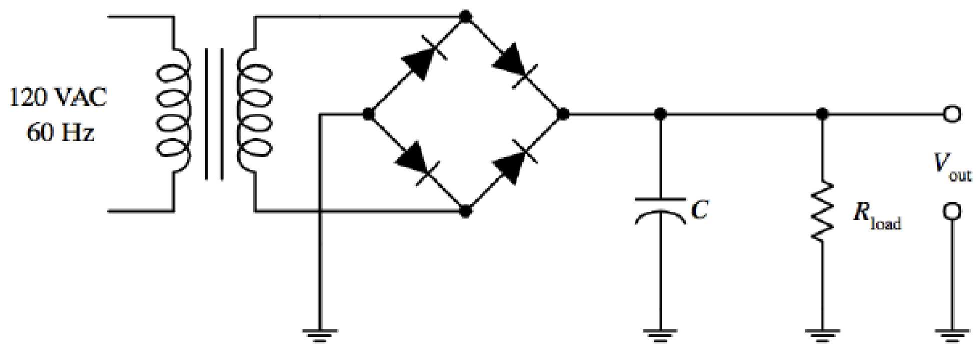


Figure 9: Schematic of an AC to DC power conversion

The provided ***Mastech DC Power Supply HY3005F-3*** is a regulated linear DC power supply with triple outputs:

- two outputs are continuously adjustable at 0-30V DC and 0-5A,
- third output is fixed at 5V DC and 3A.

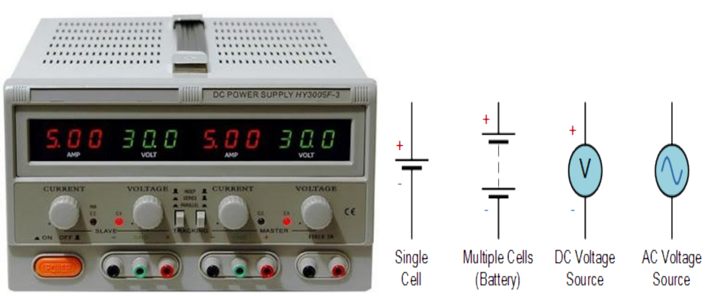


Figure 10: Mastech DC Power Supply HY3005F-3

What is more, the two outputs can be used either in **independent**, series or **parallel mode**, providing either **two independent outputs**, or **one output with twice the voltage** or **twice the current output**, up to 60V or 10A.

The unit comes with 4 color LED displays, providing accurate and clearly visible readout for the voltage and current value.

To set the output voltage of one of the channels,

- Turn the corresponding 'VOLTAGE' knob and watch the voltage readout until it settles on the desired voltage.
- You also need to set the maximum current by increasing the 'CURRENT' knob.

Note : *If too much demand is placed on the power supply, and you attempt to draw more current than what is set by the current limit knob, the supply enters constant current mode, and the CC indicator LED will come on. The current limit feature is useful if you need to prevent a load from being supplied with too much current.*

Do you know how DC batteries work? ?? Let us Find out (Homework)

Resistors

A resistor is a two-terminal **electrical component that creates an electrical potential difference across its terminals that is proportional to the current passing through it**. The ratio of potential difference (also called voltage) to current is known as its electrical resistance (or simply resistance). In SI units, the resistance is measured in ohms (O).

