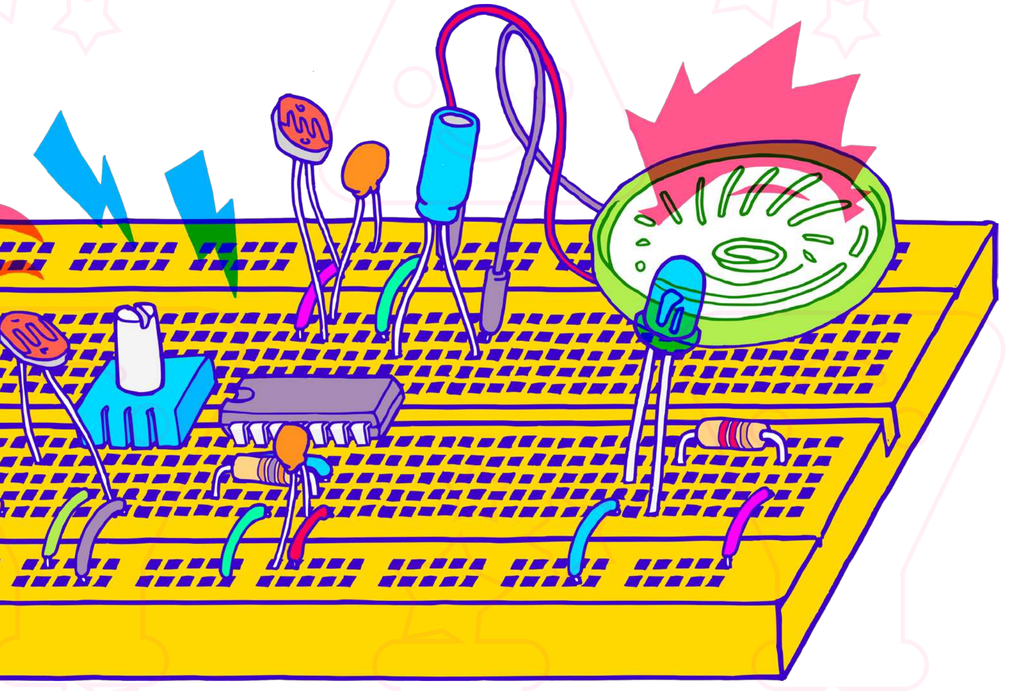
# DISCOVER
# ELECTRONICS
## LESSON BOOK



SPARKLE LABS

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# Welcome

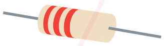
This kit will get you acquainted with the basic principles and components of electronics. These projects will teach you how to read schematics in order to build an electronic circuit and begin the process of understanding how the things around you work. Knowing basic electronics can create careers, artists and great problem solving skills. Sparkle Labs has made this friendly kit for you to become an inventor!

All of the projects in the kit will build on each other. By the end of the manual, you should be able to create your own projects. You can also get one of the Discover Electronics add-on kits to continue experimenting with different kinds of inputs and outputs. Watch the videos and get more projects online at sparklelabs.com.

Sparkle Labs

# Contents

# Components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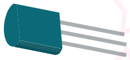
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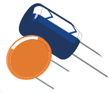
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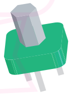
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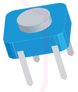
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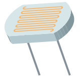
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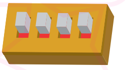
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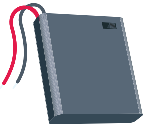
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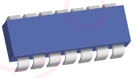
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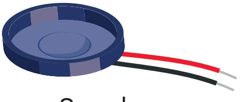
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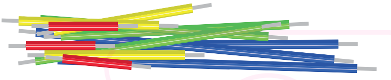
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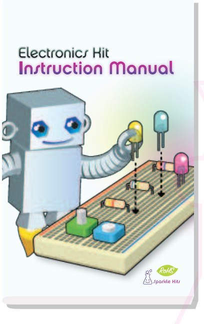

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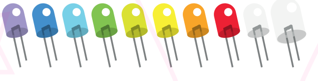
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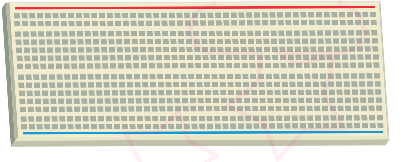
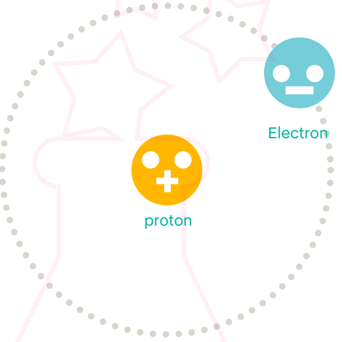

Solderless Breadboard

# Electron Proton Neutron

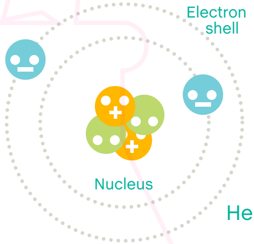



All matter is made of atoms. Atoms are made up of tiny particles we call electrons, protons and neutrons. Protons and, usually, neutrons form the center (nucleus) of the atom. Electrons spin around the nucleus.

All matter is made up of these few parts. It is only the number and arrangement of the particles that makes one type of matter different from another.

These particles can have an electrical charge. Protons have a positive electrical charge and electrons have a negative electrical charge. Positive and negative are attracted to one another while like charges repel one another.

The electrons spin in different levels called electron shells. Electrons in the smaller/closer electron shells have less energy then electrons in the further/larger shells. Electrons and protons usually balance out so the overall electrical charge of an atom is neutral, not positive or negative.




Helium atom

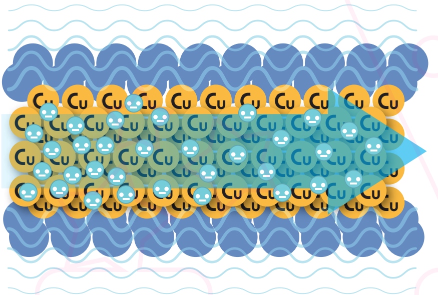
If the protons and electrons are out of balance the atom has an electrical charge. An atom with more electrons than protons has a negative electrical charge. Electrons can move from one atom to another because they are attracted to positively charged atoms and repulsed by negatively charged atoms.

Conductors are materials that conduct electricity well. Conductors, like a copper wire, are made up of atoms that gain and lose electrons easily, allowing the electrons to be passed

Electrons jump from the shell of one atom to the shell of another.

down the wire. Insulators are materials that do not allow electrons to move easily, like the rubber coating on your wire. The electrons actually move down the wire quite slowly. As they move they repulse the electrons in front of them creating a wave of repulsive force which moves down the wire very quickly.

These electrons can have a number of different effects as they move. They can bump into atoms on the way and cause them to move around which is heat. They can move up and down the electron shells of atoms. If they move down to lower energy shells they give up the excess energy in the form of photons (light). They also create invisible electromagnetic waves as they travel. These waves can create electric current in matter that they touch as well as create motion by the attraction and repulsion of magnetic waves.



We use all of these properties of electrons in different ways. We create heat to cook food and keep us warm. We create light to see. We create motion to turn fans and push trains. We also use electricity to send and receive information. It can send information through wires or create electromagnetic waves to send information through the air.

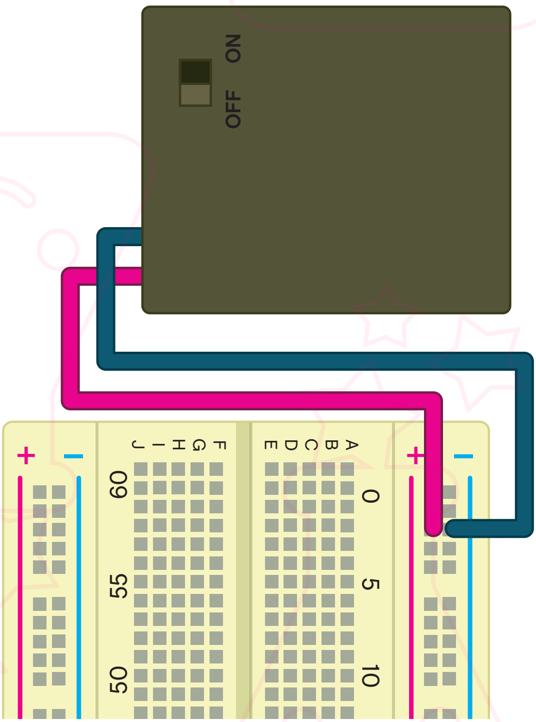
# Solderless Breadboard

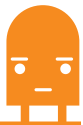
Our breadboard contains strips of metal clips we use as conductors. By connecting parts with the metal strips we can guide the flow of electrons through our circuit.

First we need to power our breadboard. As electrons must flow between positive and negative this means connecting both positive and negative sides of our power supply to the breadboard. This way electrons will be able to flow to our parts.

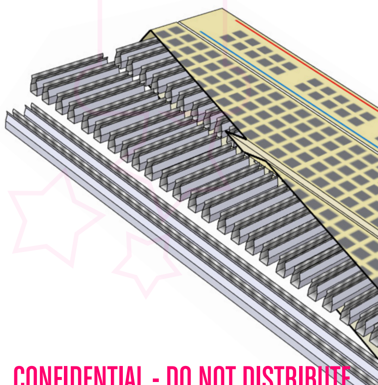
There are two long metal strips that run along the side of the board. We will use these for positive and negative. First make sure your battery pack power switch is in the OFF position. Then connect the red and black wires from the battery pack to the breadboard as shown.

Red is used for positive while blue and black are negative. This wiring will distribute positive and negative charge down one side of the board.

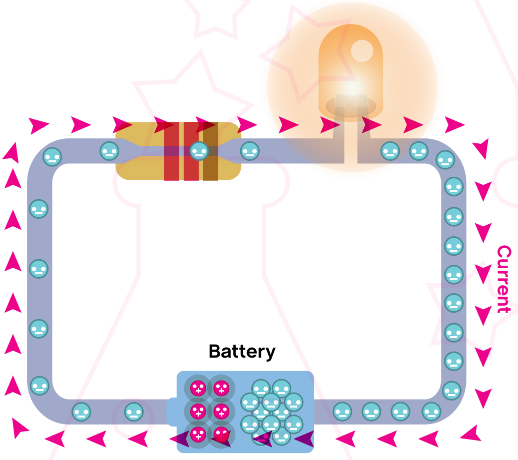


*The numbers and letters don't really matter but the strips of metal inside the board do.*



# Create a circuit




A power source provides a difference in electrical charge which causes electrons to travel through the circuit. A circuit must have a place for the electrons to come from (negative) and a place for the electrons to move to (positive). The current is said to flow from positive to negative, attracting the electrons. Positive and negative are sometimes referred to as power and ground.

