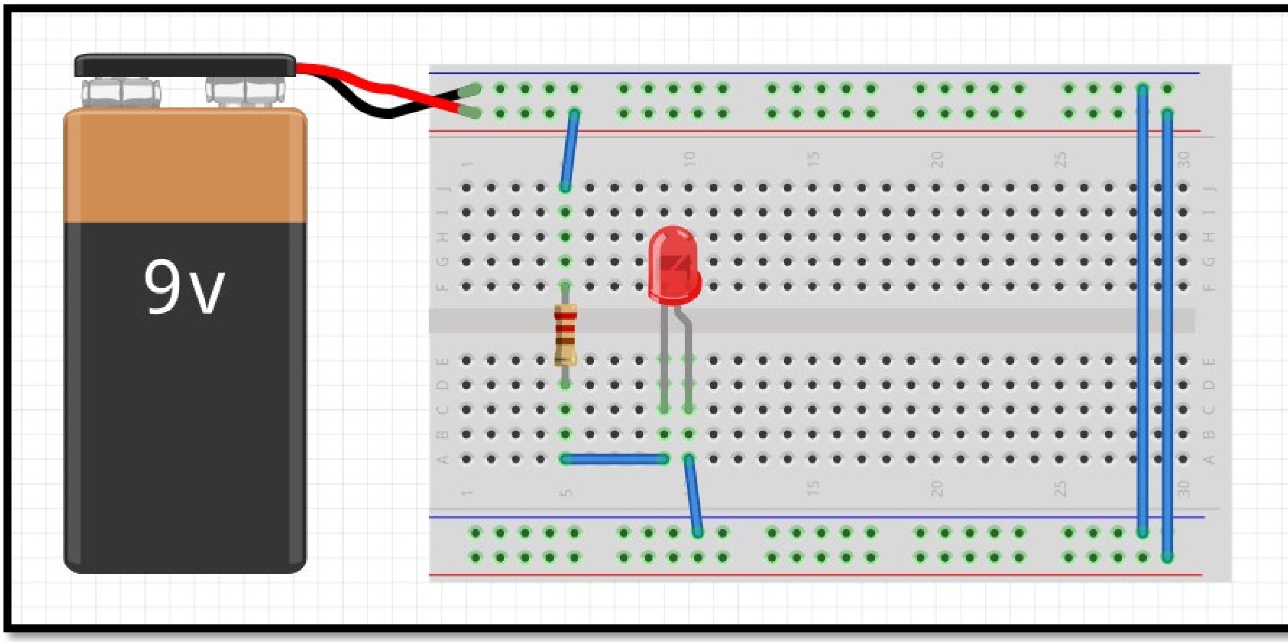
PERFORM ELECTRONIC EXPERIMENTS

GK-EK-101



Learn fundamentals of electronics the fun way!

Simulate a large variety of electronic gadgets with included components and breadboard!

No specific tools or soldering required.

*Requires a 9V battery or power supply.

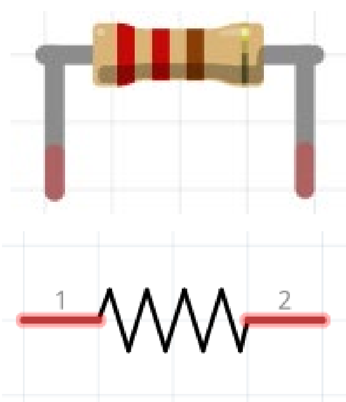
Table of Contents

Parts List

Quantity	Title	Value
1	Tactile Push Button	-
1	Resistor	470Ω
1	Resistor	1kΩ
1	Resistor	3.3kΩ
1	Resistor	10kΩ
1	Resistor	33kΩ
1	Resistor	100kΩ
1	Resistor	1MΩ
3	2N3904 Transistor	-
1	1N4148 Diode	-
1	Electrolytic Capacitor	16V 100µF
1	Electrolytic Capacitor	25V 10µF
1	Disc Capacitor	4.7nF
1	Disc Capacitor	0.047µF
1	42TL013 Transformer	-
2	Light-Emitting Diode	-
1	Variable Resistor	50kΩ
1	Speaker	8Ω
1	Breadboard	830 TIE POINTS