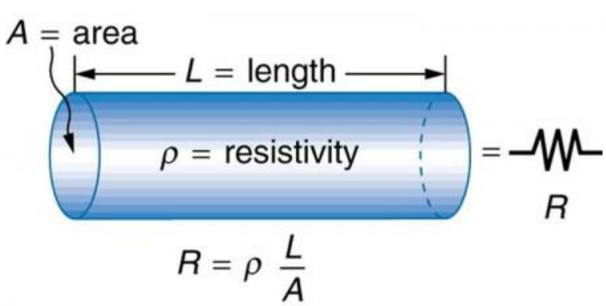


Figure 11: Resistivity

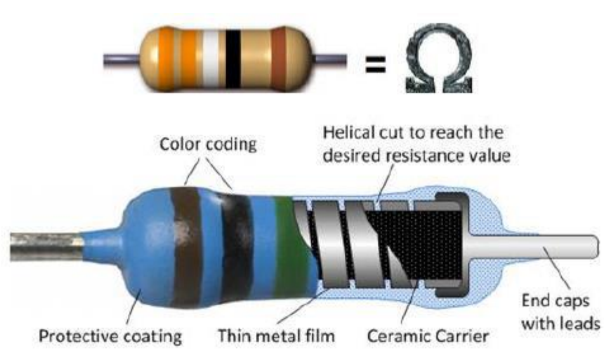
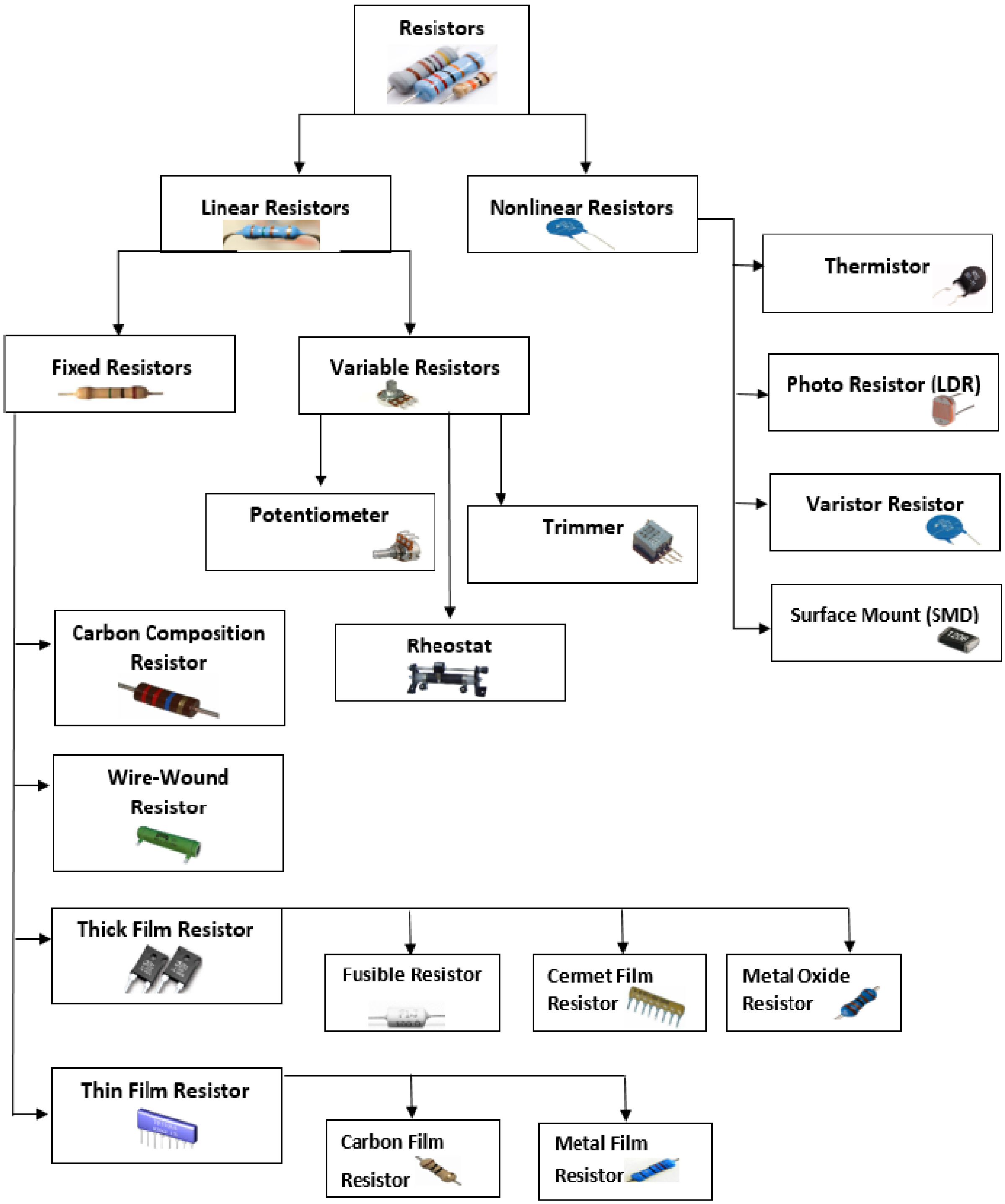


Figure 12: Cross section of a metal oxide Resistor

Classification of Resistors



Ohm's Law of Voltage, Current, and Resistance

Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points.

