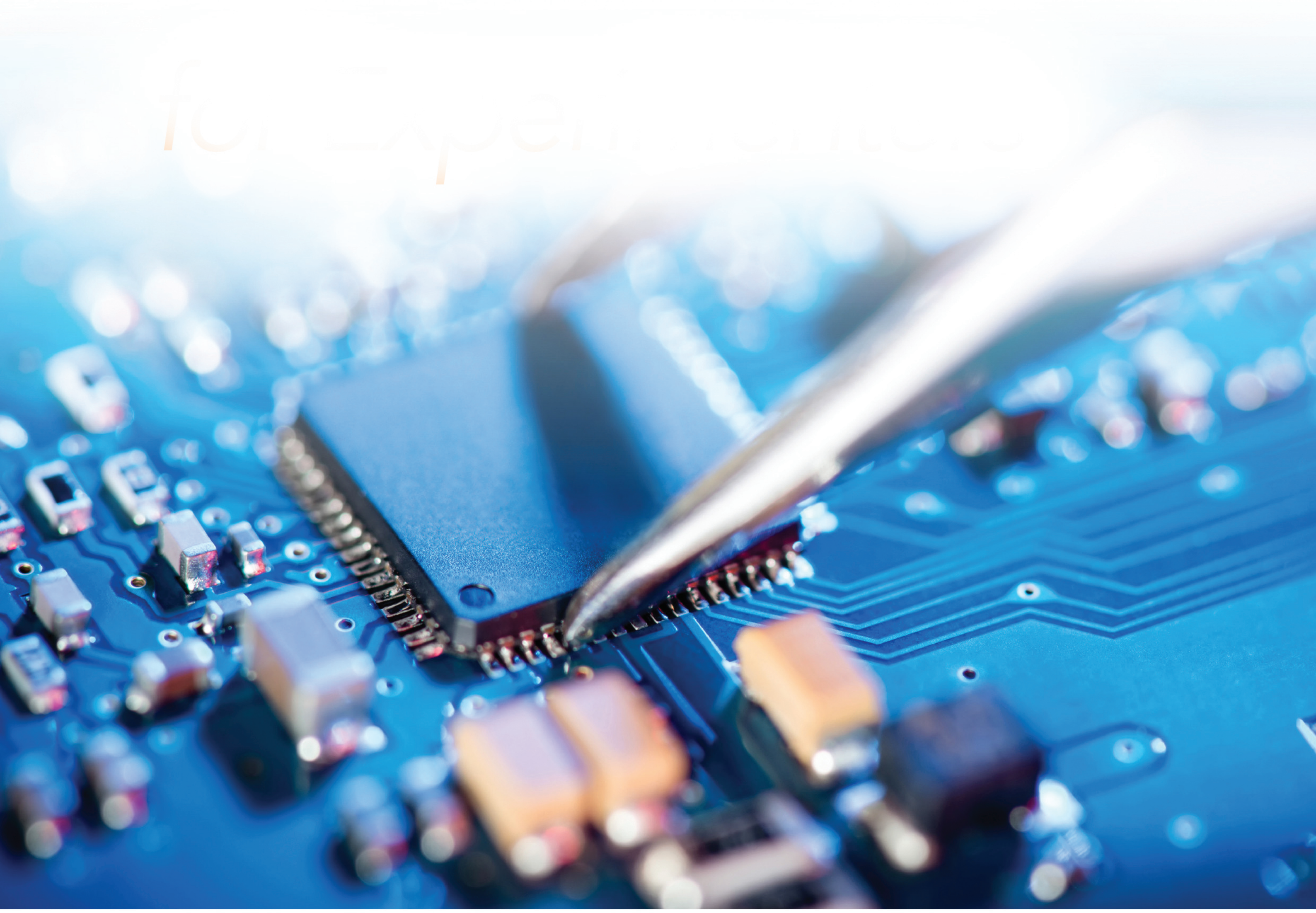
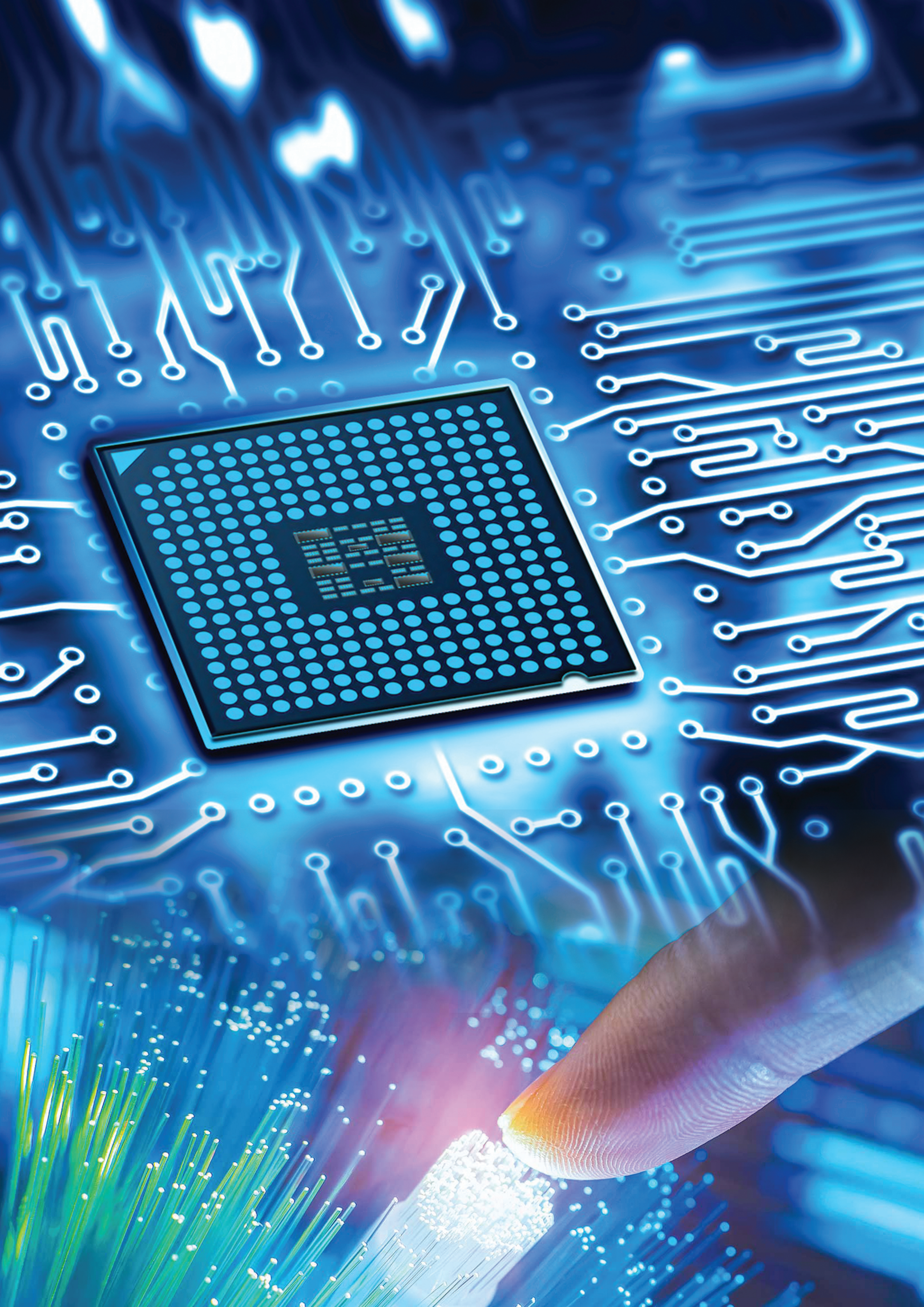
VOLUME - II

ELECTRONICS



ROBOTROD

by Olatus Systems Private Limited



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CHAPTER 1: Electronic Measurements

In order to measure the electric quantities, first we have to understand what electricity is and what its properties are.

When beginning to explore the world of electricity and electronics, it is vital to start by understanding the basics of voltage, current, and resistance. These are the three basic building blocks required to manipulate and utilize the electricity. At first, these concepts can be difficult to understand because we cannot "see" them. One cannot see with the naked eye the energy flowing through a wire or the voltage of a battery sitting on a table.

In order to detect this energy transfer, we must use measurement tools such as multimeters, spectrum analysers, and oscilloscopes to visualize what is happening with the charge in a system.

Electrical Charge (Q)

Electricity is the movement of electrons. Electrons create charge, which we can harness to do work. Your light bulb, your stereo, your phone, etc., are all harnessing the movement of the electrons in order to do work. They all operate using the same basic power source: the movement of electrons.

The three basic principles for this can be explained using electrons, or more specifically, the charge they create:

- **Voltage** is the difference in charge between two points.
- **Current** is the rate at which charge is flowing.
- **Resistance** is a material's tendency to resist the flow of charge.

Voltage

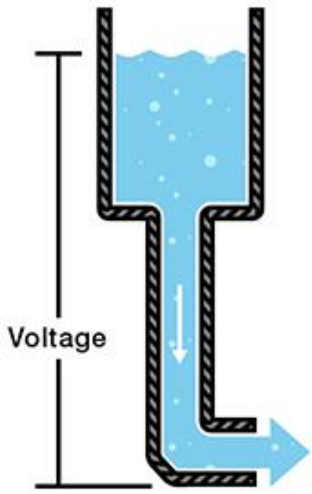
Voltage, also called electromotive force, is a quantitative expression of the potential difference in charge between two points in an electrical field. The S.I unit **"volt"** is named after the Italian physicist **Alessandro Volta** who invented what is considered the first chemical battery. Voltage is represented in equations and schematics by the letter **"V"**.

When describing voltage, current, and resistance, a common analogy is a water tank. In this analogy, charge is represented by the water *amount*, voltage is represented by the water *pressure*, and current is represented by the water *flow*.

So, for this analogy, remember:

- Water = Charge
- Pressure = Voltage
- Flow = Current

For Example - Consider a water tank at a certain height above the ground. At the bottom of this tank there is a hose.



The pressure at the end of the hose can represent voltage. The water in the tank represents charge. The more water in the tank, the higher the charge, the more pressure is measured at the end of the hose.