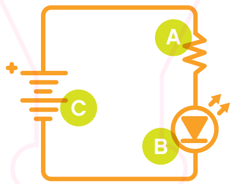
This diagram shows a light emitting diode (LED) driver circuit. A battery has a difference in electrical charge. The LED converts some of the electrical energy into light. There is also a resistor which slows the flow of electricity, protecting the LED from burning out.

We can learn a lot from this basic circuit. Build the circuit on your breadboard. Begin by analyzing an LED. LEDs are polarized meaning that current can flow through them in only one direction. Look at the wires coming from your LED. We call these wires leads (pronounced *leeds*). The longer lead must be connected to positive and is called the anode. Connect the shorter lead to the negative line on your breadboard and the longer lead to one of the numbered columns.

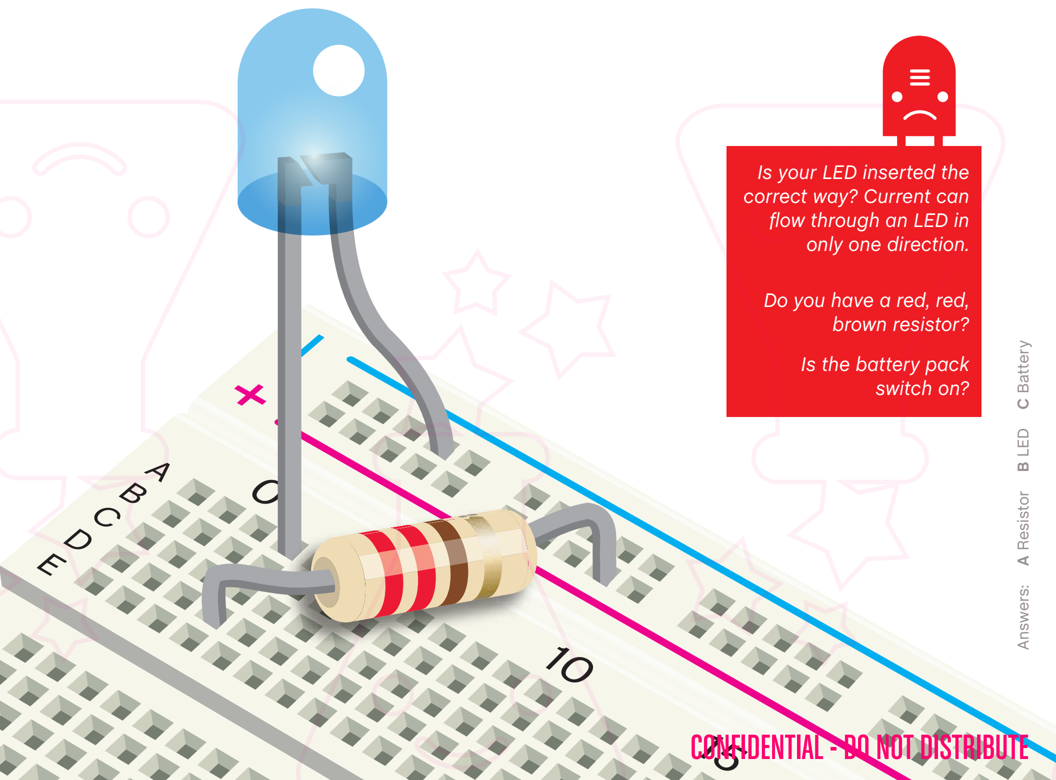
Next we need a resistor. Resistors limit the amount of current that can flow through the circuit. Colored stripes on the resistor tell us how much resistance it has. Find a resistor that has red, red, brown and then a metallic stripe.

The resistor is not polarized so it allows current to flow in either direction. Insert one lead of the resistor in the same column as the LED and the other into the positive line. This creates a complete circuit through which the current will flow. Try to envision the current flowing through the circuit. Trace the current moving from the positive lead of the power supply, through the breadboard, into the resistor, then the LED, through the breadboard again and finally into the negative lead of the battery pack.

Flip the switch on your battery pack and electricity flows through the circuit. Electrons lose energy as they move through the LED which is released as light.




Here is a schematic version of the same circuit. Can you tell which part is which?




*Is your LED inserted the correct way? Current can flow through an LED in only one direction.*

*Do you have a red, red, brown resistor?*

*Is the battery pack switch on?*

Answers: **A** Resistor **B** LED **C** Battery

# Volts Amps Ohms

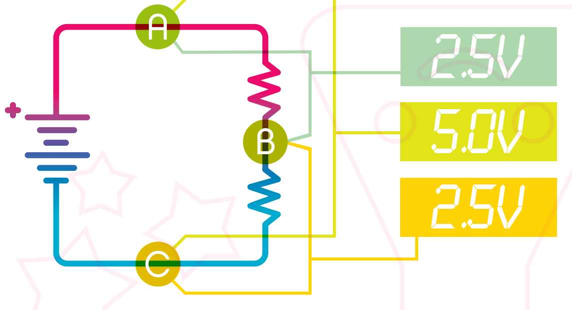
$$V=IR$$

The symbol for volts is V. As in “5V battery”.

You can think of the difference in electrical charge in a circuit as electrical pressure. The greater the difference between the two sides the more pressure there is pushing the electrons through the circuit. We call the difference in electrical charge *voltage*. We measure the amount of voltage in units called *volts*.

Voltage must be measured between two points because voltage is the difference in charge between two points.

Examine the following circuit which has two resistors connected to a 5V battery. If we measure the voltage between points **A** and **C** we will see that it is 5V. Point **B** is being pulled in both directions through the resistors. If the resistors are both the same then the voltage at this point will be half way between **A** and **C** and the difference between both points and **A/B** and **B/C** will be the same.




6.241x10^18 = 6241000000000000000

Voltage is the pressure that pulls the electrons but how many electrons move through the circuit in one second is the current. Current is measured in amperes, also called amps. One amp is defined as 6.241 × $10^{18}$ electrons moving through a given point in a circuit each second.

The symbol for amps is I.

Unlike voltage, we measure current at a single point in a circuit. In this simple circuit there is only one path for the current to flow so

Oh my! Math. You can skim this section and get the basic concepts or dig into all of the videos.

it does not matter where the point is. The current will be the same throughout the circuit.

The third measurement we use to describe a circuit is the resistance. Resistance limits the amount of current that moves through the circuit. It holds back the electrical pressure (voltage). Resistance is measured in units called Ohms.

The relationship between these three units can be described with Ohm's Law.

The symbol for ohms is Ω, the omega symbol.

## Voltage(V) = Current(I) x Resistance(R)

We can write this as V=IR. If we wanted to solve for resistance we can use R=V/I. If for current we can use I=V/R.

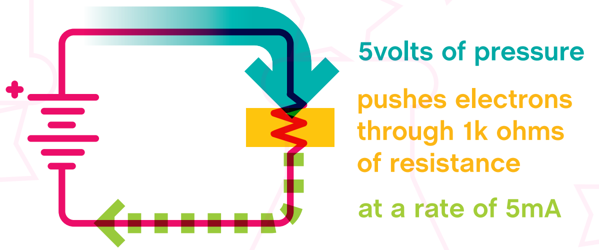
Let us examine the following circuit. Here we have a 5V battery connected with a 1000 Ohm resistor. We can use Ohm's Law to calculate the current that must run through the circuit.

Another way to say 1000 is 1K and Another way to say .005 amps is 5 milliamperes.

The current = 5 volts divided by 1000 ohms. So the current is .005 amps.

Here is the same equation again: 5mA = 5V / 1KΩ

Voltage, current, and resistance are three basic measurements used to design circuits.



# Troubled Circuits

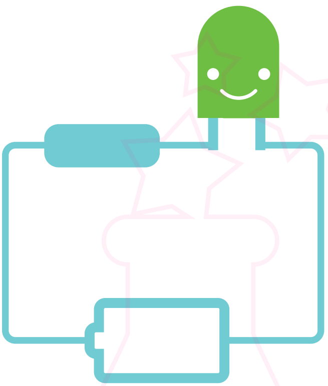
Don't worry, it is normal to have to debug your circuit. There are a lot of things that could go wrong. The first thing to do is disconnect the battery.

The most likely problem is that the wiring is incorrect. In which case, it could be a short circuit. This happens when some or all of the parts are bypassed. The metal parts of components should not touch each other in the wrong place.

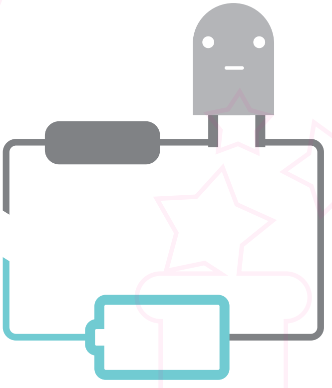
The problem could be an open circuit, meaning that positive and negative are not connected at all. A wire or lead could be in the wrong place or a component could be inserted incorrectly. The battery and LED are polarized. They must be inserted in a specific direction.

Check all of your connections carefully. Compare it with the illustrations. Sometimes there can be a loose connection that looks fine to the eye. Fix any errors you find and reconnect the battery. Other potential issues, the battery may have died, a part may be faulty, or a part may have burned out.

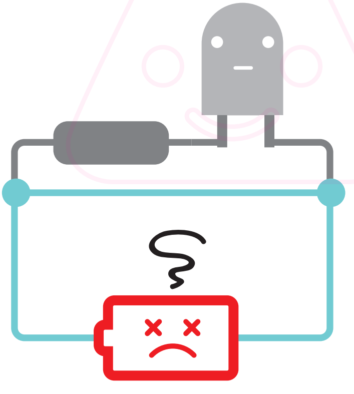
*Having trouble? Try to follow the path of the electricity as it moves from the battery, through the circuit and back to the battery.*



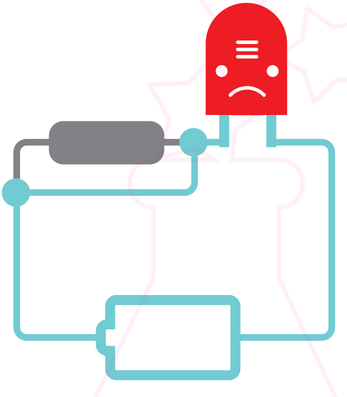
When wired correctly the circuit provides a path through all of the parts to connect the two terminals of the battery.