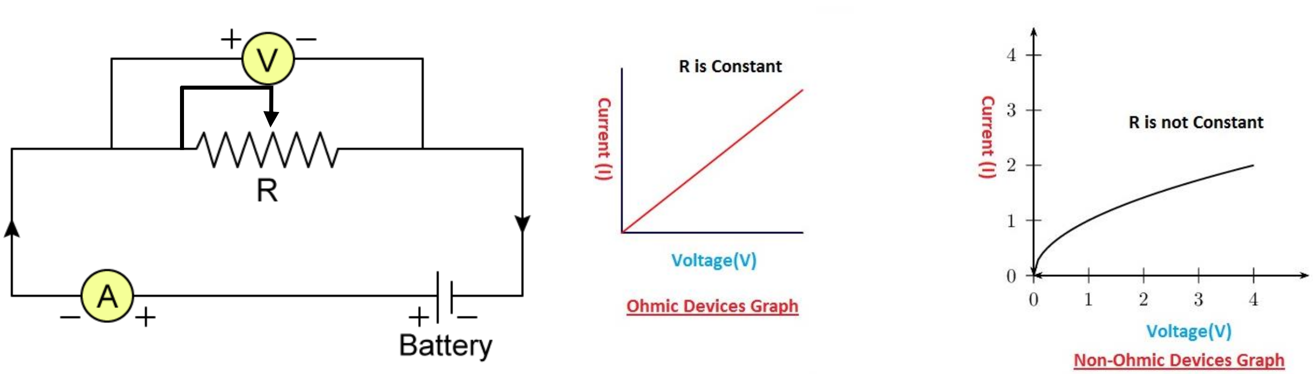


Figure 13: Ohm's Law experimental setup and Results

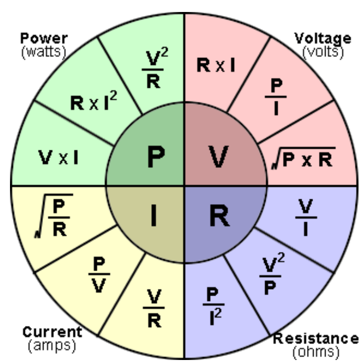
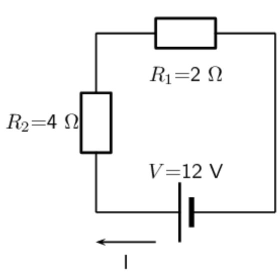
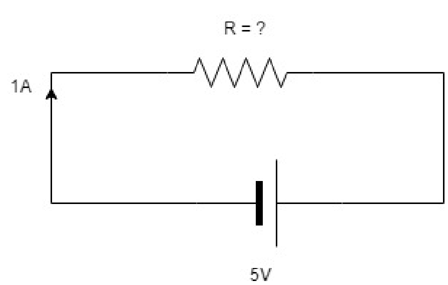
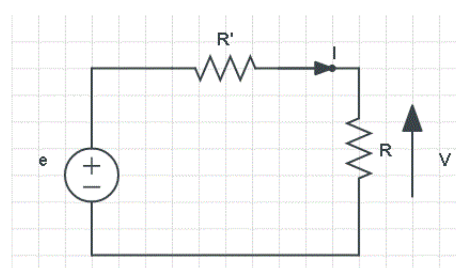


Figure 14: Simple notation for EQUATION LOVERS

Let us Practice Ohm's Law **(Find the missing I, R, V in below simple circuits)**



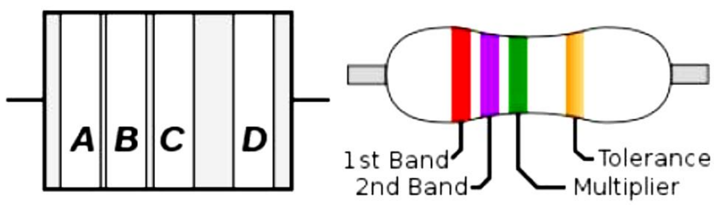




Resistor Color Coding – How to read Resistor Values

An electronic color code is used to indicate the values or ratings of resistors.

- The first significant figure of component value (left side)
- The second significant figure (some precision resistors have a third significant figure, and thus five bands).
- The decimal multiplier (number of trailing zeroes)
- If present, indicates tolerance of value in percent (no band means 20%)