We can think of this tank as a battery, a place where we store a certain amount of energy and then release it. If we drain our tank a certain amount, the pressure created at the end of the hose goes down. We can think of this as decreasing voltage, like when a flashlight gets dimmer as the batteries run down. There is also a decrease in the amount of water that will flow through the hose. Less pressure means less water is flowing, which brings us to **current.**

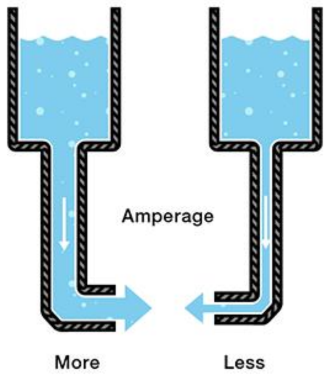
Current

A flow of electricity which results from the ordered directional movement of electrically charged particles. The S.I unit is **Ampere (A).**

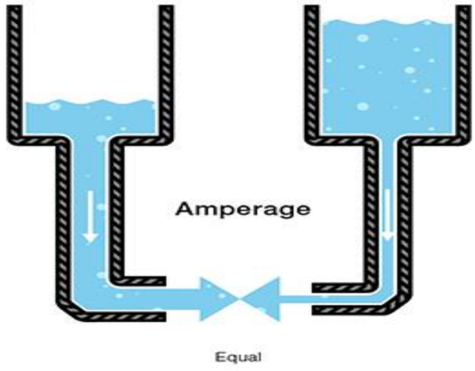
We can think of the amount of water flowing through the hose from the tank as current. Higher the pressure, higher the flow and vice-versa. With water, we would measure the volume of the water flowing through the hose over a certain period of time. With electricity, we measure the amount of charge flowing through the circuit over a period of time.

Current is measured in Amperes (usually just referred to as "Amps"). An ampere is defined as $6.241*10^{18}$electrons (1 Coulomb) per second passing through a point in a circuit. Amps are represented in equations by the letter "I".

Let's say now that we have two tanks, each with a hose coming from the bottom. Each tank has the exact same amount of water, but the hose on one tank is narrower than the hose on the other.



We measure the same amount of pressure at the end of either hose, but when the water begins to flow, the flow rate of the water in the tank with the narrower hose will be less than the flow rate of the water in the tank with the wider hose. In electrical terms, the current through the narrower hose is less than the current through the wider hose. If we want the flow to be the same through both hoses, we have to increase the amount of water (charge) in the tank with the narrower hose.



This increases the pressure (voltage) at the end of the narrower hose, pushing more water through the tank. This is analogous to an increase in voltage that causes an increase in current.

Now we're starting to see the relationship between voltage and current. But there is a third factor to be considered here: the width of the hose. In this analogy, the width of the hose is the resistance.

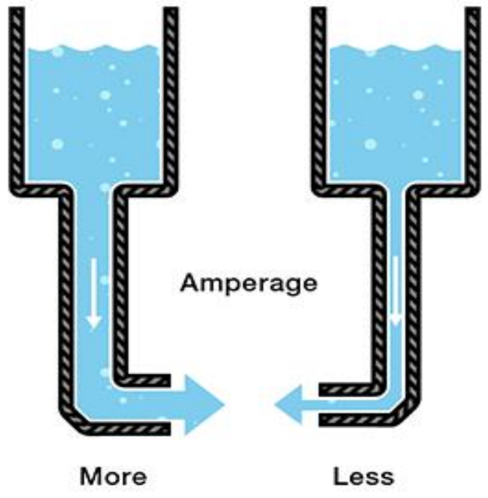
This means we need to add another term to our model:

- Water = Charge
- Pressure = Voltage
- Flow = Current
- Hose Width = Resistance

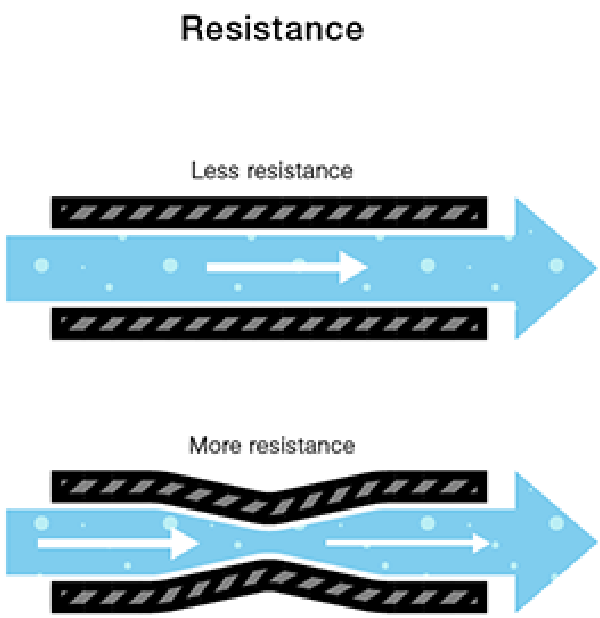
Resistance

Resistance is a measure of the opposition to current flow in an electrical circuit. Resistance is measured in ohms, symbolized by the Greek letter omega (Ω). Ohms are named after Georg Simon Ohm (1784-1854), a German physicist who studied the relationship between voltage, current and resistance.

Consider again our two water tanks, one with a narrow pipe and one with a wide pipe.



It stands to reason that we can't fit as much volume through a narrow pipe as a wider one at the same pressure. This is resistance. The narrow pipe "resists" the flow of water through it even though the water is at the same pressure as the tank with the wider pipe.



In electrical terms, this is represented by two circuits with equal voltages and different resistances. The circuit with the higher resistance will allow less charge to flow; meaning the circuit with higher resistance has less current flowing through it.

Multimeter

A multimeter has three parts:

- Display
- Selection Knob
- Ports

The display usually has four digits and the ability to display a negative sign. A few multimeters have illuminated displays for better viewing in low light situations.

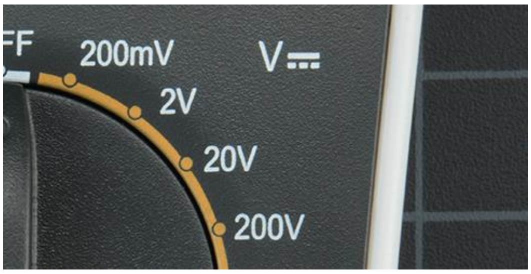
The selection knob allows the user to set the multimeter to read different things such as milliamps (mA) of current, voltage (V) and resistance (Ω).

Two probes are plugged into two of the **ports** on the front of the unit. **COM** stands for common and is almost always connected to Ground or '-' of a circuit. The **COM** probe is conventionally black but there is no difference between the red probe and black probe other than color. **10A** is the special port used when measuring large currents (greater than 200mA). **mAV Ω** is the port that the red probe is conventionally plugged in to. This port allows the measurement of current **(up to 200mA), voltage (V), and resistance (Ω).**

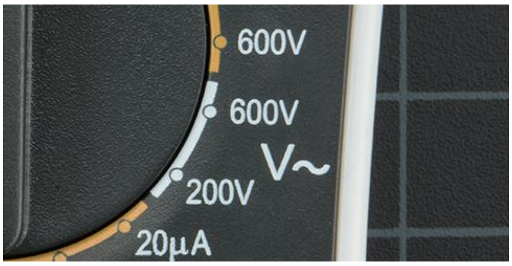
Measuring Voltage

To start, let's measure voltage on an AA battery: Plug the black probe into **COM** and the red probe into **mAVΩ**. Set the multimeter to "2V" in the DC (direct current) range. Almost all portable electronics use direct current), not alternating current. Connect the black probe to the battery's ground or '-' and the red probe to power or '+'. Squeeze the probes with a little pressure against the positive and negative terminals of the AA battery. If you've got a fresh battery, you should see around 1.5V on the display (this battery is brand new, so its voltage is slightly higher than 1.5V).

If you're measuring DC voltage (such as a battery or a sensor hooked up to an Arduino) you want to set the knob where the V has a straight line. AC voltage (like what comes out of the wall) can be dangerous, so we rarely need to use the AC voltage setting (the V with a wavy line next to it).

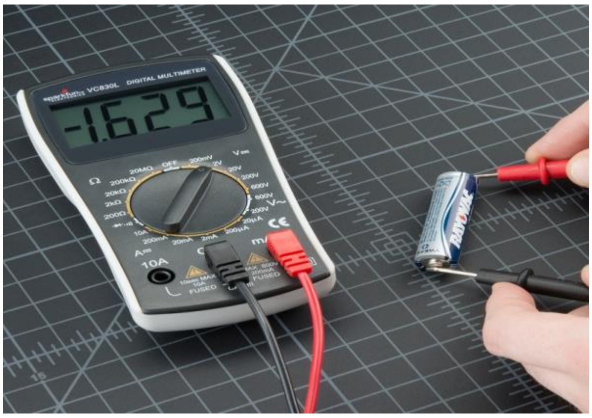


Use the V with a straight line to measure DC Voltage.

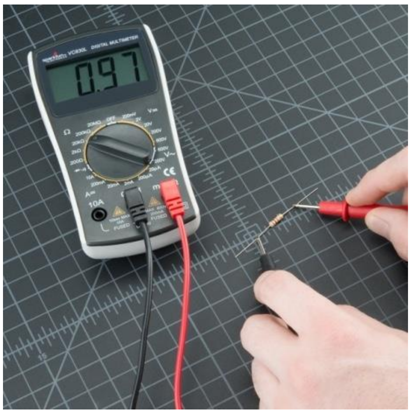


Use the V with a wavy line to measure AC Voltage.

What happens if you switch the red and black probes? The reading on the multimeter is simply negative. Nothing bad happens! The multimeter measures voltage in relation to the common probe. How much voltage is there on the '+' of the battery compared to common or the negative pin? 1.5V. If we switch the probes, we define '+' as the common or zero point. How much voltage is there on the '-' of the battery compared to our new zero? -1.5V!



Measuring Resistance



Normal resistors have color codes on them. If you don't know what they mean, that's ok! There are plenty of online calculators that are easy to use. However, if you ever find yourself without internet access, a multimeter is very handy at measuring resistance.

Pick out a random resistor and set the multimeter to the 20kΩ setting. Then hold the probes against the resistor legs with the same amount of pressure you when pressing a key on a keyboard.

The meter will read one of three things, **0.00**, **1**, or the **actual resistor value**.

- In this case, the meter reads 0.97, meaning this resistor has a value of 9.7kΩ, or about 10kΩ or 10,000 Ω (remember you are in the 20kΩ or 20,000 Ohm mode so you need to move the decimal four places to the right or 9,700 Ohms).
- If the multimeter **reads 1** or displays **OL**, it's overloaded. You will need to try a higher mode such as **200kΩ** mode or **2MΩ** (mega ohm) mode. There is no harm if this happen, it simply means the range knob needs to be adjusted.
- If the multimeter reads **0.00** or nearly zero, then you need to lower the mode to **2kΩ** or **200Ω**.

Continuity

Continuity testing is the act of testing the resistance between two points. If there is very low resistance (less than a few Ωs), the two points are connected electrically, and a tone is emitted. If there is more than a few Ωs of resistance, than the circuit is open, and no tone is emitted. This test helps insure that connections are made correctly between two points. This test also helps us detect if two points are connected that should not be.

Continuity is quite possibly the single most important function for embedded hardware gurus. This feature allows us to test for conductivity of materials and to trace where electrical connections have been made or not made.