**OPEN CIRCUIT**
An opening in the circuit breaks the path of the electricity.



**SHORT CIRCUIT**
The circuit bypasses the parts so that the terminals of the battery are directly connected. The battery will lose power and may overheat.

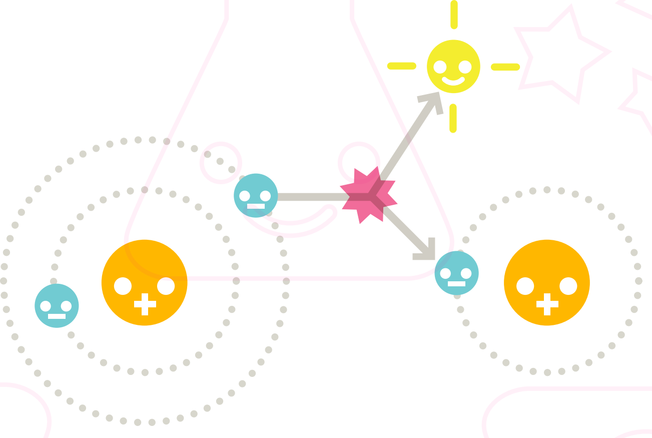


**SHORT CIRCUIT**
The circuit bypasses the resistor. The LED is exposed to too much current and may burn out.

# Light Emitting Diode

Electrons orbit atoms at different energy levels. If an electron moves from a high energy orbit to a lower energy orbit that excess energy must go somewhere.

Light emitting diodes contain a meeting of two different semiconducting materials. As electrons move through the LED they move from the atoms of one of the materials to the atoms of the other. As they pass through the junction, to a lower orbit, that energy is released as photons of light.



How much energy is lost is dependent on the types of materials used. Different energy levels of photons are different frequencies of light and different frequencies of light are different colors of light.

Current moving through the resistor creates heat. The more current the LED is exposed to, the brighter it will be, but too much current will burn it out. We use a resistor to protect our LED but if we want our LED to be as bright as possible we need to determine the lowest resistance that will still protect the LED.

| | |
|---|---|
| violet | 3.5v |
| big blue | 3.2v |
| blue | 3.4v |
| aqua | 3.5v |
| green | 2.6v |
| lime green | 2.1v |
| yellow | 2.1v |
| orange | 2.2v |
| red | 1.7v |
| white | 3.2v |

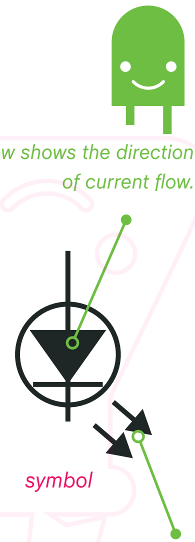

If you want to calculate the lowest possible resistor, first, choose the color of the LED you want by using the 220Ω resistor. Then look up the voltage drop for that color (see sidebar) and calculate the resistance using this formula:

**R = ( VS – VL ) / I**

Resistance equals the supply voltage (5 volts) minus the voltage drop (depends on color) divided by the desired current. For the LEDs in this kit, the desired current is .02 amps.

For example: **165 = ( 5 – 1.7) / .02**

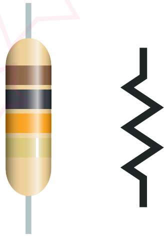
In this case, you would choose the resistor with the closest, greater value to 165Ω. Find out about resistors in the next section.



# The Resistor

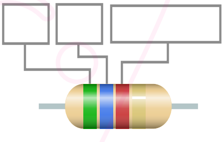
Resistors limit the flow of electricity. The material that resistors are made of limits electrical flow. Resistors can be combined in series or in parallel which changes the amount of resistance.

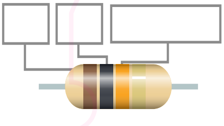
Resistors use colored stripes to indicate the amount of resistance. It is easy to read the stripes so long as you know the code. Most resistors use three colored bands plus a metallic band. The metallic is the final band and indicates only the amount of accuracy the resistor may have.

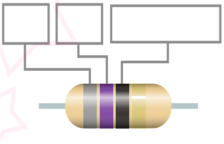


*symbol*


Solve these:







To read the code look up the number for the first color and the second color. The third color band is the multiplier, it tells you the number of zeros to put behind the other two numbers. For example, if you are looking for a 220Ω resistor, you would look on the chart to see which color stands for 2. Now we know the first two stripes are red. You want a single zero so look up the color for one. red, red, brown is a 220Ω resistor.

Big Boys Race Our Young Girls But Violet Generally Wins.

# Series / Parallel

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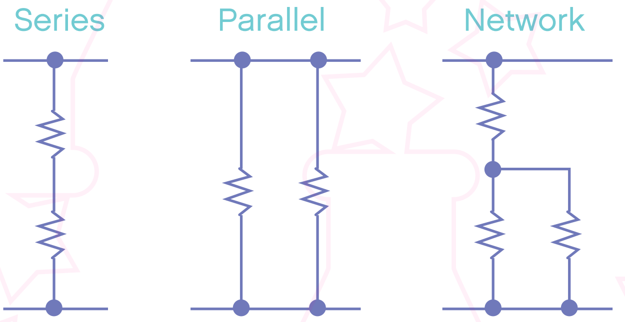



What if you don't have the resistance required? You can combine resistors to create the OHMs (Ω) you need for your circuit.

Series and parallel are an important aspect of electronic circuits.

Our first circuit was an LED in series with a resistor. The LED was in a sequence with the resistor along the electrical flow. If either were removed electrical flow would cease. Components that are in parallel run side-by-side and if either component were removed, electricity would still flow through the other components.

The total resistance for all of the resistors in series is the sum of the resistance of each resistor.

$$R_1+R_2 = R_{total}$$

For two 220Ω resistors the total resistance would be 440Ω.

For resistors in parallel add the reciprocal of each resistor to find the reciprocal of the total.

$$1/R_1+1/R_2 = 1/R_{total}$$

For two 220Ω resistors the total is 110Ω.

For a resistor network, calculate groups of resistors separately. In the network shown to the top right, you could determine the resistance of the two parallel resistors and then add it to the final resistor to determine the resistance of the overall network.

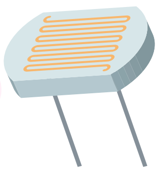
If all of these resistors are 220Ω then the solution is 330Ω.

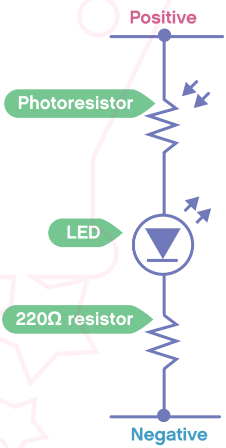
Answers: 5600Ω 10,000Ω 87Ω

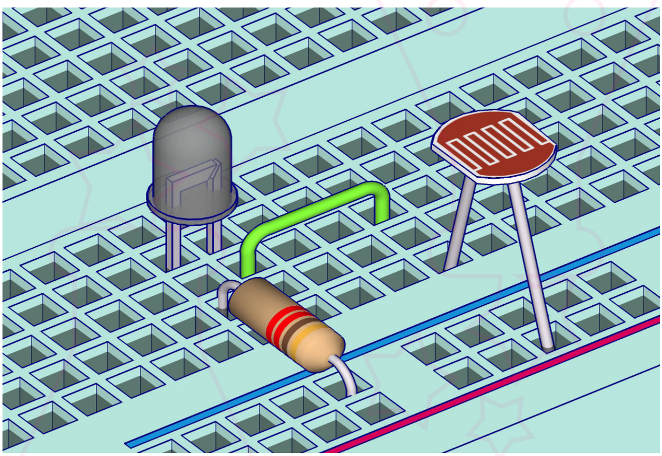
# Photoresistor

Photoresistors are a kind of variable resistor. It is a light dependent resistor (LDR). Photons hitting the photoresistor allow electricity to pass. Resistance decreases as more light hits the photoresistor. Photoresistors are often used in products as inexpensive light sensors.

Try placing it in series with the LED driver circuit. See what effect light shining on the photoresistor has on the LED. In this case, the photoresistor is limiting current to the LED. The photoresistor could also be part of a voltage divider which we will see in the next section.





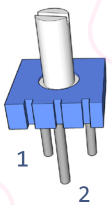
# Potentiometer

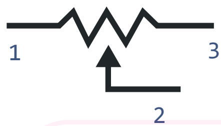
Potentiometers are resistors with variable resistance. Turning a knob changes the amount of resistance. Potentiometers are often used for controls like the volume knob on your stereo.

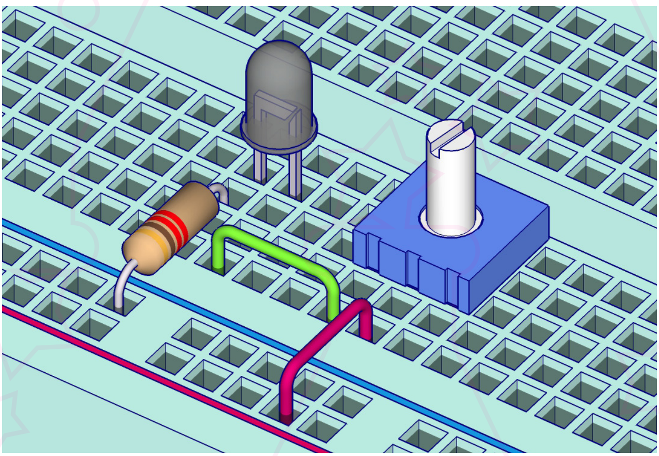
Potentiometers are described by the maximum amount of resistance they can provide. A 10K potentiometer can be adjusted to between 0Ω and 10,000Ω.

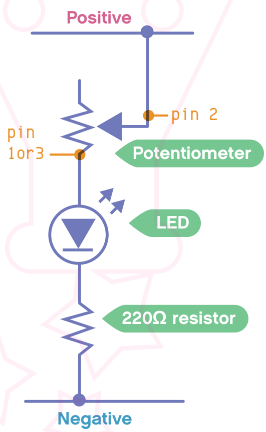
Most potentiometers have three leads. Two of the leads are on either side of the resistive element. The resistance between these two leads is always the maximum. The center lead (pin 3) is the 'wiper.' Turning the knob moves the wiper between the other two leads. The resistance between the wiper and either lead depends on the position of the knob.