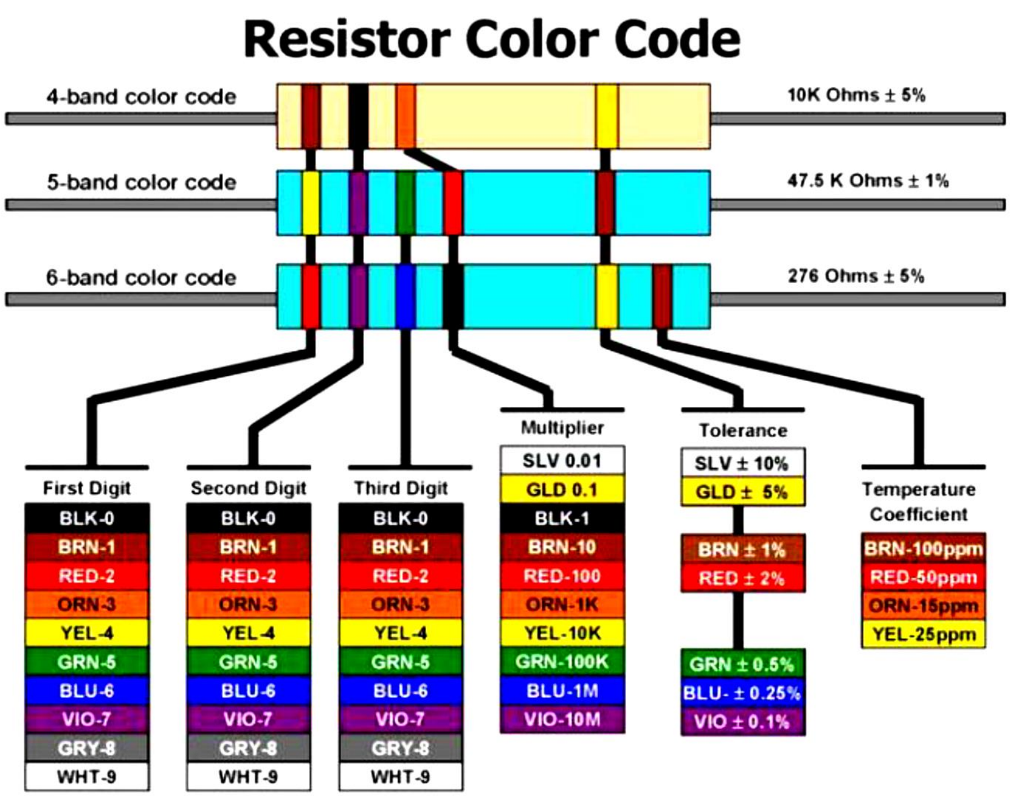


Figure 15: Resistor Color Code

Capacitors

A capacitor is a passive two-terminal electronic component that stores electrical energy in an electric field. The effect of a capacitor is known as capacitance. The capacitor's capacitance (C) is a measure of the amount of charge (Q) stored on each plate for a given potential difference or voltage (V) which appears across the plates.

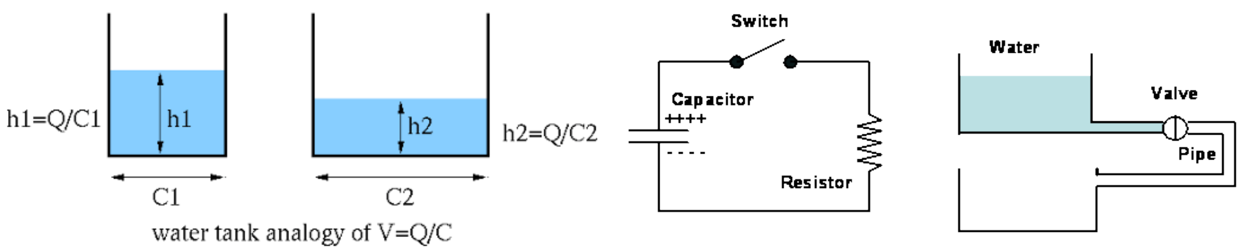


Figure 16: Water tank Analogy of Capacitors

The unit of capacitance in the International System of Units (SI) is the **farad (F)**, defined as **one coulomb per volt (1 C/V)**. Capacitance values of typical capacitors for use in general electronics range from about **1 picofarad (pF) (10^{-12} F)** to about **1 millifarad (mF) (10^{-3} F)**.

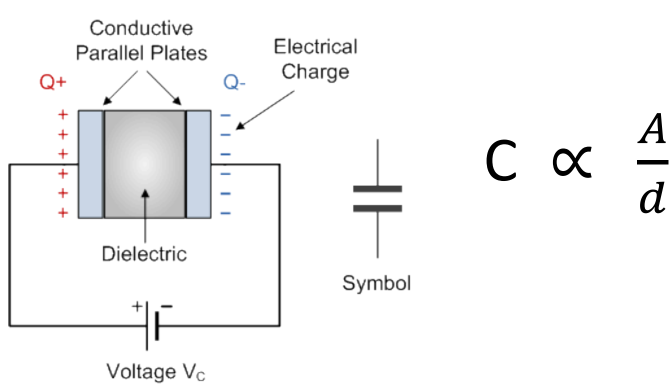


Figure 17: Parallel plate Capacitor

Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. A conductor may be a foil, thin film, sintered bead of metal, or an electrolyte. The nonconducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices.

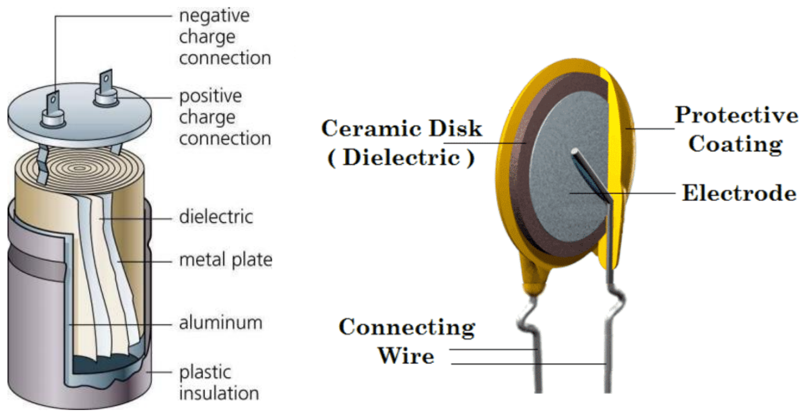


Figure 18: Cross Sections of common Capacitors

Types of Capacitors

Capacitors are divided into two mechanical groups: **Fixed capacitors with fixed capacitance values** and **variable capacitors with variable (trimmer) or adjustable (tunable) capacitance values**.