Set the multimeter to 'Continuity' mode. It may vary among DMMs, but look for a diode symbol with propagation waves around it (like sound coming from a speaker).

Now touch the probes together. The multimeter should emit a tone.

CHAPTER 2: Resistor Color Coding

There are many different types of **Resistor** available and that they can be used in both electrical and electronic circuits to control the flow of current or to produce a voltage in many different ways.

But in order to do this the actual resistor needs to have some form of "resistive" or "resistance" value. Resistors are available in a range of different resistance values from fractions of an Ohm (Ω) to millions of Ohms.

Obviously, it would be impractical to have available resistors of every possible value for example, 1Ω, 2Ω, 3Ω, 4Ω etc, because literally tens of hundreds of thousands, if not tens of millions of different resistors would need to exist to cover all the possible values. Instead, resistors are manufactured in what are called "preferred values" with their resistance value printed onto their body in colored ink.

The resistance value, tolerance, and wattage rating are generally printed onto the body of the resistor as numbers or letters when the resistors body is big enough to read the print, such as large power resistors. But when the resistor is small such as a 1/4W carbon or film type, these specifications must be shown in some other manner as the print would be too small to read.

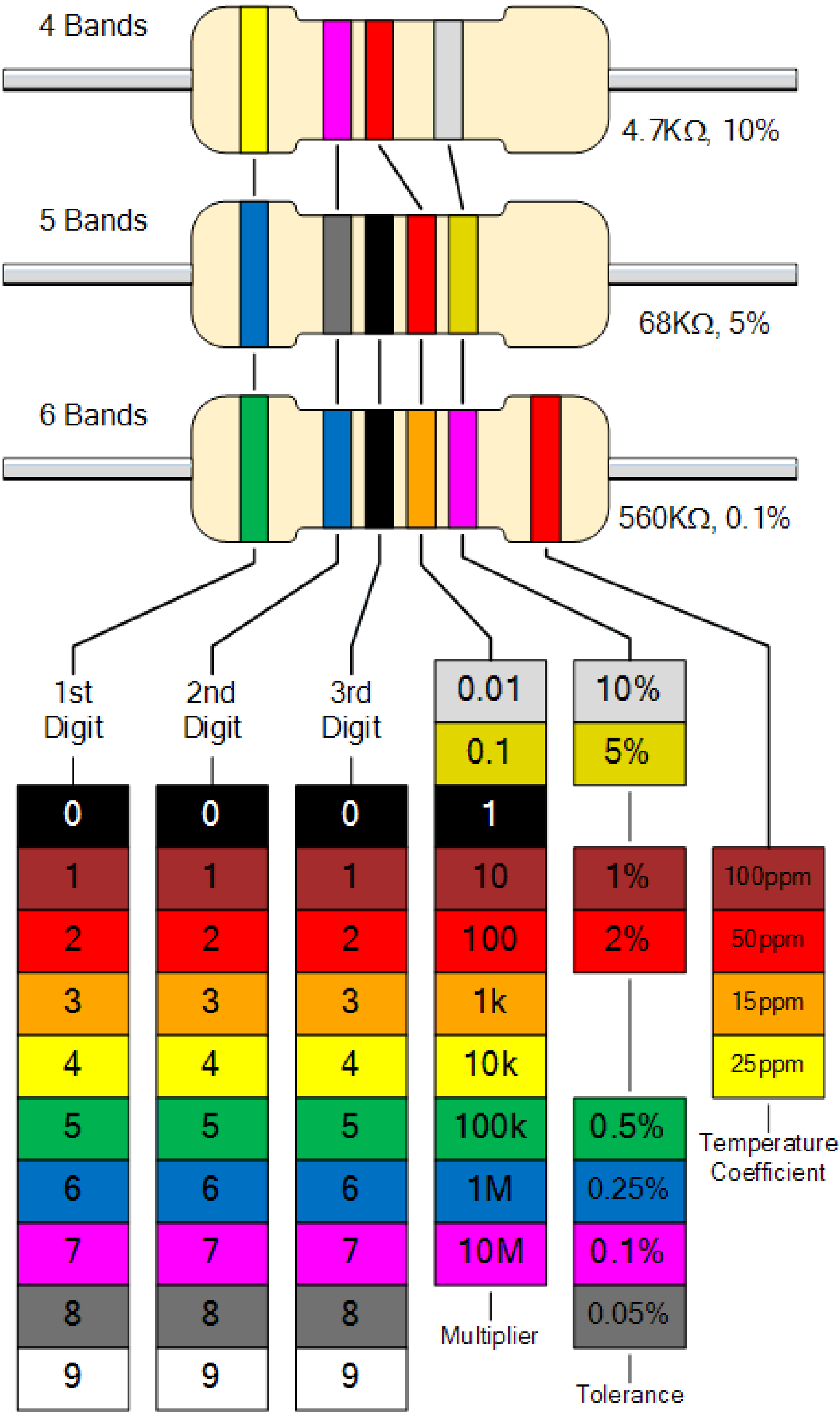
So to overcome this, small resistors use colored painted bands to indicate both their resistive value and their tolerance with the physical size of the resistor indicating its wattage rating. These colored painted bands produce a system of identification generally known as a **Resistors Color Code**.

An international and universally accepted resistor color code scheme was developed many years ago as a simple and quick way of identifying a resistors ohmic value no matter what its size or condition. It consists of a set of individual colored rings or bands in spectral order representing each digit of the resistors value.

The resistor color code markings are always read one band at a time starting from the left to the right, with the larger width tolerance band oriented to the right side indicating its tolerance. By matching the color of the first band with its associated number in the digit column of the color chart below the first digit is identified and this represents the first digit of the resistance value.

Again, by matching the color of the second band with its associated number in the digit column of the color chart we get the second digit of the resistance value and so on. Then the resistor color code is read from left to right as illustrated below:

The Standard Resistor Color Code Chart



The Resistor Color Code Table

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		± 0.05%
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

Calculating Resistor Values

The **Resistor Color Code** system is all well and good but we need to understand how to apply it in order to get the correct value of the resistor. The “left-hand” or the most significant colored band is the band which is nearest to a connecting lead with the color coded bands being read from left-to-right as follows;

Digit, Digit, Multiplier = Color, Color x 10 ^{color} in Ohm’s (Ω’s)

For example, a resistor has the following colored markings;

Yellow Violet Red = 4 7 2 = 4 7 x 10^2 = 4700Ω or 4k7.

The fourth and fifth bands are used to determine the percentage tolerance of the resistor. Resistor tolerance is a measure of the resistors variation from the specified resistive value and is a consequence of the manufacturing process and is expressed as a percentage of its “nominal” or preferred value.

ACTIVITY

Find the values of resistors

Instructions

- Gather any five resistors from the box.
- Find the value of resistance from color coding method.
- Now check the value of resistance using multimeter.
- Record your observations in the table below.

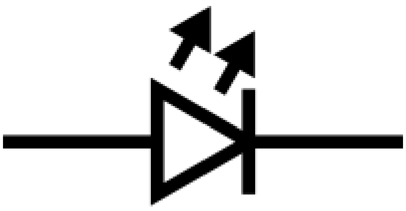
Resistor	Value (by color coding method)	Value (by multimeter)
1		
2		
3		
4		
5		

CHAPTER 3: LED (Light Emitting Diode)

LED (Light Emitting Diode), it is a special type of electronic component that emits photons when electricity flows through it in the right direction. Over the last two decades, LED technology has changed and improved dramatically. LEDs now come in so many countless types and configurations, it would be impossible to survey them all in this class. On account of their versatility and pervasiveness, you could say that LEDs currently shine brighter than all other lights. LEDs are all around us in our phones, our cars and even our homes. Any time something electronic lights up, there's a good chance that an LED is behind it. They come in a huge variety of sizes, shapes, and colors.

LEDs (that's "ell-ee-dees") are a particular type of diode that convert electrical energy into light.

Schematic for LED is:

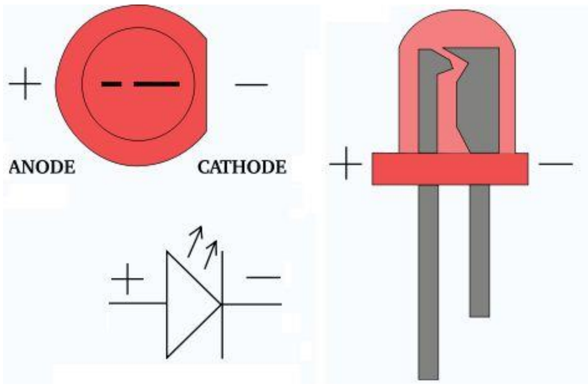


light emitting diode

In short, LEDs are like tiny light bulbs. However, LEDs require a lot less power to light up by comparison. They're also more energy efficient, so they don't tend to get hot like conventional light bulbs do. This makes them ideal for mobile devices and other low-power applications. High-intensity LEDs have found their way into accent lighting, spotlights and even automotive headlights.

Polarity of LED

In electronics, polarity indicates whether a circuit component is symmetric or not. LEDs, being diodes, will only allow current to flow in one direction. And when there's no current-flow, there's no light. Luckily, this also means that you can't break an LED by plugging it in backwards. Rather, it just won't work.



The positive side of the LED is called the **"anode"** and is marked by having a longer "lead," or leg. The other, negative side of the LED is called the **"cathode."** Current flows from the anode to the cathode and never the opposite direction. A reversed LED can keep an entire circuit from operating properly by blocking current flow.

The brightness of an LED is directly dependent on how much current it draws. That means two things. The first being that super bright LEDs drain batteries more quickly, because the extra brightness comes from the extra power being used. The second is that you can control the brightness of an LED by controlling the amount of current through it.

If you connect an LED directly to a current source it will try to dissipate as much power as it's allowed to draw, and it will destroy itself. That's why it's important to limit the amount of current flowing across the LED.

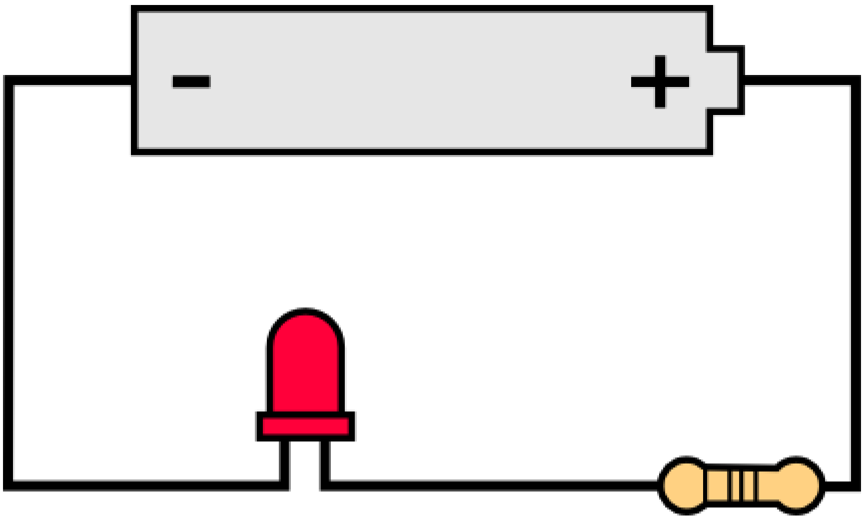
For this, we employ resistors. Resistors limit the flow of electrons in the circuit and protect the LED from trying to draw too much current. Don't worry; it only takes a little basic math to determine the best resistor value to use.