Use a potentiometer to vary the resistance in an LED driver circuit. Place the potentiometer in series with the LED so that electricity can flow through the wiper to one of the leads. The other lead is not connected.



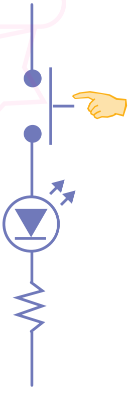



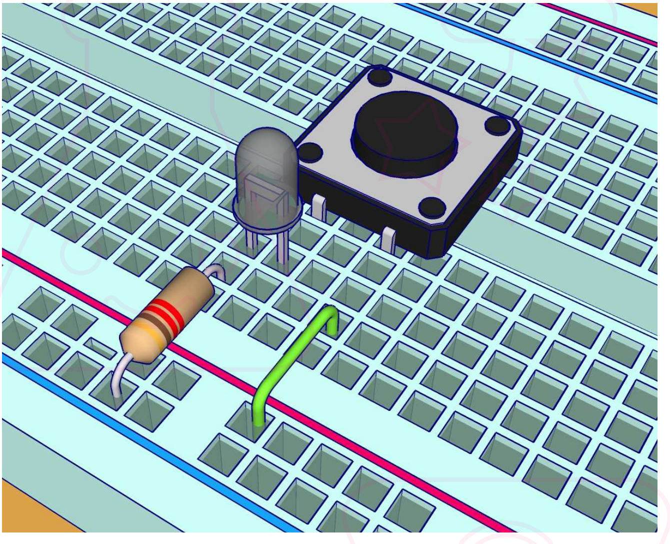


# Buttons & switches

Switches are electromechanical devices that allow you to open and close the circuit at will. They are a kind of sensor that can detect when they are pressed like a light switch. Flip the switch on and electricity passes through the switch. Flip it off and it opens the circuit, not allowing any electricity to pass.

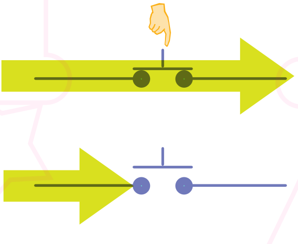


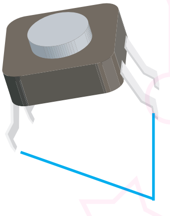
Notice that the switch can go anywhere in the series so long as it breaks the circuit.



The buttons in this kit have two pairs of leads. Each lead in a pair is always connected. Both pairs are connected to one another only while the button is pressed.

Try placing a button in your LED circuit. If the LED is always on, rotate it 90° and replace it in the circuit.



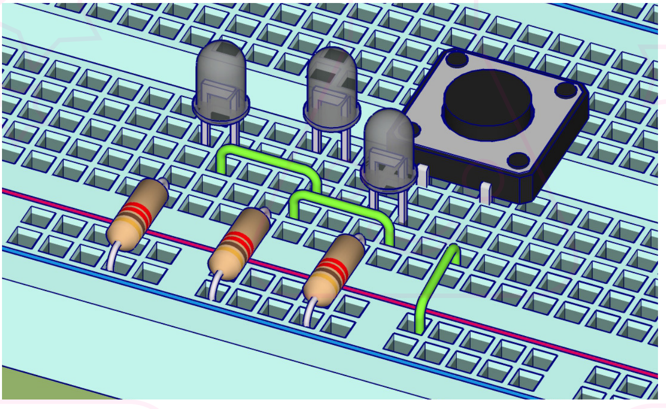



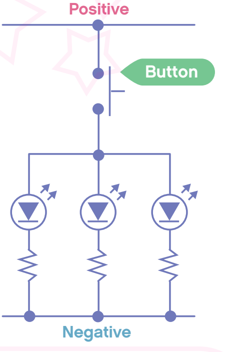
## Control three LEDs at once!

The button connects to positive, and all three LEDs. Each LED connects to a resistor. And each resistor connects to negative.

*Note: Different colors use different amounts of current. An LED may use too much current to allow other LEDs to light. If you have problems try using different colors or calculating the correct resistor for each color (see page 12).*

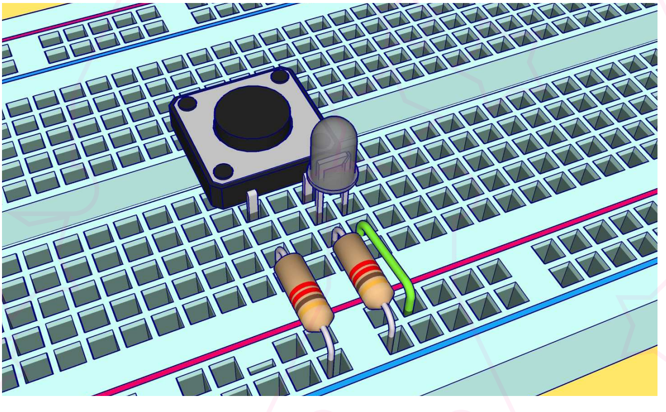
*It is standard to have the top line in a schematic represent positive and the bottom line represent negative.*

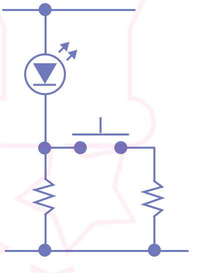





## Make an LED brighter!

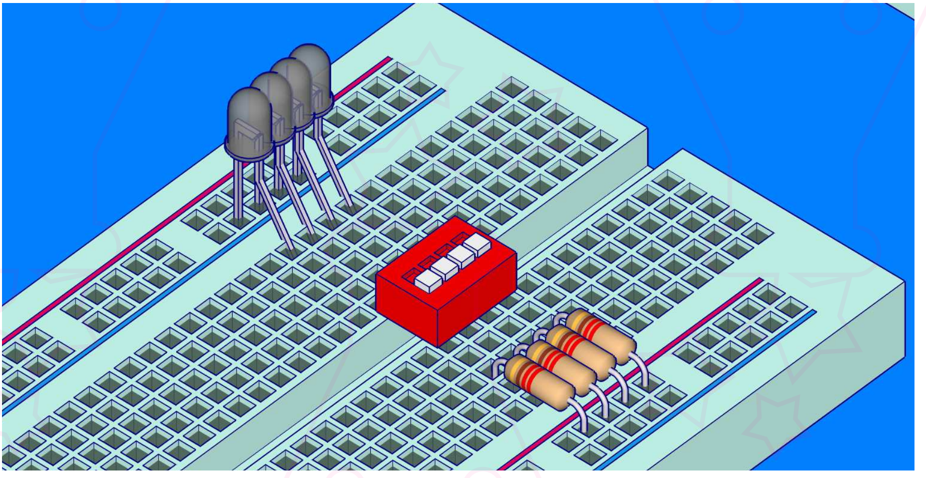
A switch used to brighten an LED. Using two resistors reduces the resistance through the circuit brightening the LED.





## DIP Switch

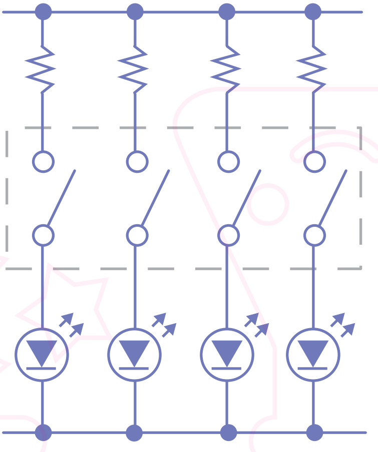
This dual in-line package switch contains 4 separate switches.



How high can you count with a 4 position DIP switch?

| | |
|---|---|
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |
| 10 | 1010 |
| 11 | 1011 |
| 12 | 1100 |
| 13 | 1101 |
| 14 | 1110 |
| 15 | 1111 |

0=off 1=on

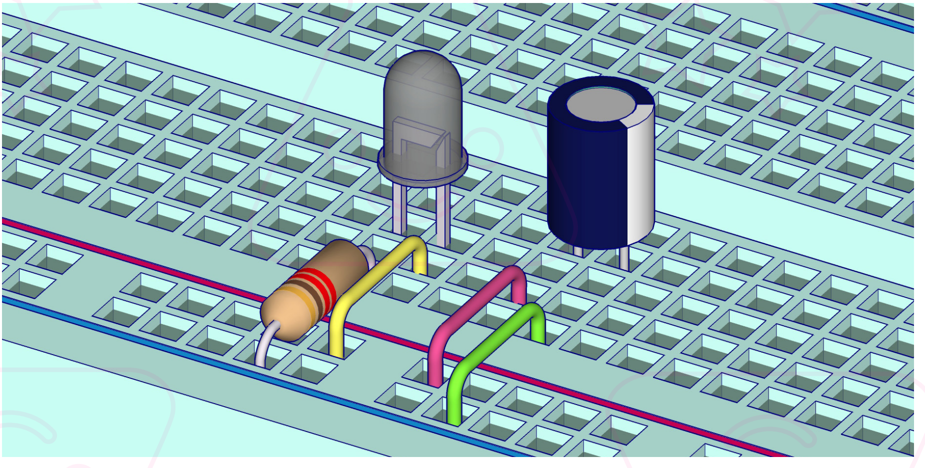


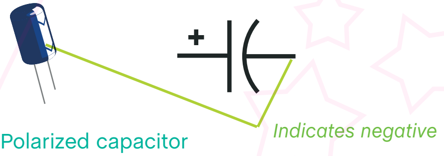
# Capacitor

Capacitors are like water tanks but instead of storing water, they store energy. Current can flow through them until they are fully charged. Once they are full, current will no longer be able to flow through them.

In this circuit, while the circuit is powered on, the 220μF capacitor is charged. Turn off the power and the capacitor will discharge through the LED.

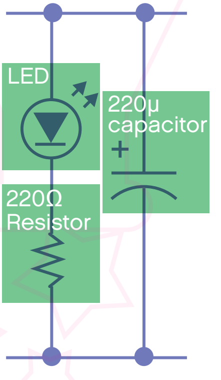
μF Stands for Micro Farads. A Farad is unit of capacitance. μ stands for micro which means 1 millionth. 220μF is 220 millionths of a Farad.