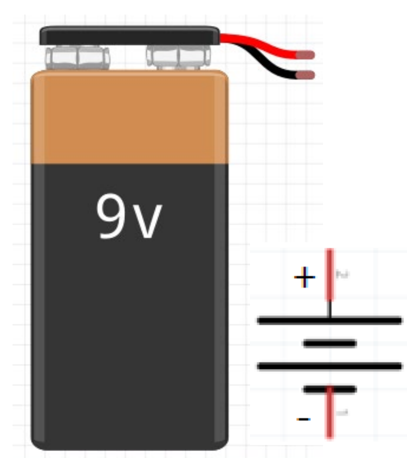
Basic Components Introduction

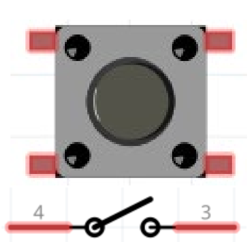
To obtain a better understanding of the way certain electronic components function, think of electricity as water flowing through pipes. Using this analogy, wires can be compared with pipes. As it's known, electricity flows through wires as water flows through pipes. Voltage represents the size of the pipe, current represents the quantity of water flowing through, and resistance could represent the rocks within the pipe blocking the water to a certain extent.



The resistor is what reduces the flow of electricity the same way the flow of water is reduced to reach your home because you do not need so much water. The higher the value of the resistor, the higher the resistance. Obviously, the rocks in your pipes cannot be relied on in a real-life scenario, so the size of the pipe is simply smaller (the same way the flow of electricity can also be reduced by decreasing the voltage). The resistor values are identified by the colors arranged in the order as shown. More details on that later. The unit is ohms (Ω) (also referred to as R).

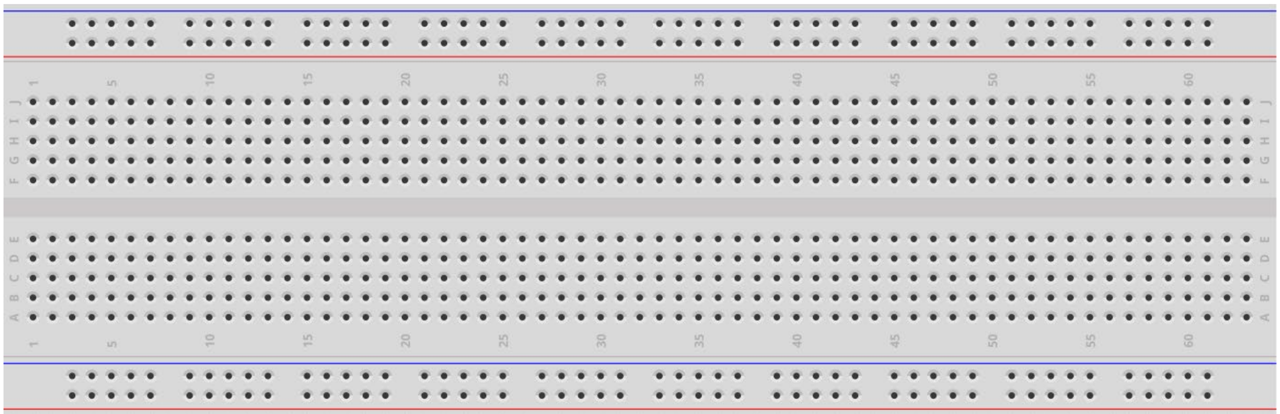
The batteries are required to produce the electricity that must flow through the wires to bring the circuit to life. Using the analogy, the battery can be referred to as a water pump. Normally, 9V batteries such as the one shown will be using a clip with two wires attached to it – red and black – that identify which is a positive (+) and a negative (-) polarity. To put it simply, they represent the direction in which the battery will produce the flow of electricity. Universally, red is positive and black is negative.