- **Ceramic capacitors** have a ceramic dielectric.
- **Film and paper capacitors** are named for their dielectrics.
- **Aluminum, tantalum,** and **niobium electrolytic capacitors** are named after the material used as the anode and the construction of the cathode (electrolyte)
- **Polymer capacitors** are aluminum, tantalum, or niobium electrolytic capacitors with conductive polymer as electrolyte
- **Double-layer (or supercapacitors)** were named for the physical phenomenon of the Helmholtz double-layer
- **Silver mica, glass, silicon, airgap,** and **vacuum capacitors** are named for their dielectric

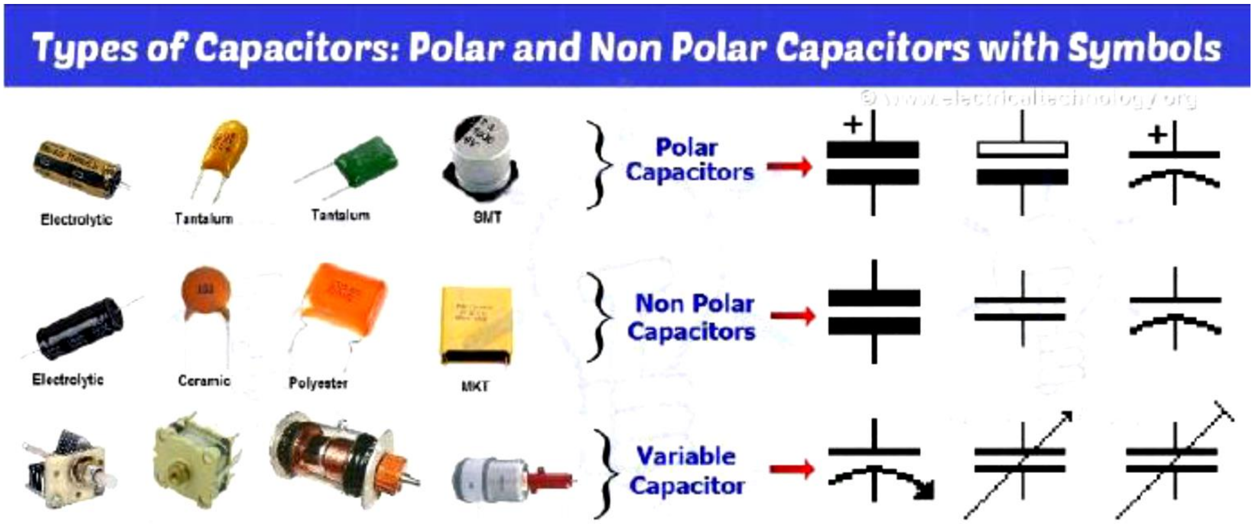


Figure 19: Different types of Capacitors

Fixed capacitors can be further classified as polar and non-polar capacitors. A **non-polarized** capacitor is a type of capacitor that has no implicit polarity -- it can be connected either way in a circuit. Ceramic, mica, and some electrolytic capacitors are non-polarized.

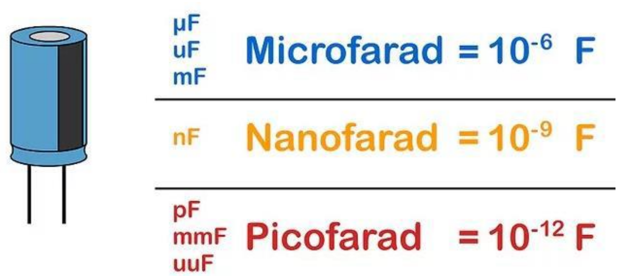
You will also sometimes hear people call them "bipolar" capacitors. A **polarized** capacitor is a type of capacitor that have implicit polarity -- it can only be connected one way in a circuit. The positive lead is shown on the schematic (and often on the capacitor) with a little "+" symbol. The negative lead is generally not shown on the schematic but may be marked on the capacitor with a bar or "-" symbol. Polarized capacitors are generally electrolytic.

Capacitors Coding- how to read capacitance values

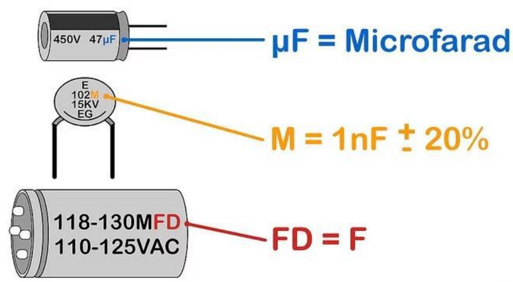
Unlike resistors, reading capacitance values can be a bit more challenging because the coding and terminology used are not straightforward most of the times. Follow the steps below to accurately determine the value of capacitances.