Polarized capacitor

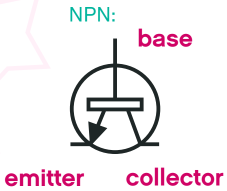
Non-polarized capacitor

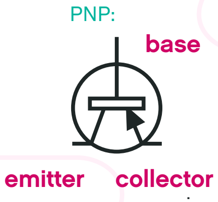


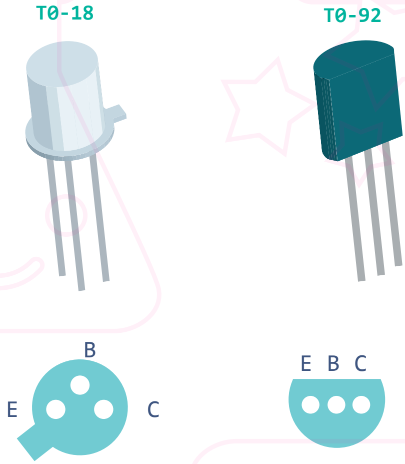
# Transistor

Transistors amplify current. A very small current at the *base* will allow a much larger current to pass between the *collector* and *emitter*. Transistors are often used as amplifiers or switches.

There are many different kinds of transistors. NPN and PNP are two basic types. They can also come in different styles (packages) which can have different leads.



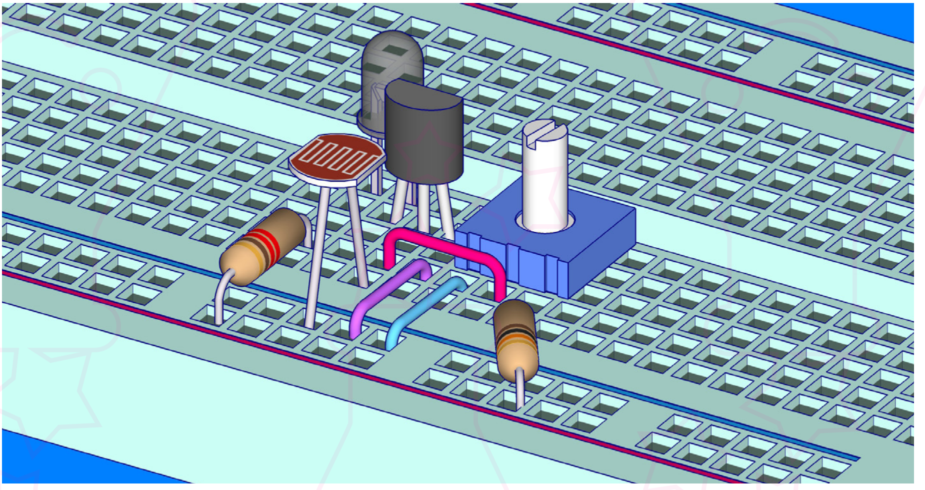

*viewed from the bottom*

## Dark detector

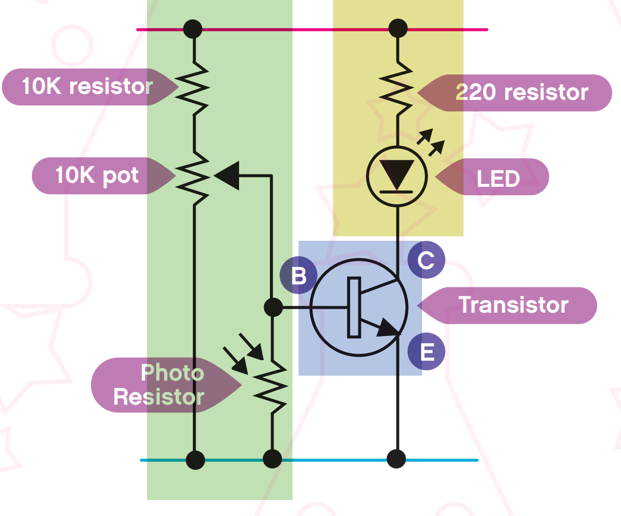
This circuit will turn on the LED when it is dark enough. The potentiometer is used to adjust the sensitivity level of the photoresistor for your particular lighting situation. Try it out in the dark!

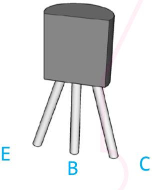
Section green is a voltage divider. Section yellow is an LED driver. As the photoresistor gets less light its resistance becomes greater. This pulls the voltage at pin B upwards and allows current to flow through the transistor.

*Pay attention to which lead is which as incorrect wiring can damage your transistor.*



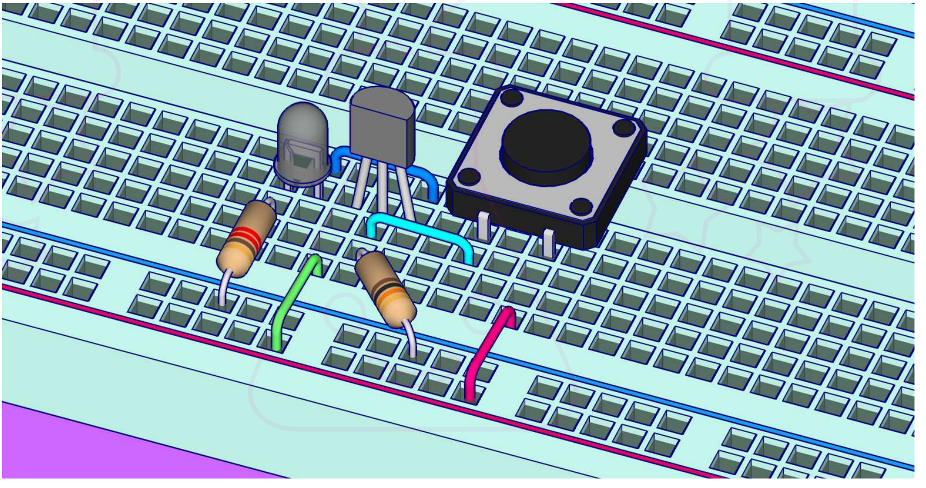
1. Place the transistor on the breadboard.
2. Connect pin B of the transistor to negative with a photoresistor.
3. Also connect pin B of transistor to the wiper of the potentiometer with a jumper wire.
4. Connect one side of the potentiometer to positive with a 10k resistor and the other to negative.
5. Connect transistor pin C to the LED cathode with a jumper wire.
6. Connect the LED anode to positive with a 220Ω resistor.
7. Connect pin E of the transistor to negative with a jumper wire.

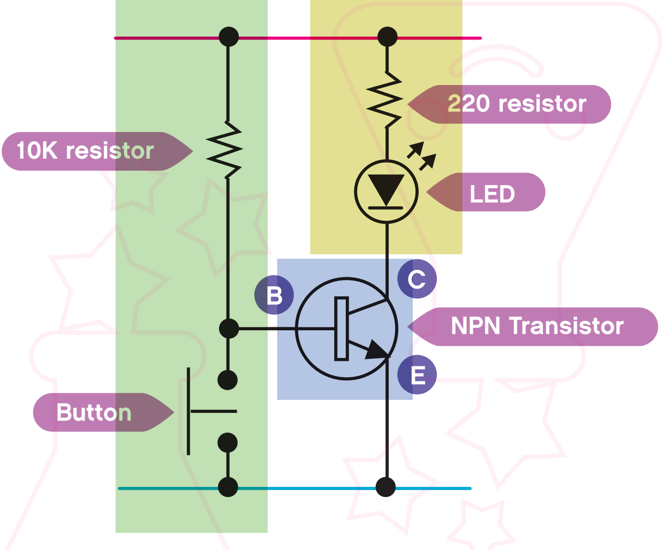


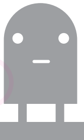



## Transistor NOT gate

The button circuit we made previously turned an LED on when the switch was closed. What if you wanted an LED to turn *off* when a switch is closed? A *NOT gate* turns on when the switch is NOT closed.



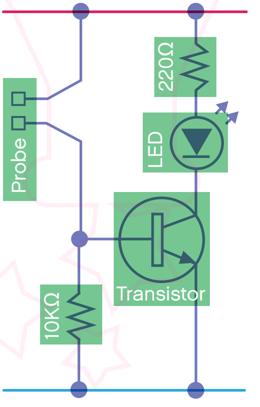


*You can view the circuit as a series of stages, each having its own job.*

# Water Detector

This simple circuit is a sensor that will turn on a light when water reaches a certain level. You will need two paperclips as well as the alligator clips that came with your kit.

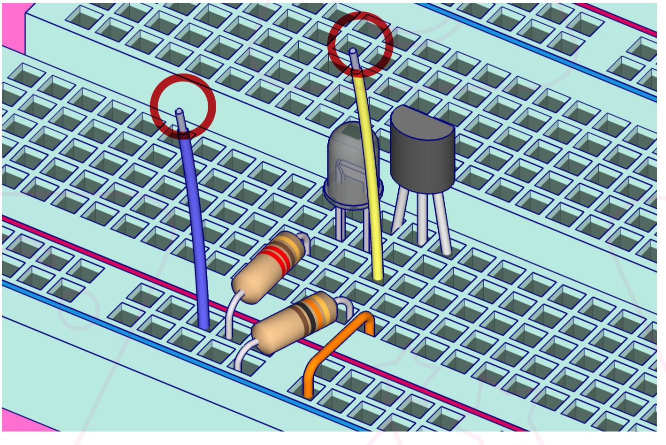



## The Sensor Probe

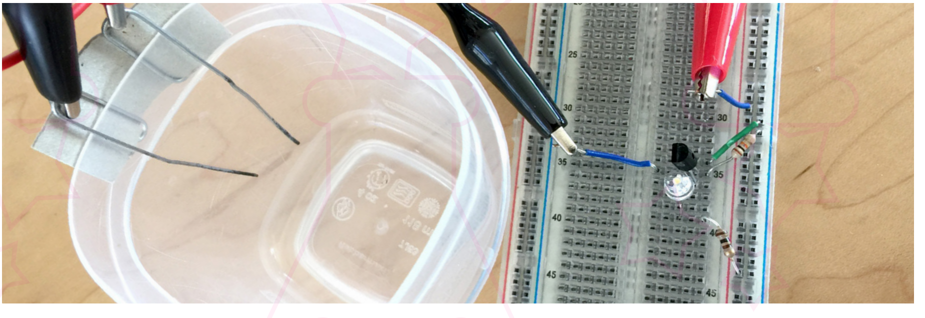
Two metal paperclips will serve as the probes that will sense the water. Straighten one turn of the paperclips and affix the clips to the lip of a cup so that the long end of the clip is inside the cup.