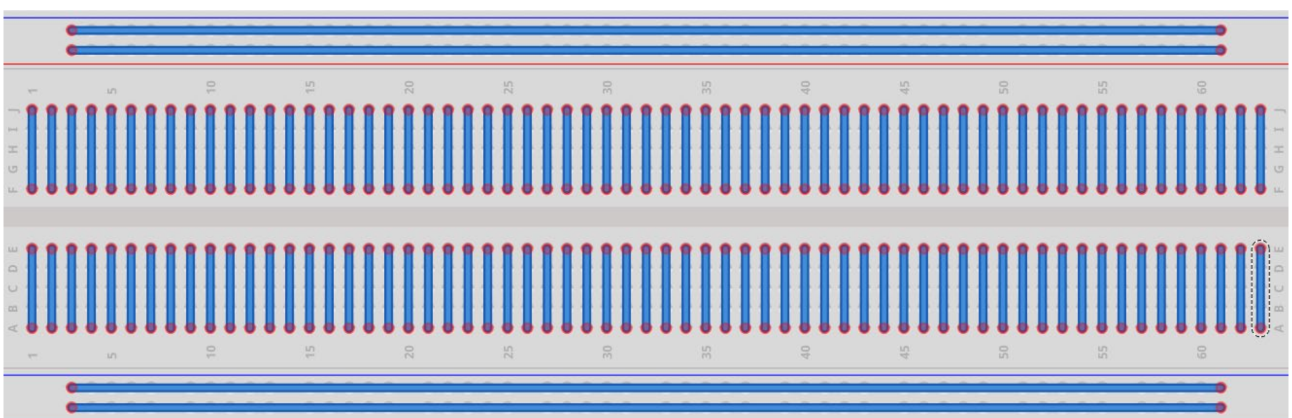


The switch is used to permit and/or stop the flow of electricity through the wire, the same way the water valve is used is turn the flow of water on and off. Some switches must be pressed and held and keep the flow of electricity constant, some must be pressed only once, it is depending on the switch.

The breadboards are used for mounting the electronic components and make connections that compose a circuit. Those circuits are used in PCBs (Printable Circuit Boards) that are inside all electronics. Breadboards serve the purpose to prototype those circuits to ensure that they will function properly on the PCB.

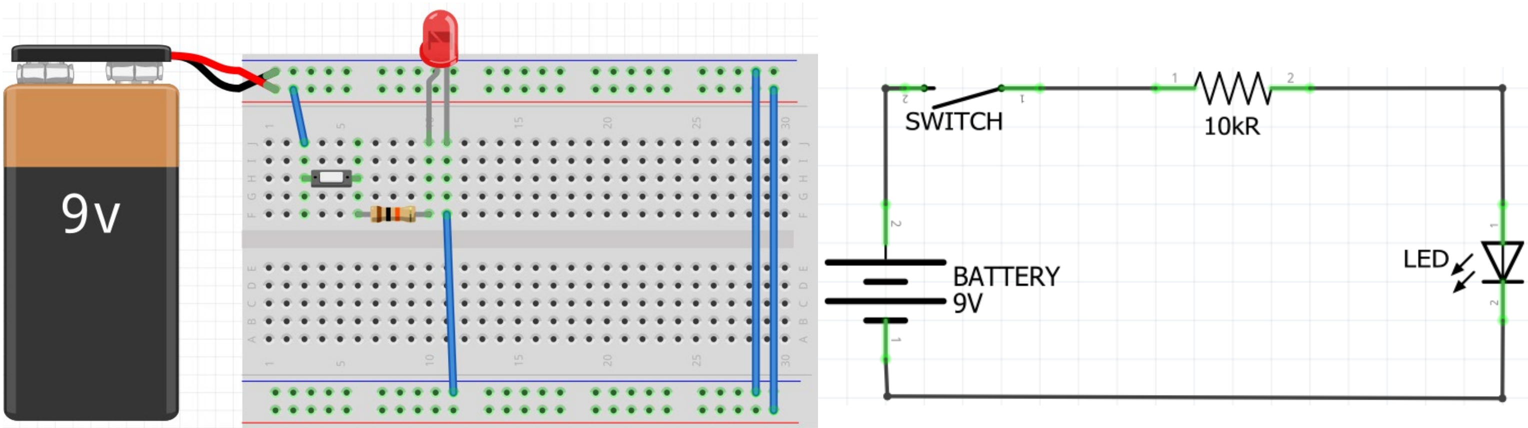


Breadboards vary in size. However, the wiring will always be internally connected the same way, unless the colors of the power and ground rails do not meet halfway where in that case, you'd have to use wires to connect them.



Sometimes the ground will also be referred to with a blue color instead of black. The top and bottom rails are reserved for the power supply, in this case it being a 9V battery. The holes in between the power rails are reserved for the components. The first experiment will go in-depth about the correct placements and how to prevent unsafe prototyping habits which majority of the time involve the shorting of the parts. Unintentional short-circuits provoke high heat and potential explosion in those areas of the breadboard.