Large Capacitors:

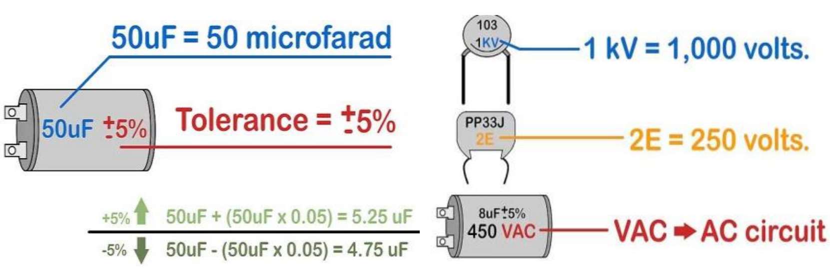
1. Identify the unit of Measurement



2. Read the capacitance Value

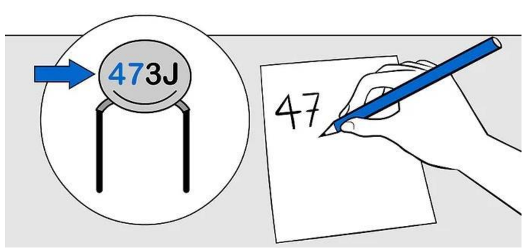


3. Look for the Tolerance Value and Voltage Rating

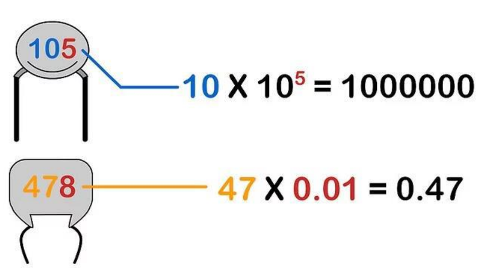


Compact Capacitors

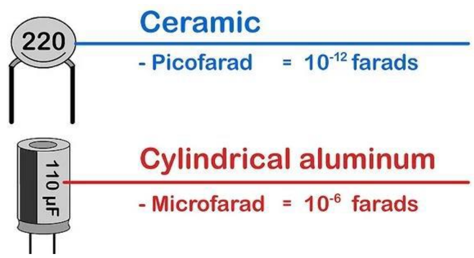
1. Write down the first two digits of the capacitance



2. Use the third digit as a zero multiplier. Note: If the third digit is 8, multiply by 0.01 and if it is 9, then multiply by 0.1



3. Workout the Capacitance units

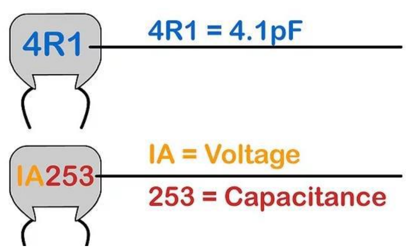


4. Reading the codes that contain letters

- If the letter is an **R**, replace it with a decimal point to get the capacitance in **pF**. For example, **4R1** means a capacitance of **4.1pF**

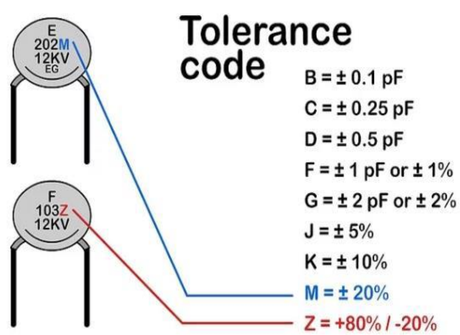
- If the letter is **p, n,** or **u,** this tells you the units ***(pico-, nano-, or microfarad)*** Replace this letter with a decimal point. For example, **n61** means **0.61 nF**, and **5u2** means **5.2uF**.

- A code like **"1A253"** is two codes. **1A** tells you the voltage, and **253** tells you the capacitance as described above.



5. Read tolerance codes on ceramic capacitors

Ceramic capacitors, which are usually tiny "pancakes" with two pins, typically list the tolerance value as one letter immediately after the three-digit capacitance value. This letter represents the tolerance of the capacitor, meaning how close the actual value of the capacitor can be expected to be to the indicated value of the capacitor



LEDs (Light-Emitting Diodes)

A Diode is an electronic component that only **conducts electricity in one direction**. The **"Forward Voltage"** rating of a diode will determine the minimum voltage difference between the anode and cathode to allow current to flow. For example, let us consider a diode with a forward voltage of 0.7 volts. If you apply +1 volts to the anode and 0 volts to the cathode, then current will flow. However, reversing the voltages to apply 0 volts to the anode and +1V to the cathode, prevents current from flowing!

A "Light Emitting Diode" (LED) is a variant of the standard diode with the same characteristics. The obvious difference is that when current flows through an LED it generates visible (non-visible) light. When looking at the specifications for a LED, there are two key ratings to note: the **"Forward Voltage"** and the **"Forward Current."**

The **Forward voltage** defines the amount of voltage required for the current to flow through the diode junction. Any voltages below this level cause the LED to remain "open" or non-conductive. This open state also means any components in series with the LED will not have current flowing through them either! Current can flow through the LED once the voltage drops across it reaches the forward voltage. A resistor is called a linear device because the current that runs through it is directly proportional to the voltage applied and its resistance. (You might know this as Ohm's Law.) A diode or LED is different because the voltage and current has a non-linear relationship.