## The Detector Circuit

The Base of the transistor is a voltage divider that is usually pulled towards negative with the 10k resistor but when there is water between the probes, current flows and pulls the transistor base to positive.



*The sensitivity can be adjusted by changing the 10k resistor to another value.*



# 555/556 timer

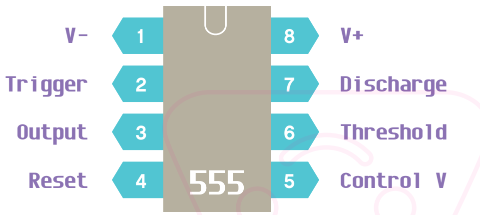
The 556 is a great little chip with many uses.  The 556 contains two 555 chips in one package. The 555 is over 30 years old and is still in use today.

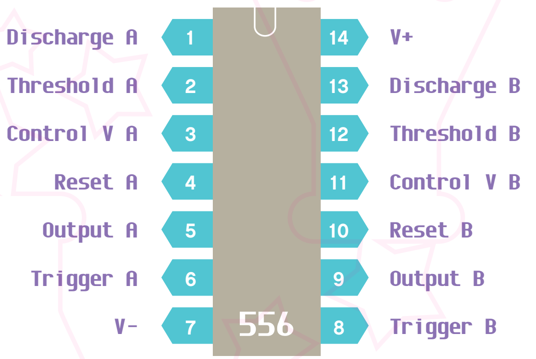
A capacitor charges through a resistor at a particular rate. A 555 IC (integrated circuit) will use this fact to perform various timing operations. The chip compares the changing voltage of the capacitor to a threshold which triggers a high or low output.

555/556 chips can be configured as an astable vibrator, which oscillates back and forth, or as a monostable vibrator, which resets back to one state after a set amount of time.

**What pin is it?**
*Use this chart to determine equivalent pins between the 555 and 556.*

| 555 | 556a | 556b |
|---|---|---|
| 1 | 7 | 7 |
| 2 | 6 | 8 |
| 3 | 5 | 9 |
| 4 | 4 | 10 |
| 5 | 3 | 11 |
| 6 | 2 | 12 |
| 7 | 1 | 13 |
| 8 | 14 | 14 |

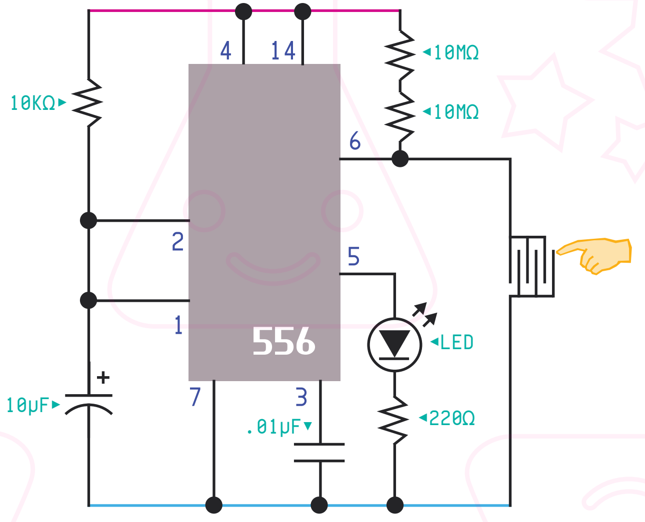


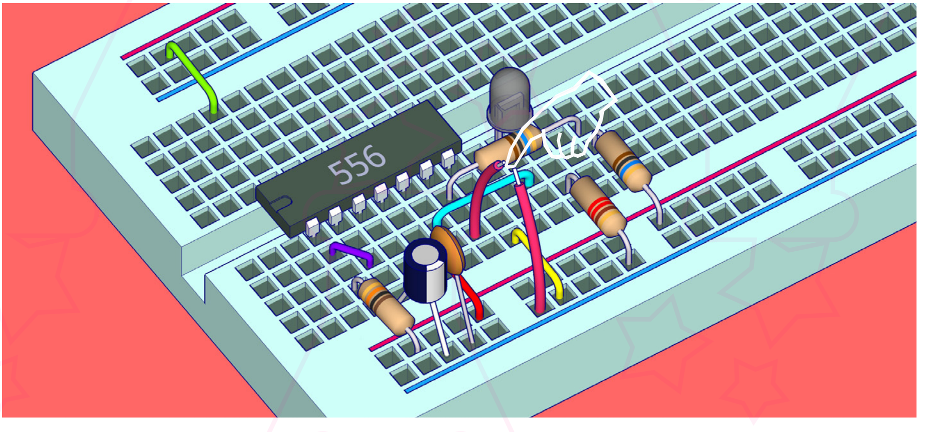



# Touch Switch

This circuit uses a 555/556 to create a sensitive touch activated switch. You can use two wires as a probe or make a larger one from a metal surface and alligator clips.

Here we are using the switch to light an LED but you could use it to activate many circuits. Change the value of the larger capacitor to change the timing.

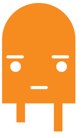


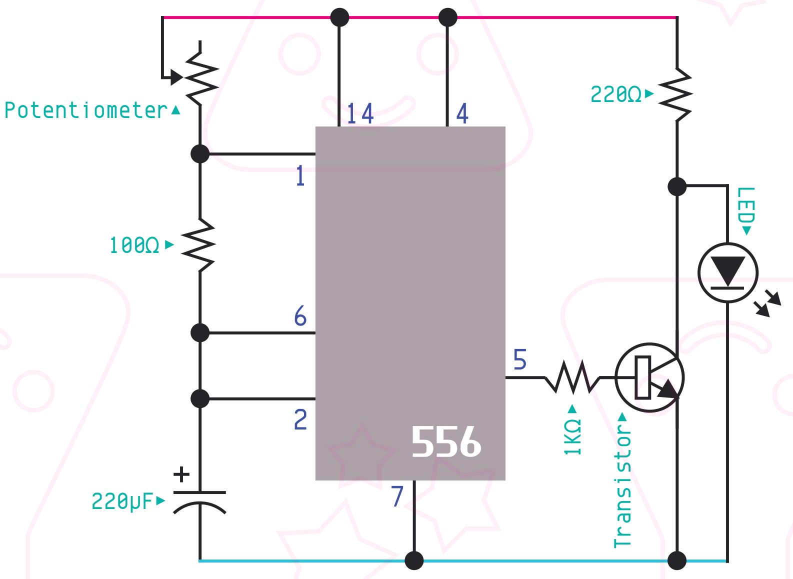
# LED Flasher

This circuit uses the resistance of a potentiometer to set the rate of a flashing LED. Try changing the value of the capacitor. What happens?

The transistor uses the small current from the 556 to switch on the LED. Can you figure out how to use the transistor to switch off an LED?

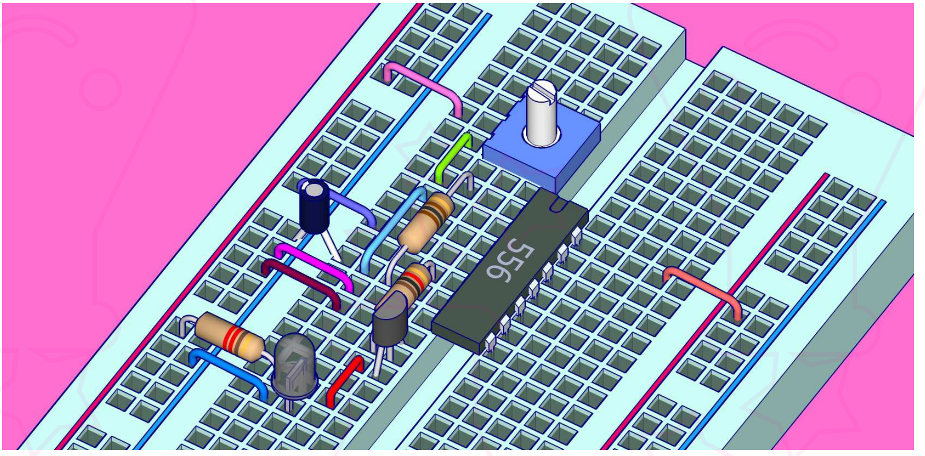


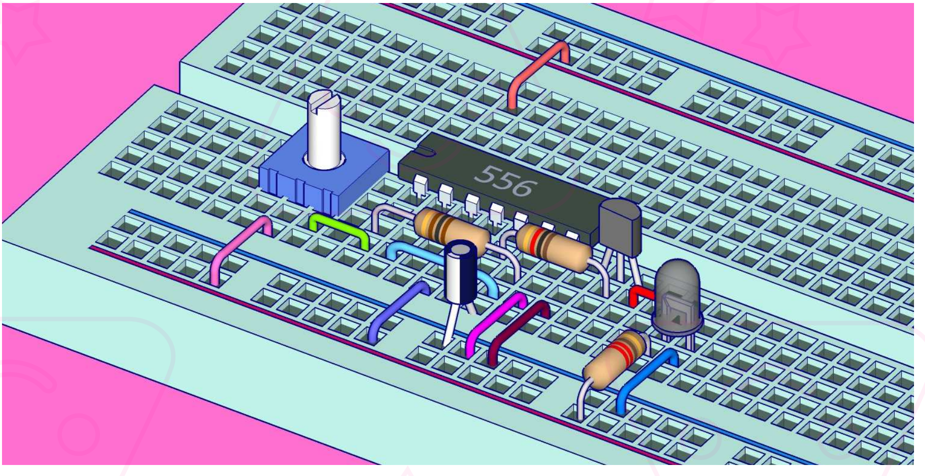
**This project uses positive and negative on both sides of the breadboard. You will need to use jumper wires to bring power to both sides of the board.**




**The pin numbers in the schematic are not in the correct order so that the lines are easier to see. Use the diagram on the previous page to determine which pin is which.**

***Extra credit:*** *Make two flashers on one chip.*




**Pin 1** connects to positive with a potentiometer. Pin 1 also connects to pin 6 with a 100Ω resistor

**Pin 2** connects to 6 with a jumper wire. Pin 2 also connects to negative with an electrolytic capacitor

**Pin 4** connects to positive with a jumper wire

**Pin 5** connects to the 1kΩ resistor which connects to **Pin B** of the transistor

**Pin C** of the transistor connects to positive through a 220Ω resistor and to negative through an LED.

**Pin E** of the transistor connects to negative with a jumper wire.

**Pin 7** connects to negative

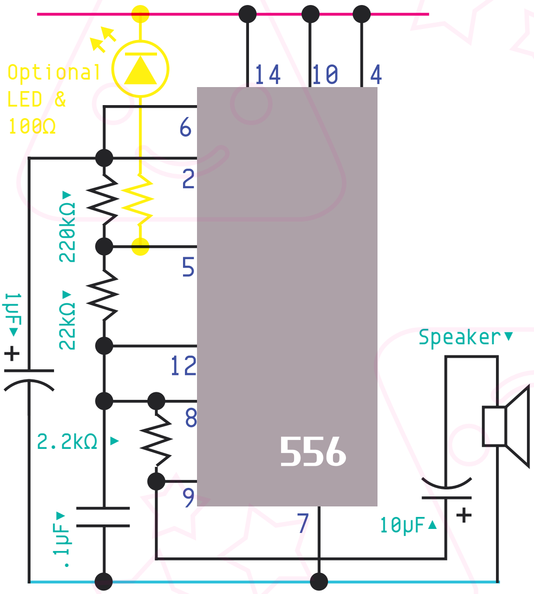
**Pin 14** connects to positive

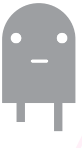
# Siren Circuit

Here is a siren circuit. The first 555 creates an on/off pulse which changes the frequency of the pulse coming from the second 555 and out to the speaker.