Operating voltage of LED

Before we talk about the technical stuff, let's hook up some LEDs.

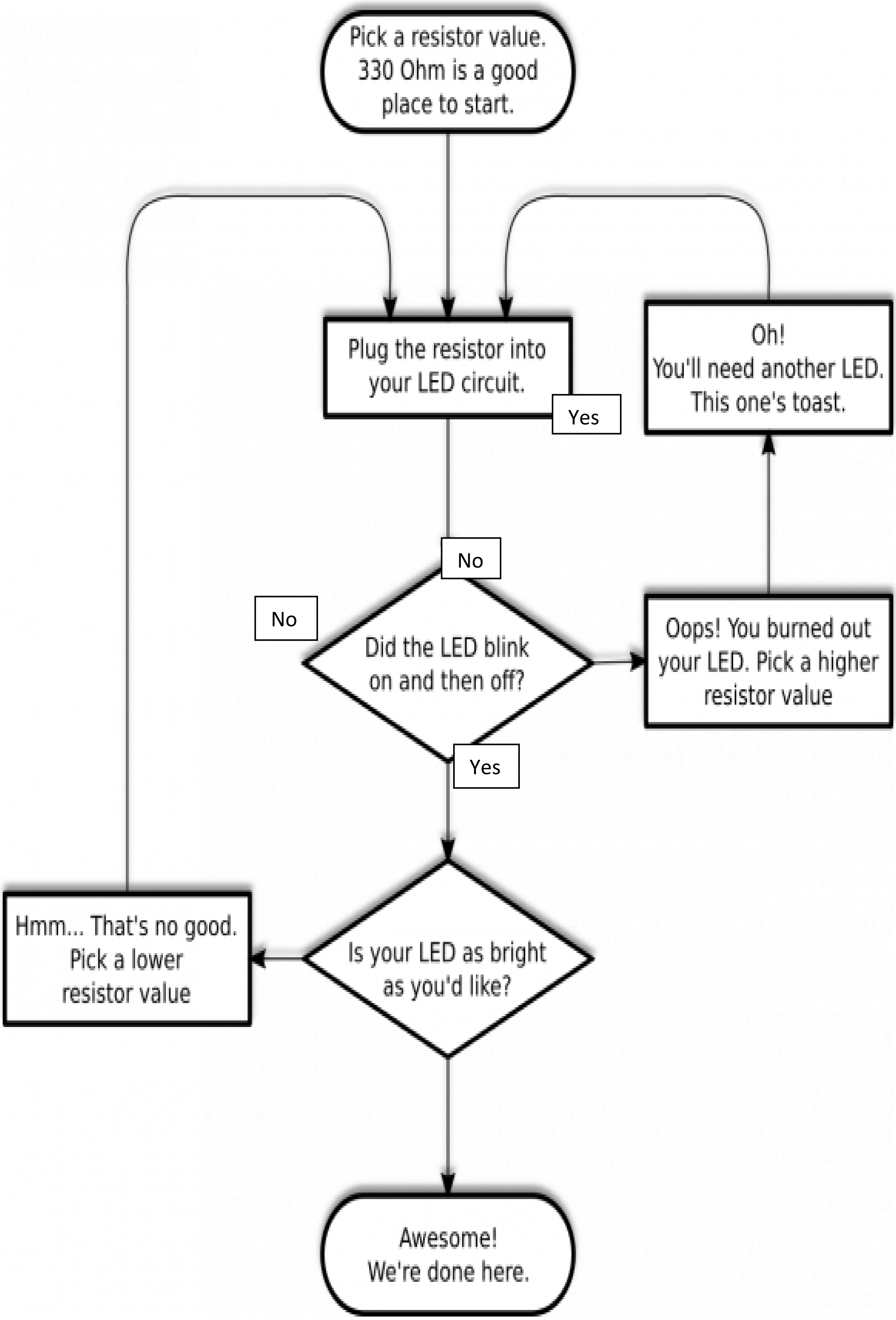
As you've probably put together from the info in the last section, you'll need a battery, a resistor and an LED. We're using a battery as our power source, because they're easy to find and they can't supply a dangerous amount of current.

The basic template for an LED circuit is pretty simple; just connect your battery, resistor and LED in series. Like this:

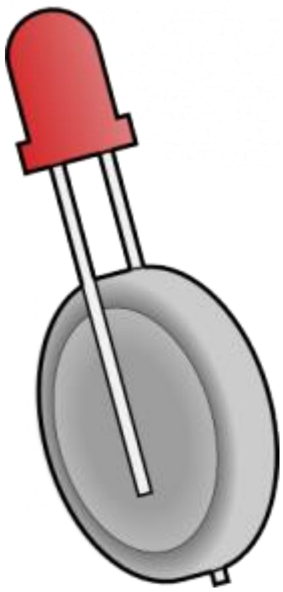


A good resistor value for most LEDs is 330 Ohms. You can use the information from the last section to help you determine the exact value you need, but this is LEDs *without* math… So, start by popping a 330 Ohm resistor into the above circuit and see what happens.

The interesting thing about resistors is that they'll dissipate extra power as heat, so if you have a resistor that's getting warm, you probably need to go with a smaller resistance. If your resistor is too small, however, you run the risk of burning out the LED! Given that you have a handful of LEDs and resistors to play with, here's a flow chart to help you design your LED circuit by trial and error:


Pick a resistor value. 330 Ohm is a good place to start.
Plug the resistor into your LED circuit.
Yes
Oh! You'll need another LED. This one's toast.
No
No
Did the LED blink on and then off?
Oops! You burned out your LED. Pick a higher resistor value
Yes
Hmm... That's no good. Pick a lower resistor value
Is your LED as bright as you'd like?
Awesome! We're done here.

Another way to light up an LED is to just connect it to a coin cell battery! Since the coin cell can't source enough current to damage the LED, you can connect them directly together! Just push a CR2032 coin cell between the leads of the LED. The long leg of the LED should be touching the side of the battery marked with a "+".



Of course, if you're not getting great results with the trial and error approach, you can always get out your calculator and math it up. Don't worry; it's not hard to calculate the best resistor value for your circuit. But before you can figure out the optimal resistor value, you'll need to find the optimal current for your LED.

As an example we'll peruse the datasheet for our Basic Red 5mm LED.

LED Current

Starting at the top and making our way down, the first thing we encounter is this charming table:

ITEMS	Symbol	Absolute Maximum Rating	Unit
Forward Current	I_F	20	mA
Peak Forward Current	I_{FP}	30	mA
Suggestion Using Current	I_{SU}	16-18	mA
Reverse Voltage (V_R=5V)	I_R	10	uA
Power Dissipation	P_D	105	mW
Operation Temperature	T_{OPR}	-40 ~ 85	℃
Storage Temperature	T_{STG}	-40 ~ 100	℃
Lead Soldering Temperature	T_{SOL}	Max. 260℃ for 3 Sec. Max. (3mm from the base of the expoxy bulb)	

What does it all mean?

The first row in the table indicates how much current your LED will be able to handle continuously. In this case, you can give it 20mA or less, and it will shine its brightest at 20mA. The second row tells us what the maximum peak current should be for short bursts. This LED can handle short bumps to 30mA, but you don't want to sustain that current for too long. This datasheet is even helpful enough to suggest a stable current range (in the third row from the top) of 16-18mA. That's a good target number to help you make the resistor calculations we talked about.

The following few rows are of less importance for the purposes of this tutorial. The reverse voltage is a diode property that you shouldn't have to worry about in most cases. The power dissipation is the amount of power in milliWatts that the LED can use before taking damage. This should work itself out as long as you keep the LED within its suggested voltage and current ratings.

LED Voltage

Let's see what other kinds of tables

ITEMS	Symbol	Test condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=20mA	1.8	---	2.2	V
Wavelenength (nm) or TC(k)	$\Delta\lambda$	I_F=20mA	620	---	625	nm
*Luminous intensity	I_v	I_F=20mA	150	---	200	mcd

This is a useful little table! The first row tells us what the **forward voltage** drop across the LED will be. Forward voltage is a term that will come up a lot when working with LEDs. This number will help you decide how much voltage your circuit will need to supply to the LED. If you have more than one LED connected to a single power source, these numbers are really important because the forward voltage of all of the LEDs added together can't exceed the supply voltage.

LED Wavelength

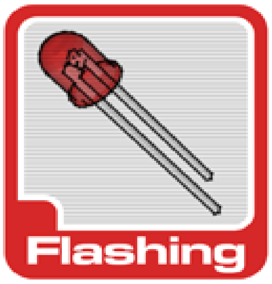
The second row on this table tells us the wavelength of the light. Wavelength is basically a very precise way of explaining what color the light is. There may be some variation in this number so the table gives us a minimum and a maximum. In this case it's 620 to 625nm, which is just at the lower red end of the spectrum (620 to 750nm).

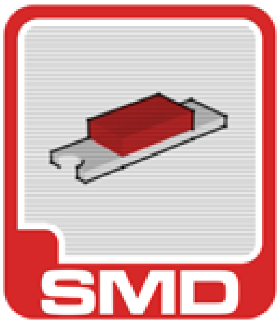
LED Brightness

The last row (labeled "Luminous Intensity") is a measure of how bright the LED can get. The unit mcd, or **millicandela**, is a standard unit for measuring the intensity of a light source. This LED has a maximum intensity of 200 mcd, which means it's just bright enough to get your attention but not quite flashlight bright. At 200 mcd, this LED would make a good indicator.