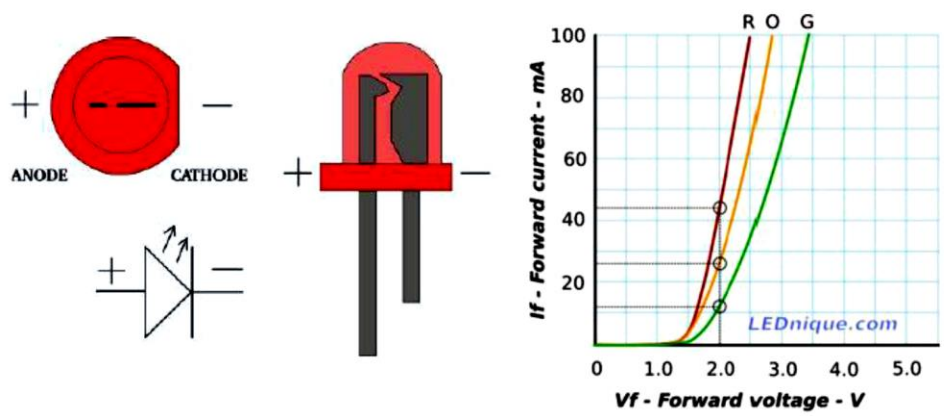


Figure 20: LED structure and the *non-linear* current-voltage curve

Now let us look at a practical example. Consider a LED with a forward voltage rated at 3.0 volts. What happens if you attach the anode to the positive (+) terminal of an AA battery and the cathode to the negative (-) terminal? Will the LED do anything? No! The AA battery only has a nominal voltage of 1.5 volts. Until you add a second battery, the LED will not light up.

So, if you use 2 nominal AA batteries in series and connect them to this diode, it will light up, and all is good, right? Well, No. Inside the LED, that the diode junction turns into a (near) short-circuit when the forward voltage is applied. This behavior means the LED could draw ALL the current it can from the battery. This situation is not good because you are short-circuiting the battery! Not only will this damage the battery, but will overheat or destroy the LED and you end up with a Dark Emitting Diode (DED) ☹

As mentioned before, applying the forward voltage turns an LED into a short circuit. As a short, the LED will draw all the current the supply allows AND will damage itself. So, you must limit the amount of **Forward current** allowed to flow through the LED. There is where the name **"current limiting resistor"** comes in.

A resistor placed in series with the LED limits the current that flows through it.

The next question to address is, what value resistor is needed?

To calculate the resistance for your circuit, subtract the voltage drop from the supply voltage and divide by the desired current i.e., $R = (V-V_d)/Id$. So, for a 9V supply and V_d =3V and I_d= 20mA, R= (9V-3V)/20mA= 300 ohms.

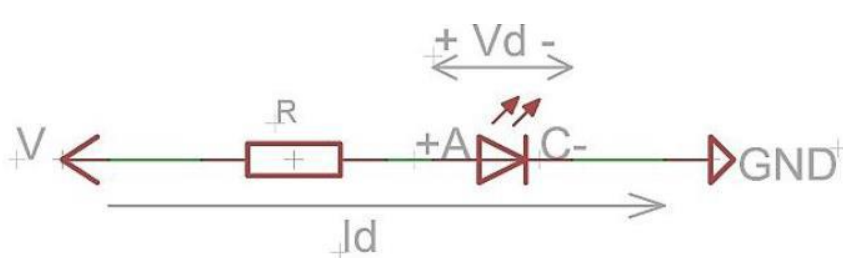


Figure 21: LED connected with a current-limiting resistor

Digital Multi-meter

A **Digital Multimeter (DMM)** is a test tool used to measure two or more electrical values principally voltage (volts), current (amps) and resistance (ohms). It is a standard diagnostic tool for technicians in the electrical/electronic industries.

DMMs long ago replaced needle-based analog meters due to their ability to measure with greater accuracy, reliability, and increased impedance. Fluke introduced its first DMM in 1977.

DMMs combine the testing capabilities of single-task meters—the voltmeter (for measuring volts), ammeter (amps) and ohmmeter (ohms). Often, they include several additional specialized features or advanced options. Technicians with specific needs, therefore, can seek out a model targeted for particular tasks.

The face of a DMM typically includes four components:

- Display: Where measurement readouts can be viewed.
- Buttons: For selecting various functions; the options vary by model.
- Dial (or rotary switch): For selecting primary measurement values (volts, amps, ohms).
- Input jacks: Where test leads are inserted

Figure 22: Parts of a DMM

Measuring Resistance

1. Connect the **RED** colored Probe to the corresponding input jack and the **BLACK** probe to the COM jack on the DMM as shown below

2. Rotate the dial to the Ohm (Ω) scale.

3. If you want to measure the resistance of any resistor, connect the other end of the probes to the leads of the resistor and the value will show on the display panel.