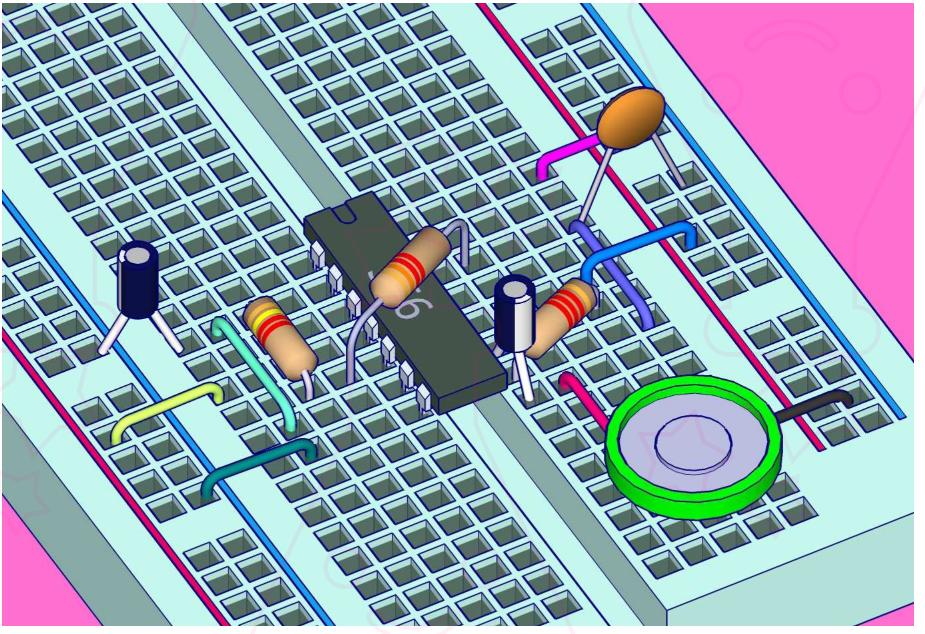
You can experiment with different resistors and capacitors to create different sounds. Start out with small changes so you can hear what happens.

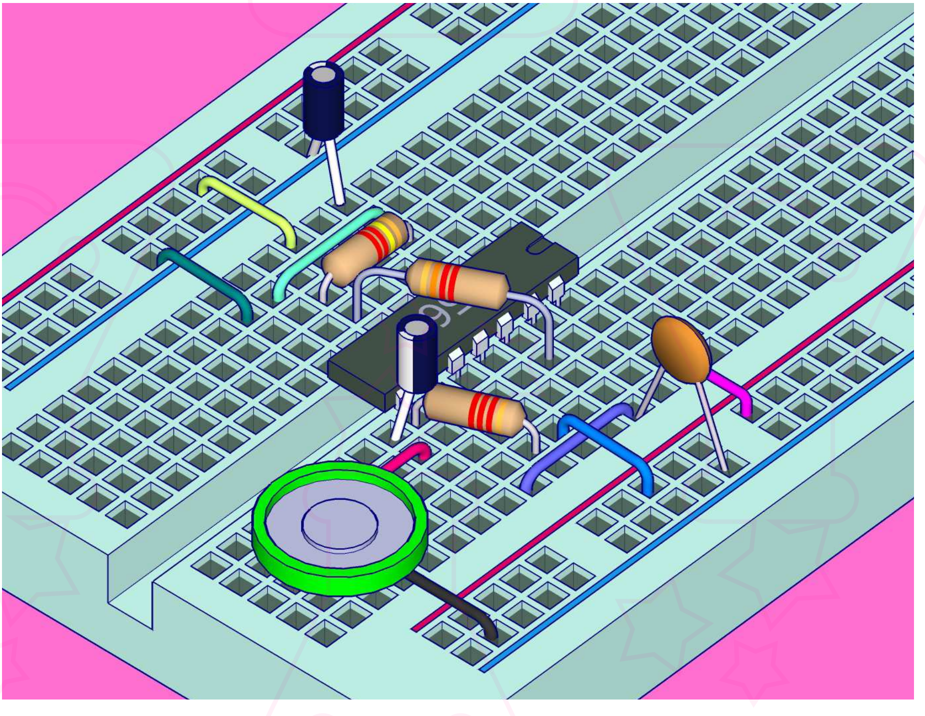
You can also put a resistor or a potentiometer on the speaker so it is not so loud.



The three power pins can all be connected to a dark / light or water detector instead of power.

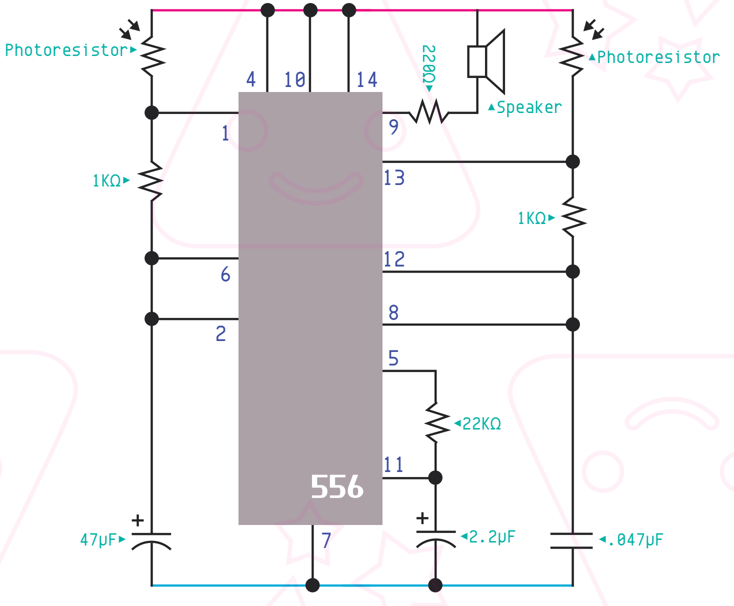




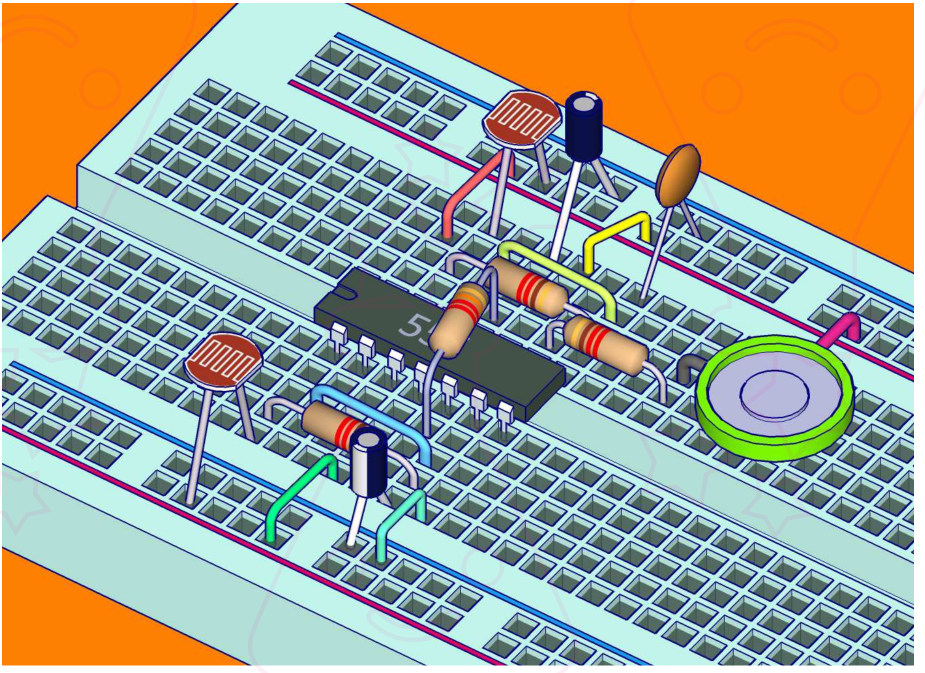
# Make Some Noise!