Types of LEDs

Congratulations, you know the basics! Maybe you've even gotten your hands on a few LEDs and started lighting stuff up. Now let's talk about different types of LEDs





- RGB (Red-Green-Blue) LEDs are actually three LEDs in one! But that doesn't mean it can only make three colors. Because red, green, and blue are the additive primary colors, you can control the intensity of each to create every color of the rainbow. Most RGB LEDs have four pins: one for each color and a common pin. On some, the common pin is the anode, and on others, it's the cathode.
- Some LEDs are smarter than others. Take the flashing LED, for example. Inside these LEDs, there's actually an integrated circuit that allows the LED to blink without any outside controller.
- SMD LEDs aren't so much a specific kind of LED but a package type. As electronics get smaller and smaller, manufacturers have figured out how to cram more components in a smaller space. **SMD (Surface Mount Device)** parts are tiny versions of their standard counterparts. SMD LEDs come in several sizes, from fairly large to smaller than a grain of rice! Because they're so small, and have pads instead of legs.
- There are even LEDs that emit light outside of the normal visible spectrum. You probably use Infrared LEDs every day, for instance. They're used in things like TV remotes to send small pieces of information in the form of invisible light! On the opposite end of the spectrum you can also get Ultraviolet LEDs. Ultraviolet LEDs will make certain materials fluoresce, just like a blacklight! They're also used for disinfecting surfaces, because many bacteria are sensitive to UV radiation.

Applications of LED

Indicators and signs

The low energy consumption, low maintenance and small size of LEDs have led to uses as status indicators and displays on a variety of equipment and installations. Large-area LED displays are used as stadium displays, dynamic decorative displays, and dynamic message signs on freeways. Thin, lightweight message displays are used at airports and railway stations, and as destination displays for trains, buses, trams, and ferries.

Red and green LED traffic signals

One-color light is well suited for traffic lights and signals, exit signs, emergency vehicle lighting, ships' navigation lights or lantern and LED-based Christmas lights. In cold climates, LED traffic lights may remain snow-covered. Red or yellow LEDs are used in indicator and alphanumeric displays in environments where night vision must be retained: aircraft cockpits, submarine and ship bridges, astronomy observatories, and in the field, e.g. night time animal watching and military field use.

Lighting

With the development of high-efficiency and high-power LEDs, it has become possible to use LEDs in lighting and illumination.

LEDs are used as street lights and in other architectural lighting. The mechanical robustness and long lifetime are used in automotive lighting on cars, motorcycles, and bicycle lights. LED light emission may be efficiently controlled by using non-imaging optics principles.

LED street lights are employed on poles and in parking garages.

LEDs are used in aviation lighting. Airbus has used LED lighting in its Airbus A320 Enhanced since 2007, and Boeing uses LED lighting in the 787. LEDs are also being used now in airport and heliport lighting. LED airport fixtures currently include medium-intensity runway lights, runway centerline lights, taxiway centerline and edge lights, guidance signs, and obstruction lighting.

Data communication and other signaling

Light can be used to transmit data and analog signals. For example, lighting white LEDs can be used in systems assisting people to navigate in closed spaces while searching necessary rooms or objects.

Assistive listening devices in many theaters and similar spaces use arrays of infrared LEDs to send sound to listeners' receivers. Light-emitting diodes (as well as semiconductor lasers) are used to send data over many types of fiber optic cable, from digital audio over TOSLINK cables to the very high bandwidth fiber links that form the Internet backbone. For some time, computers were commonly equipped with IrDA interfaces, which allowed them to send and receive data to nearby machines via infrared.

Because LEDs can cycle on and off millions of times per second, very high data bandwidth can be achieved.

Other applications

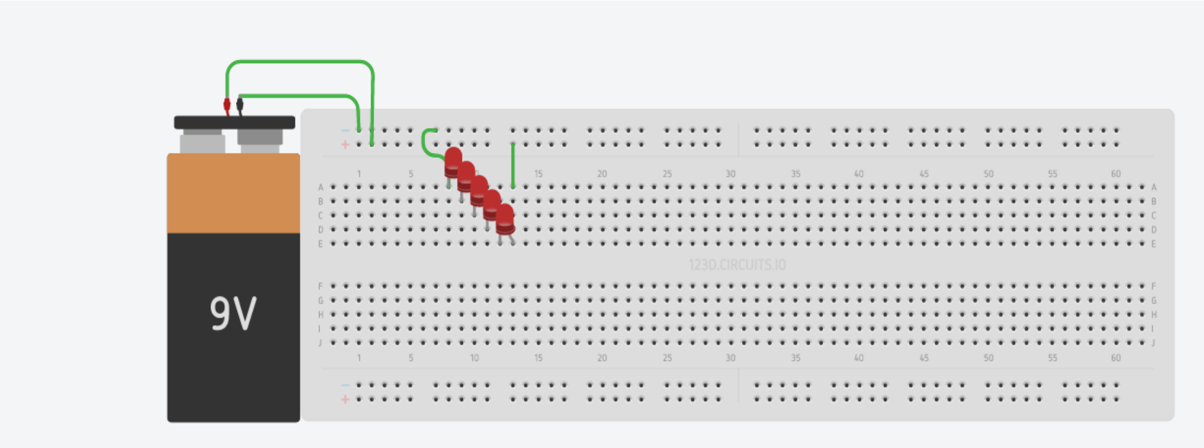
LED costume is for stage performers

The light from LEDs can be modulated very quickly so they are used extensively in optical fiber and free space optics communications. This includes remote controls, such as for TVs, VCRs, and LED Computers, where infrared LEDs are often used. Opto-isolators use an LED combined with a photodiode or phototransistor to provide a signal path with electrical isolation between two circuits. This is especially useful in medical equipment where the signals from a low-voltage sensor circuit (usually battery-powered) in contact with a living organism must be electrically isolated from any possible electrical failure in a recording or monitoring device operating at potentially dangerous voltages.

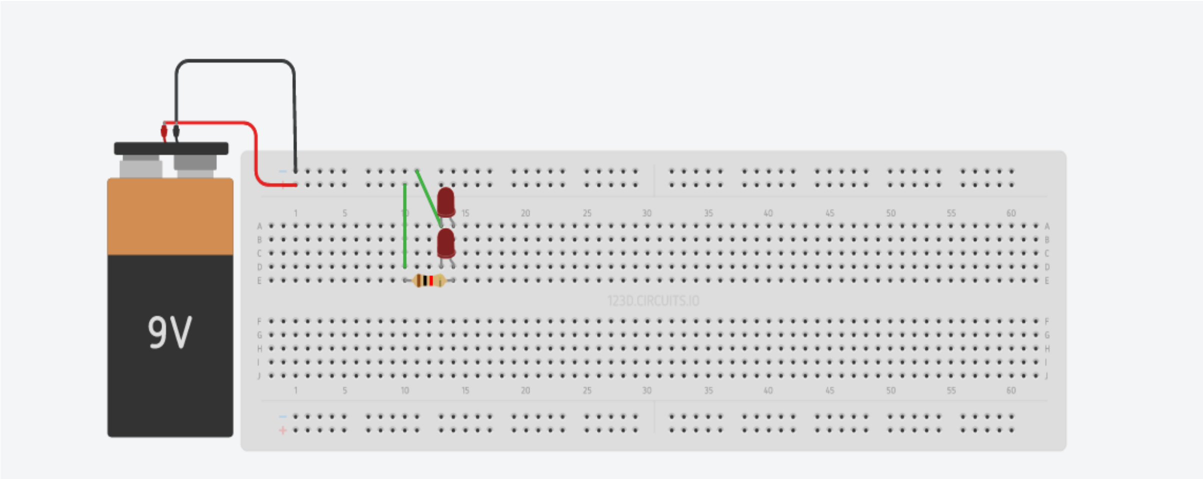
Activity

Make a Series and parallel LED circuit

Circuit Diagram (Series)



Circuit Diagram (Parallel)



Material Required

Name	Quantity
9V Battery	1
Resistors	1
LED	5
Breadboard	1

Instructions

For Series circuit

- Gather all the components from the list.
- Assemble all the components except the battery according to the circuit diagram shown above.
- Now connect the battery to the circuit.
- Now record your observations in the table below.

For Parallel circuit

- Gather all the components from the list.
- Assemble all the components except the battery according to the circuit diagram shown above.
- Now connect the battery to the circuit.
- Now record your observations in the table below.

Observations

	Intensity of LED(Dim)	Intensity of LED(Bright)
Series		
Parallel		

What is the difference between series and parallel connection?

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Why did we used resistance in parallel circuit?

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CHAPTER 4: POTENTIOMETER

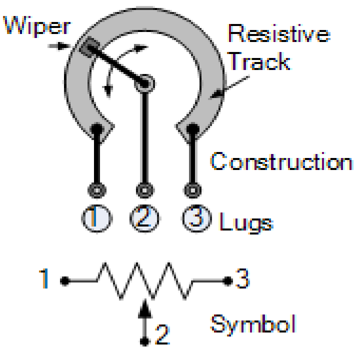
Resistors provide a fixed value of resistance that blocks or resists the flow of electrical current around a circuit, as well as producing a voltage drop in accordance with Ohm's law.

They can be manufactured to have either a fixed resistive value in Ohms or a variable resistive value adjusted by some external means.

Resistors provide a fixed value of resistance that blocks or resists the flow of electrical current around a circuit, as well as producing a voltage drop in accordance with Ohm's law. They can be manufactured to have a fixed resistive value in Ohms or a variable resistive value adjusted by some external means.

The **potentiometer**, commonly referred to as a "pot", is a three-terminal mechanically operated rotary analogue device which can be found and used in a large variety of electrical and electronic circuits. They are passive devices, meaning they do not require a power supply or additional circuitry in order to perform their basic linear or rotary position function. Variable potentiometers are available in a variety of different mechanical variations allowing for easy adjustment to control a voltage, current, or the biasing and gain control of a circuit to obtain a zero condition.

The name "potentiometer" is an acronym of the words *Potential Difference* and *Metering*, which came from the early days of electronics development when it was thought that adjusting large wire- wound resistive coils metered or measured out a set amount of potential difference making it a type of voltage-metering device.



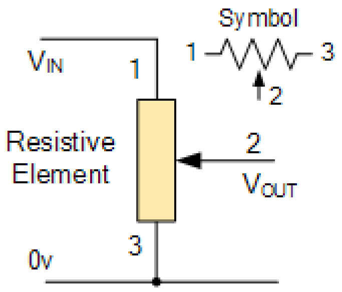
Today, potentiometers are much smaller and much more accurate than those early large and bulky variable resistances, and as with most electronic components, there are many different types and names ranging from variable resistor, preset, trimmer, rheostat and of course variable potentiometer.But whatever their name, these devices all function in exactly the same way in that their output resistance value can be changed or varied by the movement of a mechanical contact or wiper given by some external action.

Variable resistors in whatever format, are generally associated with some form of control, whether that is adjusting the volume of a radio, the speed of a vehicle, the frequency of an oscillator or accurately setting the calibration of a circuit, single-turn and multiple-turn potentiometers, trim-pots and rheostats find many uses in everyday electrical items.

The term *potentiometer* and *variable resistor* are often used together to describe the same component, but it is important to understand that the connections and operation of the two are different. However, both share the same physical properties in that the two ends of an internal resistive track are brought out to contacts, in addition to a third contact connected to a moveable contact called the "slider" or "wiper".