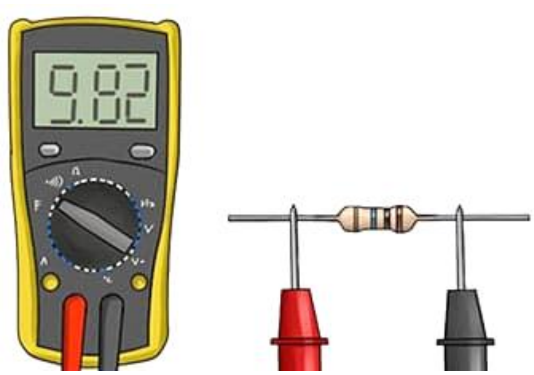


Figure 23: Measuring Resistance using DMM

Measuring Voltage

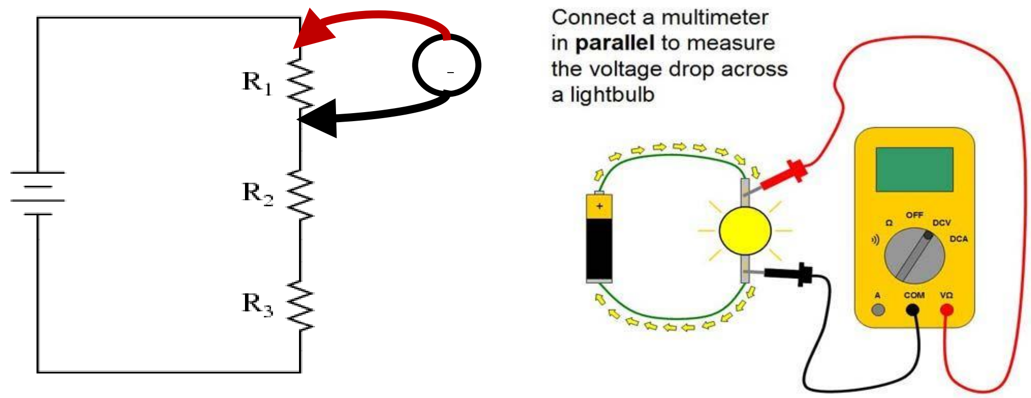


Figure 24: DMM parallel connection with Resistor

- Connect the probes in the same way you connected them for measuring the resistance.
- Rotate the Dial to the Preferred Voltage measurement DC or AC (Make sure you select the correct type of voltage to measure to avoid wrong measurements and possible damage to the equipment)
- The voltage across any two points in a circuit can be measured in this way

Measuring Current

Connect the RED Probe to the input jack depending on the range of current being measured (either A, mA or µA). Make sure to choose the correct range to avoid damages to the equipment. In your multi-meter you have an alarm to warn you regarding a wrong selection.

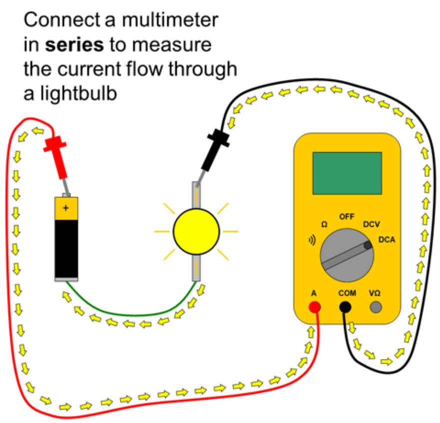


Figure 25: DMM Series connection with a component

1. Make sure the BLACK probe fix to the COM Port

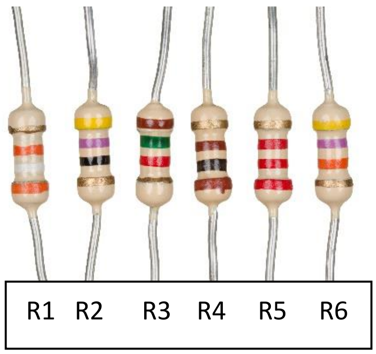
2. Rotate the dial to the preferred current measurement **A, mA, µA**

3. Connect your multi-meter in series with the circuit to measure the current.

Exercises

(Task 1)

You are provided with 6 unknown resistors as given below. Using the knowledge of color coding, find the value of these resistors and record them. Now, verify if the values agree with what you measure with the multimeter. (use Tinkercad)

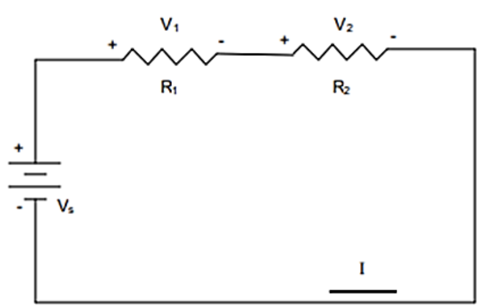


(Task 2)

Read the following Capacitors

(Task 3)

Construct the circuit using Tinkercad as shown in the figure below. Measure using the multimeter the values of the current I, and the voltages across R1 and R2 respectively and record the values.
Is Vs = V1 + V2?



(Task 4)

Construct the circuit using Tinkercad as shown in figure below. Measure using the multi-meter the values of the current I, and the voltages across R1 and R2 respectively and record the values. Also measure the currents I1 and I2 following through each of the resistors. Is I = I1 + I2?