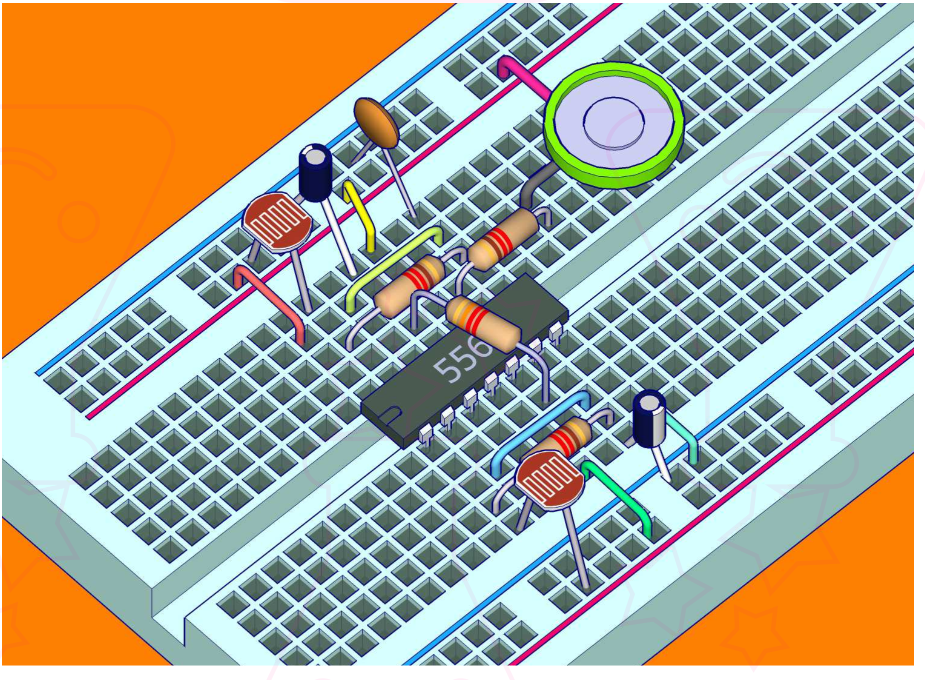
This circuit uses both of the 555s in the 556 to create various noises. One 555 uses the level of the photoresistor to send a signal to the other 555. The second 555 uses this signal and it's own photoresistor to create a waveform which is sent to the speaker.

You can experiment with the values of the capacitors and replace one or both of the photoresistors with potentiometers. Mix it up!




Your particular lighting situation will have a large effect on this circuit. Try different lighting and see what happens.


55


556

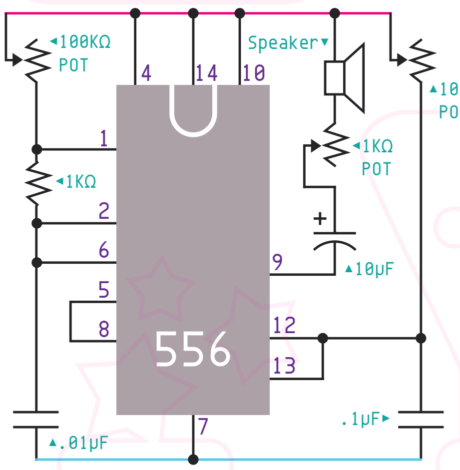
# Atari Punk Console

This circuit is a noise maker from Forest Mim's *Engineers Mini-Notebook 555 Timer IC circuits.* This circuit turns on and off power to the speaker very quickly. This causes the speaker to vibrate the air which is the sound we hear.

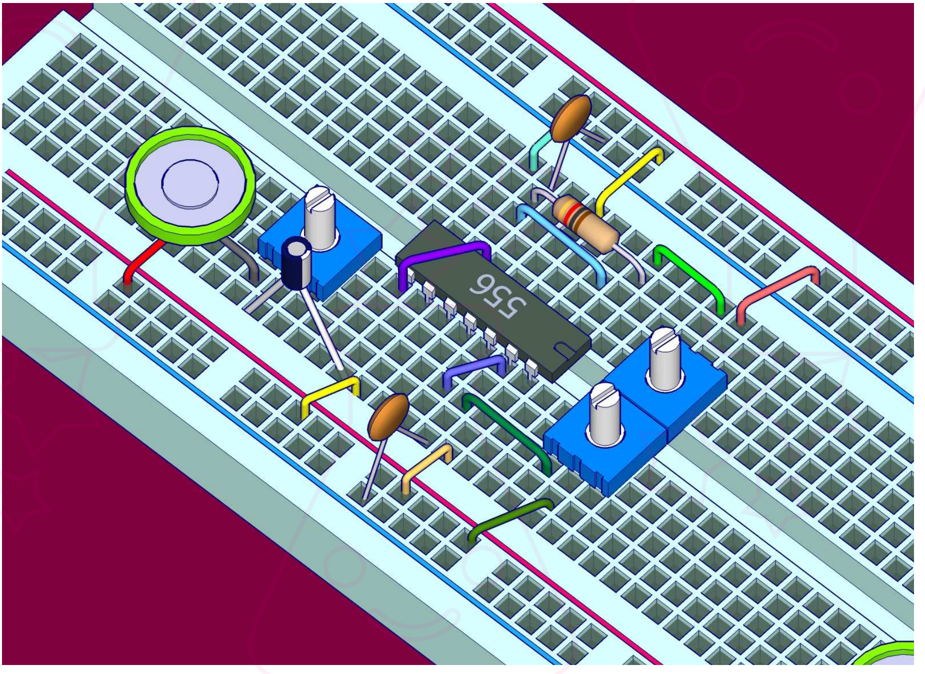
Each time power to the speaker is turned on and then off it is a pulse of energy. One of the potentiometers increases the number of pulses per second. This is the frequency of the pulses. The other pot controls the length of the individual pulses. A long pulse means there is power to the speaker for longer. This is the wavelength.

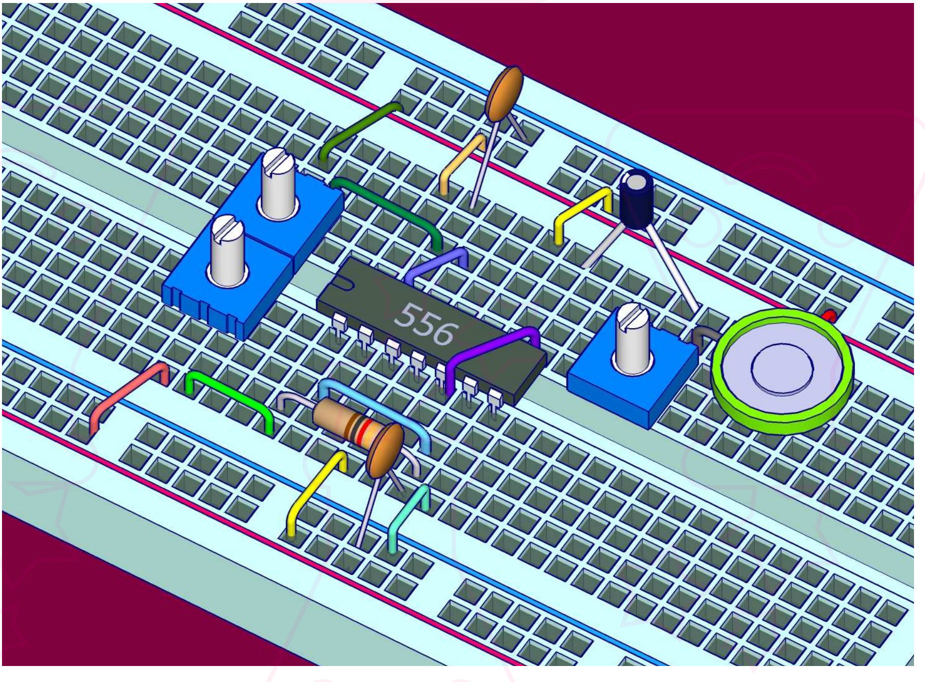
The speaker contains a coil of wire wound around a magnet. When ever electricity runs through the coil it creates an electromagnetic field that pulls the magnet. When the pulse ends the magnet is released and springs back into place.

Applying power to the speaker only pulls the magnet. Sending many pulses to the speaker shakes the magnet back and forth which vibrates the air and makes noise.




Online we have videos of this circuit as well as what the pulses look like on an oscilloscope.


556

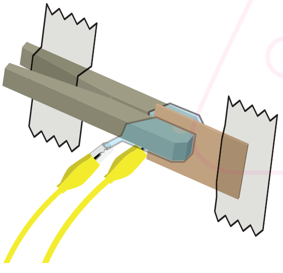

556

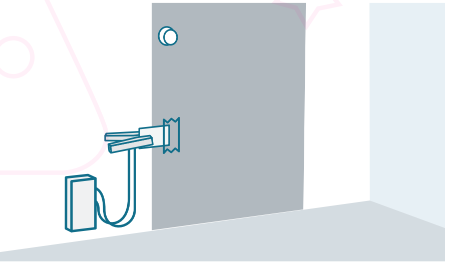
# Create your own switches & sensors

There are many ways to create your own switches and sensors. Included with the kit are a pair of alligator clips. These can be attached to your own contraptions to make them work with your circuit.

## Door switch

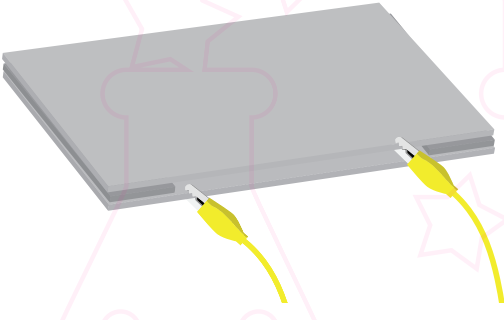
Here is a clothespin with aluminum foil wrapped around the ends. A piece of cardboard is used to hold the two sides apart. Attach the clothespin to the wall and the cardboard to a door. When the cardboard is removed the switch will close.





## Floor switch

Here, two pieces of cardboard wrapped in aluminum foil are separated by two small pieces of cardboard. When someone steps or sits on it the two aluminum covered pieces touch each other and the switch is closed.



# Moving Forward

## Multimeter
Get yourself a multimeter. Multimeters test voltage, current, resistance and continuity. Inexpensive meters go for around $15US and are fine for hobby electronics.

## Wire
A spool of 20 gauge solid-core wire along with a wire stripper and snipper can be very useful. You can make wires any length you desire as well as trim leads to make your breadboard neat.

## Project Box
When you complete a nice circuit you will want to protect it. You can buy many plastic and metal boxes or you can make one from cardboard. Cardboard is easy to cut holes in and to decorate.

## Soldering
Breadboard circuits are only meant to be temporary. When you want a circuit to last you will have to solder it on to a piece of perf board. This will make your circuit permanent. Soldering is actually pretty easy.

## Microcontrollers
These are programmable IC chips. They are used with many of these basic circuits to create designs that can have complex reactions to sensors and user input.

The Arduino is a platform for learning to program these chips. It is easier than you think and this kit has given you an insight into the circuits you could connect to an Arduino.

We have an ***Arduino Expansion Pack*** for your ***Discover Electronics Kit*** that will walk you through setting up your Arduino and start you programming.

**Great job! There are more projects and things to learn online. We even have homework assignments for you to complete. *http://sparklelabs.com/discoverelectronics***