Potentiometer

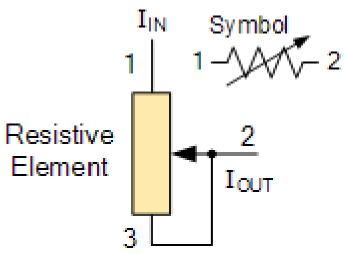
When used as a potentiometer, connections are made to both ends as well as the wiper, as shown. The position of the wiper then provides an appropriate output signal (pin 2) which will vary between the voltage level applied to one end of the resistive track (pin 1) and that at the other (pin 3).



The potentiometer is a three-wire resistive device that acts as a voltage divider producing a continuously variable voltage output signal which is proportional to the physical position of the wiper along the track.

Variable Resistor

When used as a variable resistor, connections are made to only one end of the resistive track (either pin 1 or pin 3) and the wiper (pin 2) as shown. The position of the wiper is used to vary or change the amount of effective resistance connected between itself, the movable contact, and the stationary fixed end.



Sometimes it is appropriate to make an electrical connection between the unused end of the resistive track and the wiper to prevent open-circuit conditions.

Then a variable resistor is a two-wire resistive device that provides an infinite number of resistance values controlling the current offered to the connected circuit in proportion to the physical position of the wiper along the track.

Potentiometer Types

Variable potentiometers are an analogue device consisting of two main mechanical parts. 1. A fixed or stationary resistive element, track or wire coil that defines its resistive value, such as 1kΩ, 10kΩ, etc, and 2. a mechanical part that allows a wiper or contact to move along the whole length of the resistive track changing its resistive value as it moves. There are many different ways to move the wiper across the resistive track either mechanically of electrically.

But as well as the resistive track and wiper, potentiometers also comprise of housing, a shaft, slider block, and a bush or bearing. The movement of the sliding wiper or contact can itself be a rotatory (angular) action or a linear (straight) action. There are four basic groups of variable potentiometers.

Rotary Potentiometer

Rotary potentiometer (the most common type) varies their resistive value as a result of an angular movement. Rotating a knob or dial attached to the shaft causes the internal wiper to sweep around a curved resistive element. The most common use of a rotary potentiometer is the volume-control pot.

Carbon rotary potentiometers are designed to be mounted onto the front panel of a case, enclosure or printed circuit board (PCB) using a ring nut and locking washer. They can also have one single resistive track or multiple tracks, known as a ganged potentiometer that all rotate together using one single shaft. For example, a dual-gang pot to adjust the left and right volume control of a radio or stereo amplifier at the same time. Some rotary pots include on-off switches.

Rotary potentiometers can produce a linear or logarithmic output with tolerances of typically 10 to 20 percent. As they are mechanically controlled, they can be used to the measure the rotation of a shaft, but a single-turn rotary potentiometer normally offers less than 300 degrees of angular movement from minimum to maximum resistance. However, multi-turn potentiometers, called trimmers, are available that allow for a higher degree of rotational accuracy.

Multi-turn potentiometers allow for a shaft rotation of more than 360 degrees of mechanical travel from one end of the resistive track to the other. Multi-turn pots are more expensive, but very stable with high precision used mainly for trimming and precision adjustments. The two most common multi-turn potentiometers are the 3-turn (1080^o) and 10-turn (3600^o), but 5-turn, 20-turn and higher 25-turn pots are available in a variety of ohmic values.

Slider Potentiometer

Slider potentiometers, or slide-pots, are designed to change the value of their contact resistance by means of a linear motion and as such there is a linear relationship between the position of the slider contact and the output resistance.

Slide potentiometers are mainly used in a large range of professional audio equipment such as studio mixers, faders, graphic equalizers and audio tone control consoles allowing the users to see from the position of the plastic square knob or finger-grip the actual setting of the slide.

One of the main disadvantages of a slider potentiometer is that they have a long open slot to allow the wiper lug to move freely up and down along the full length of the resistive track. This open slot makes the resistive track inside susceptible to contamination from dust and dirt, or by sweat and grease from the users hands. Slotted felt covers and screens can be used to minimise the effects of resistive track contamination.

As the potentiometer is one of the simplest ways of converting a mechanical positional into a proportional voltage, they can also be used as resistive position sensors, also known as a linear displacement sensor. Sliding carbon track potentiometers measure a precise linear (straight) motion with the sensor part of a linear sensor being the resistive element attached to a sliding contact. This contact is in turn attached via a rod or shaft to the mechanical mechanism to be measured. Then the position of the slide changes with respect to the quantity being sensed (the measurand) which in turn changes the resistive value of the sensor.

Presets and Trimmer's

Preset or trimmer potentiometers are small "set-and-forget" type potentiometers that allow for very fine or occasional adjustments to be easily made to a circuit, (e.g. for calibration). Single-turn rotary preset potentiometers are miniature versions of the standard variable resistor designed to be mounting directly on a printed circuit board and are adjusted by means of a small bladed screwdriver or similar plastic tool.

Generally, these linear carbon track preset pots are of an open skeleton design or of a closed square shape that once the circuit is adjusted and factory set, are then left at this setting, being only adjusted again if some changes occur to the circuit settings.

Being of an open construction, skeleton preset's are prone to mechanical and electrical degradation affecting the performance and accuracy so are therefore not suitable for continuous use, and as such, preset pots are only mechanically rated for a few hundred operations. However, their low cost, small size and simplicity makes them popular in non-critical circuit applications.

Presets can be adjust from its minimum to maximum value within a single turn, but for some circuits or equipment this small range of adjustment may be too coarse to allow for very sensitive adjustments. Multi-turn variable resistors however, operate by moving the wiper arm using a small screwdriver some number of turns, ranging from 3 turns to 20 turns enabling very fine adjustments.

Trimmer potentiometers or “trim pots” are multi-turn rectangular devices with linear tracks that are designed to be installed and soldered directly onto a circuit board either through-hole or as surface-mount. This gives the trimmer both electrical connections and mechanical mounting and encasing the track within a plastic housing avoids the problems of dust and dirt during use associated with skeleton presets.

Rheostats

Rheostats are the big boys of the potentiometer world. They are two connection variable resistors configured to provide any resistive value within their ohmic range to control the flow of current through them.

While in theory, any variable potentiometer can be configured to operate as a rheostat, generally rheostats are large high wattage, wire-wound variable resistors, used in high current applications as the main advantage of the rheostat is their higher power rating.

When a variable resistor is used as a two-terminal rheostat, only the portion of the total resistive element that is in between the end terminal and the movable contact will be dissipating power. Also, unlike the potentiometer configured as a voltage divider, all the current flowing through the rheostats resistive element also passes through the wiper circuit. Then the contact pressure of the wiper on this conductive element must be capable of carrying the same current.

Potentiometer Applications

Potentiometers are rarely used to directly control significant amounts of power (more than a watt or so). Instead they are used to adjust the level of analog signals (for example volume controls on audio equipment), and as control inputs for electronic circuits. For example, a light dimmer uses a potentiometer to control the switching of a TRIAC and so indirectly to control the brightness of lamps.

Audio control

Linear potentiometers (faders)Low-power potentiometers, both linear and rotary, are used to control audio equipment, changing loudness, frequency attenuation, and other characteristics of audio signals.
The 'log pot' is used as the volume control in audio power amplifiers, where it is also called an "audio taper pot", because the amplitude response of the human ear is approximately logarithmic. It ensures that on a volume control marked 0 to 10, for example, a setting of 5 sounds subjectively half as loud as a setting of 10. There is also an *anti-log pot* or *reverse audio taper* which is simply the reverse of a logarithmic potentiometer. It is almost always used in a ganged configuration with a logarithmic potentiometer, for instance, in an audio balance control.

Potentiometers used in combination with filter networks act as tone controls or equalizers.

- ### Television

Potentiometers were formerly used to control picture brightness, contrast, and color response. A potentiometer was often used to adjust "vertical hold", which affected the synchronization between the receiver's internal sweep circuit (sometimes a multivibrator) and the received picture signal, along with other things such as audio-video carrier offset, tuning frequency (for push-button sets) and so on.

- ### Motion control

Potentiometers can be used as position feedback devices in order to create "closed loop" control, such as in a servomechanism. This method of motion control used in the DC Motor is the simplest method of measuring the angle, speed and displacement.

- ### Transducers

  Potentiometers are also very widely used as a part of displacement transducers because of the simplicity of construction and because they can give a large output signal.

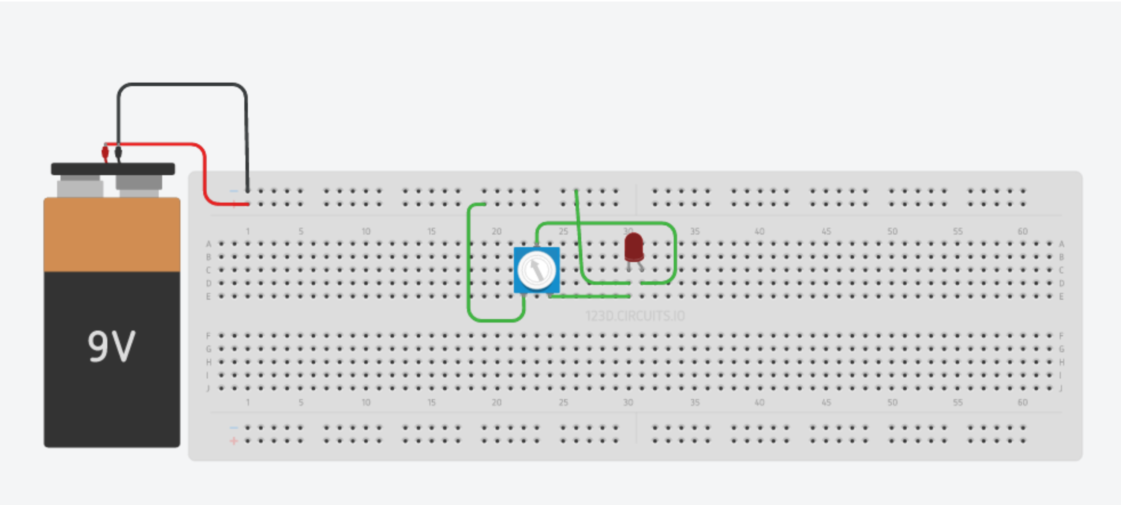
- ### Computation

  In analog computers, high precision potentiometers are used to scale intermediate results by desired constant factors, or to set initial conditions for a calculation. A motor-driven potentiometer may be used as a function generator, using a non-linear resistance card to supply approximations to trigonometric functions. For example, the shaft rotation might represent an angle, and the voltage division ratio can be made proportional to the cosine of the angle.

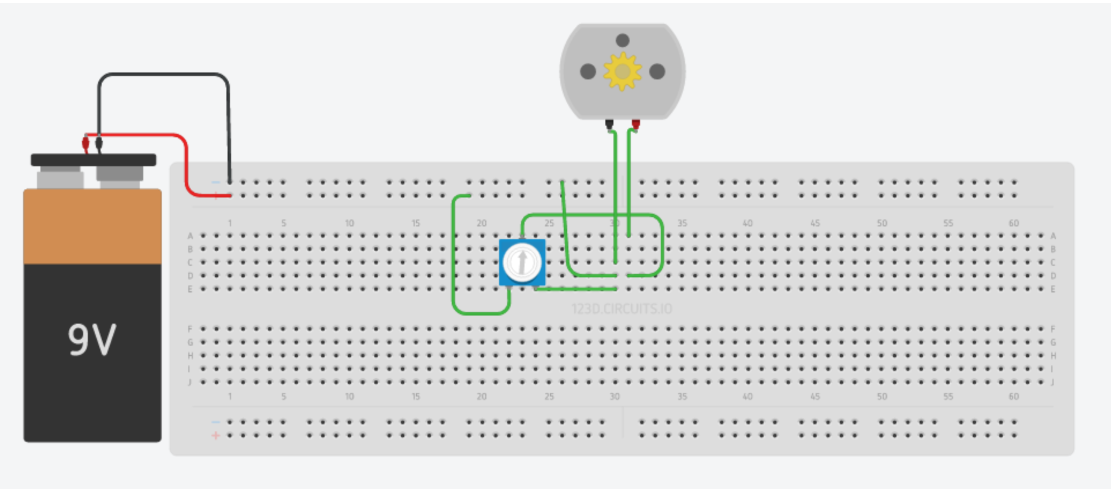
Activity

Make a dimmable LED and fan circuit using potentiometer

Circuit Diagram (LED)



Circuit Diagram (fan)



Material Required

Name	Quantity
9V Battery	1
Potentiometer	1
LED	1
Breadboard	1
Motor	1

Instructions

For LED circuit

- Gather all the components from the list.
- Assemble all the components except the battery according to the circuit diagram shown above.
- Now connect the battery to the circuit.
- Now rotate the pot and record your observations in the table below.

For Fan circuit

- Gather all the components from the list.
- Assemble all the components except the battery according to the circuit diagram shown above.
- Now connect the battery to the circuit.
- Now rotate the pot and record your observations in the table below.

Observations

Position of Pot	Intensity of LED	Speed of Fan
Extreme Left		
Extreme Right		
Middle		

Explain the reason behind your observation.

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What will happen when you increase the resistance?

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Chapter 5:7-SEGMENT DISPLAY

An LED or Light Emitting Diode is a solid state optical PN-junction diode which emits light energy in the form of “photons” when it is forward biased by a voltage allowing current to flow across its junction, and in Electronics we call this process electroluminescence.

The actual colour of the visible light emitted by an LED, ranging from blue to red to orange, is decided by the spectral wavelength of the emitted light which itself is dependent upon the mixture of the various impurities added to the semiconductor materials used to produce it.

Light emitting diodes have many advantages over traditional bulbs and lamps, with the main ones being their small size, long life, various colours, cheapness and are readily available, as well as being easy to interface with various other electronic components and digital circuits.

But the main advantage of light emitting diodes is that because of their small die size, several of them can be connected together within one small and compact package producing what is generally called a **7-segment Display**.

Seven Segment Display

The *7-segment display*, also written as “seven segment display”, consists of seven LEDs (hence its name) arranged in a rectangular fashion as shown. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit (both Decimal and Hex) to be displayed. An additional 8th LED is sometimes used within the same package thus allowing the indication of a decimal point, (DP) when two or more 7-segment displays are connected together to display numbers greater than ten.

Each one of the seven LEDs in the display is given a positional segment with one of its connection pins being brought straight out of the rectangular plastic package. These individually LED pins are labelled from a through to g representing each individual LED. The other LED pins are connected together and wired to form a common pin.

So by forward biasing the appropriate pins of the LED segments in a particular order, some segments will be light and others will be dark allowing the desired character pattern of the number to be generated on the display. This then allows us to display each of the ten decimal digits 0 through to 9 on the same 7-segment display.

Each one of the seven LEDs in the display is given a positional segment with one of its connection pins being brought straight out of the rectangular plastic package. These individually LED pins are labelled from a through to g representing each individual LED. The other LED pins are connected together and wired to form a common pin.

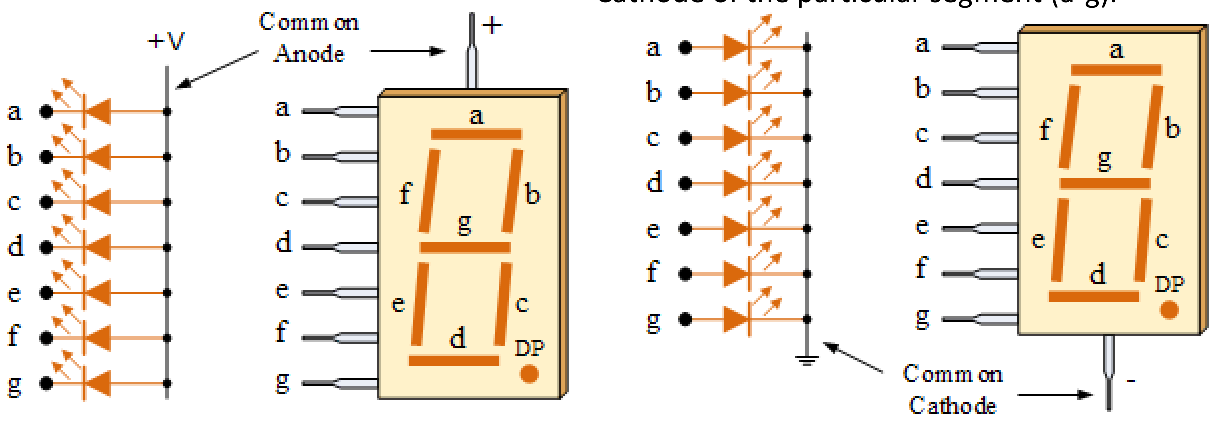
So by forward biasing the appropriate pins of the LED segments in a particular order, some segments will be light and others will be dark allowing the desired character pattern of the number to be generated on the display. This then allows us to display each of the ten decimal digits 0 through to 9 on the same 7-segment display.

The displays common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the "Anode" and the other called the "Cathode", there are therefore two types of LED 7-segment display called: **Common Cathode** (CC) and **Common Anode** (CA).

The difference between the two displays, as their name suggests, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows.

1. The Common Cathode (CC) – In the common cathode display, all the cathode connections of the LED segments are joined together to logic "0" or ground. The individual segments are illuminated by application of a "HIGH", or logic "1" signal via a current limiting resistor to forward bias the individual Anode terminals (a-g).

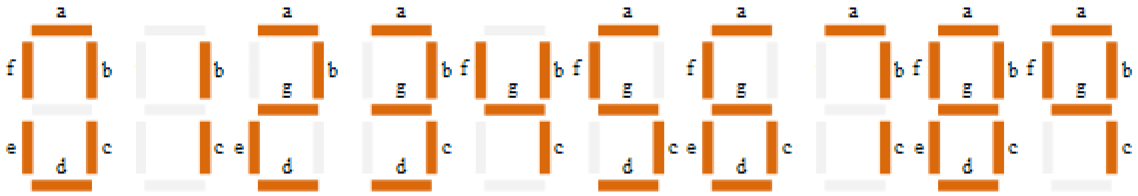
2. The Common Anode (CA) – In the common anode display, all the anode connections of the LED segments is joined together to logic "1". The individual segments are illuminated by applying a ground, logic "0" or "LOW" signal via a suitable current limiting resistor to the Cathode of the particular segment (a-g).



In general, common anode displays are more popular as many logic circuits can sink more current than they can source. Also note that a common cathode display is not a direct replacement in a circuit for a common anode display and vice versa, as it is the same as connecting the LEDs in reverse and hence light emission will not take place.

Depending upon the decimal digit to be displayed, the particular set of LEDs is forward biased. For instance, to display the numerical digit 0, we will need to light up six of the LED segments corresponding to a, b, c, d, e and f. Then the various digits from 0 through 9 can be displayed using a 7-segment display as shown.

7-Segment Display Segments for all Numbers

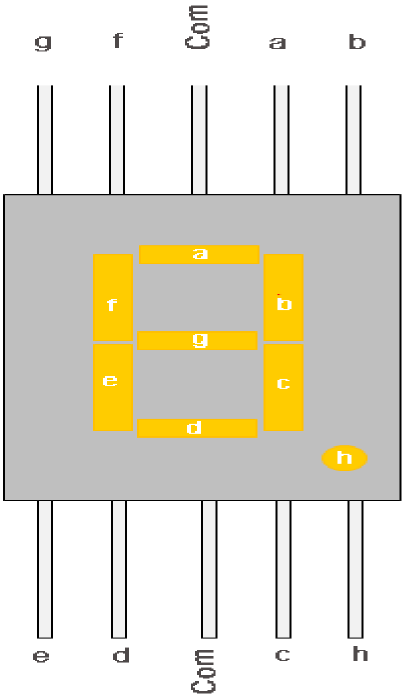


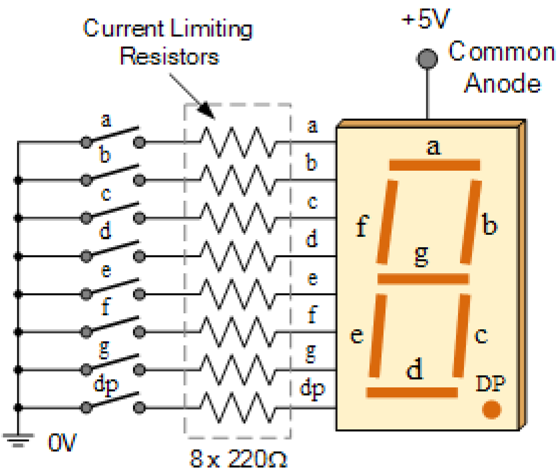
Then for a 7-segment display, we can produce a truth table giving the individual segments that need to be illuminated in order to produce the required decimal digit from 0 through 9.

7-segment Display Truth Table

Decimal Digit	Individual Segments Illuminated						
	a	b	c	d	e	f	g
0	x	x	x	x	x	x	
1		x	x				
2	x	x		x	x		x
3	x	x	x	x			x
4		x	x			x	x
5	x		x	x		x	x
6	x		x	x	x	x	x
7	x	x	x				
8	x	x	x	x	x	x	x
9	x	x	x			x	x

Pin Structure of Seven Segment Display





In this example, the segments of a common anode display are illuminated using the switches. If switch “a” is closed, current will flow through the “a” segment of the LED to the current limiting resistor connected to pin “a” and to 0 volts, making the circuit. Then only segment a will be illuminated. So, a LOW condition (switch to ground) is required to activate the LED segments on this common anode display.

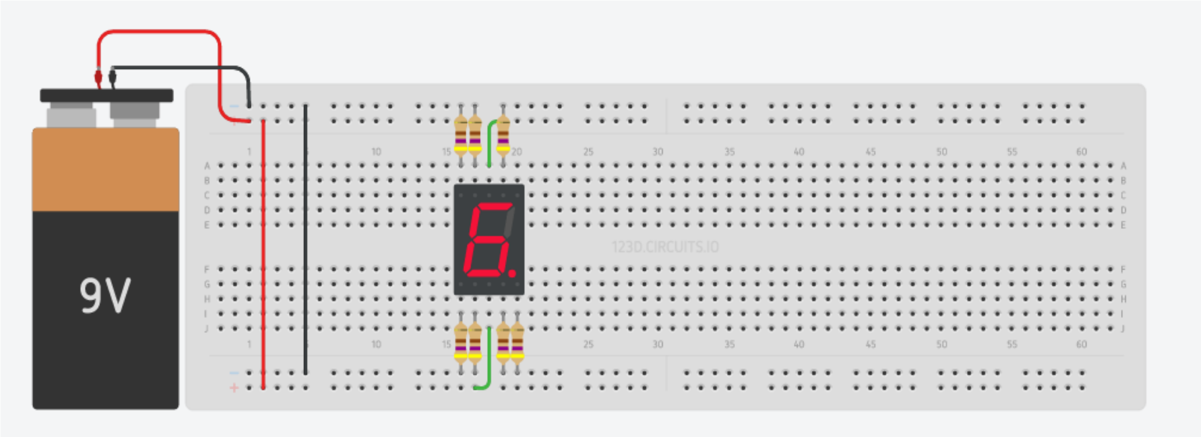
But suppose we want the decimal number “4” to illuminate on the display. Then switches b, c, f and g would be closed to light the corresponding LED segments. Likewise, for a decimal number “7”, switches a, b, c would be closed. But illuminating 7-segment displays using individual switches is not very practical.

7-segment Displays are usually driven by a special type of integrated circuit (IC) commonly known as a 7-segment decoder/driver, such as the CMOS 4511. This 7-segment display driver which is known as a Binary Coded Decimal or BCD to 7-segment display decoder and driver are able to illuminate both common anode and common cathode displays. But there are many other single and dual display drivers available such as the very popular TTL 7447.

Activity

Display a number on seven segment display

Circuit Diagram (LED)



Material Required

Name	Quantity
9V Battery	1
Resistance	8
Seven Segment Display	1
Breadboard	1

Instructions

For displaying number 6

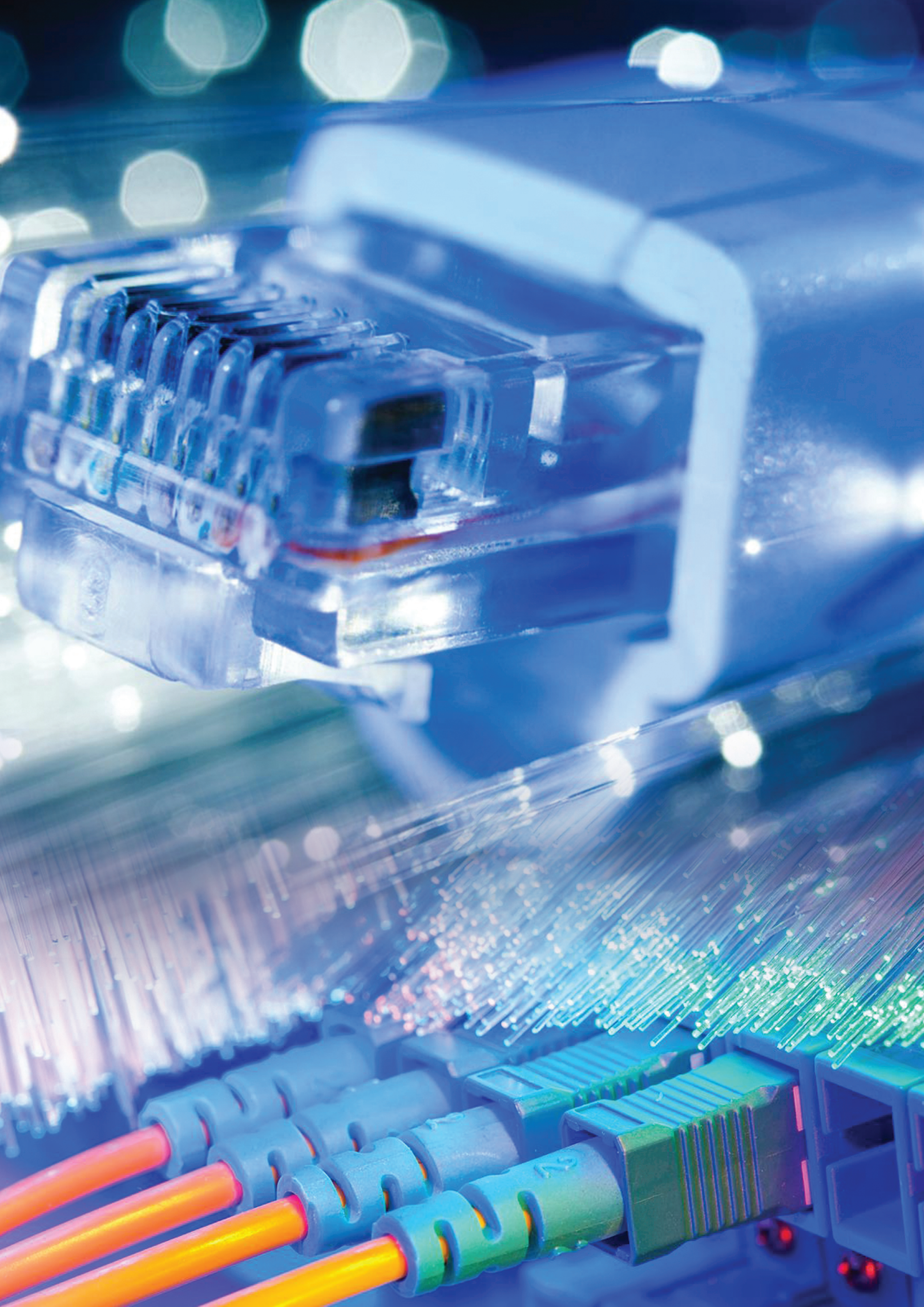
- Gather all the components from the list.
- Assemble all the components except the battery according to the circuit diagram shown above.
- Now connect the battery to the circuit.
- Record your observations in table below.

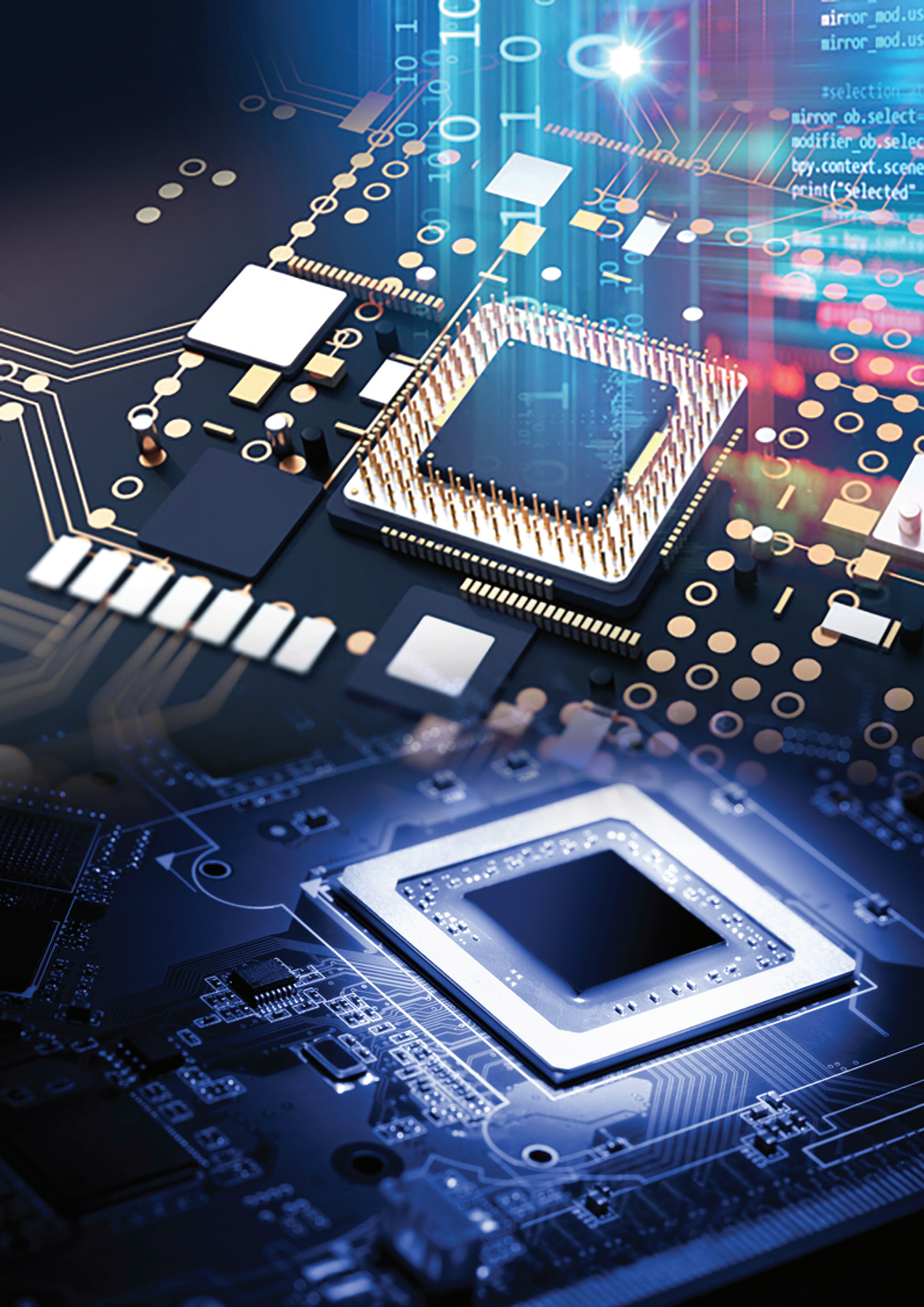
Observations

Pin connected	6
A	
B	
C	
D	
E	
F	
G	
DP	

Now try displaying different numbers and record your observations in table below.

Pin connected	Number-	Number-	Number-
A			
B			
C			
D			
E			
F			
G			
DP			




mirror_mod.us
mirror_mod.us
#selection
mirror_ob.select=
modifier_ob.selec
bpy.context.scene
print("Selected"