Experiment #1: The Light Bulb



Parts Required:

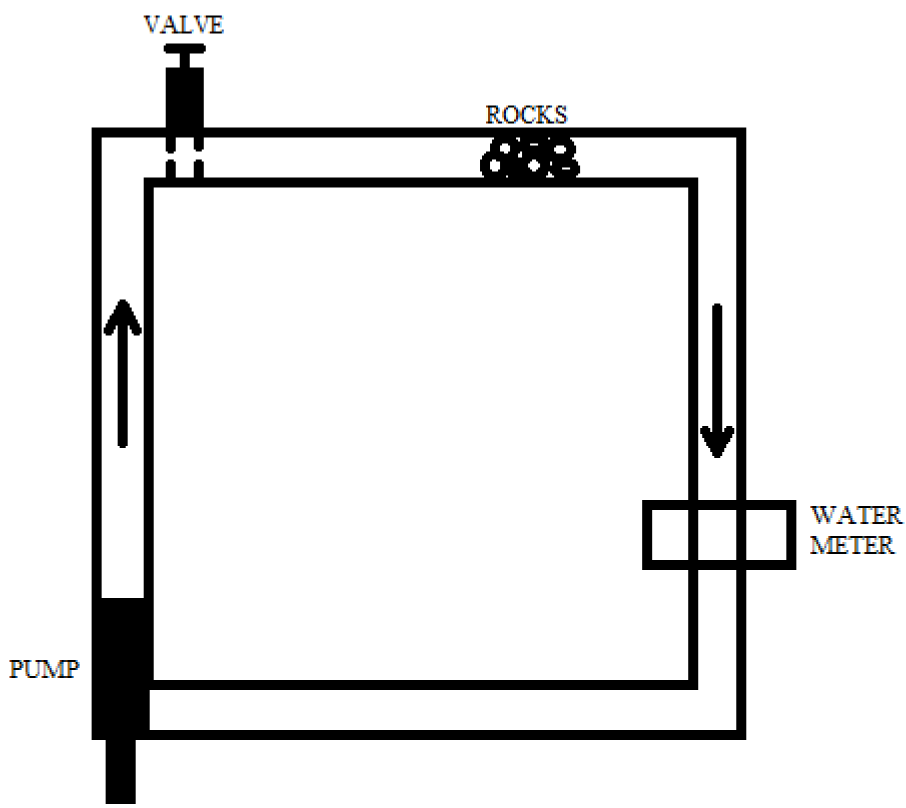
- 9V battery or power supply.
- One switch.
- One 10kΩ resistor (as marked on the board above).
- One LED.

Since this is your very first experiment, serve mentioned tips as a guide to wire future experiments if needed. Take note of how the components are placed on the breadboard: both pins are in the same row. It's perfectly okay if both pins are in different rows as long as they're never in the same column because that causes a short to occur. Do you see those two long wires at the end of the rails? They connect the upper and lower power rails to allow the use of the lower rail to ground the LED (Light Emitting Diode). The polarity of the switch and the resistor do not matter.

It is <u>always important</u> to identify the polarity of the LED before grounding it. The negative polarity of the LED is identified by its flat side as shown in the above diagram. The positive polarity has a little bump to its side. Incorrectly placed polarities may cause the LED to explode.

Observe the resistor and take note of the colors. Here, you can see colors are brown, black, orange and gold from left to right. The following are colors universally recognized as numbers: Black–0; Brown–1; Red–2; Orange–3; Yellow–4; Green–5; Blue–6; Purple–7; Gray–8; White–9. The first color identifies the first digit of the value, the second color identifies the second digit, the third color identifies the multiplier, and the fourth color identifies the tolerance. Majority of the time, the tolerance will always be gold, which is ±5%. The multiplier is determined by the number of zeroes that come after a number 10 (black meaning no zeroes, brown meaning one zero, etc.). In summary, the resistor's value is 10 * 1,000 = 10kR with 5% tolerance. Pick up another resistor and try identifying its value!

When you make the circuit, plug in the red wire of the battery to the red side of the rail of the breadboard, and the black to blue, then press the switch and observe the brightness of the LED. Be careful that the leads of components do not touch each other when the circuit is powered. Take note of the LED's brightness and replace the resistor with one that has a lower value. It is safe practice to unplug the battery from the circuit before making any changes. Press the switch again and observe the increased brightness of the LED. You've just decreased the number of rocks in the pipe to allow more water to flow through. Neat, right? An even higher value resistor would simply add more rocks, in which case the LED might appear very dim and that's when you can try putting your palm around the LED to reduce the amount of light in your room surrounding it to see better. The diagram below attempts to debunk the schematic beside the wiring diagram:

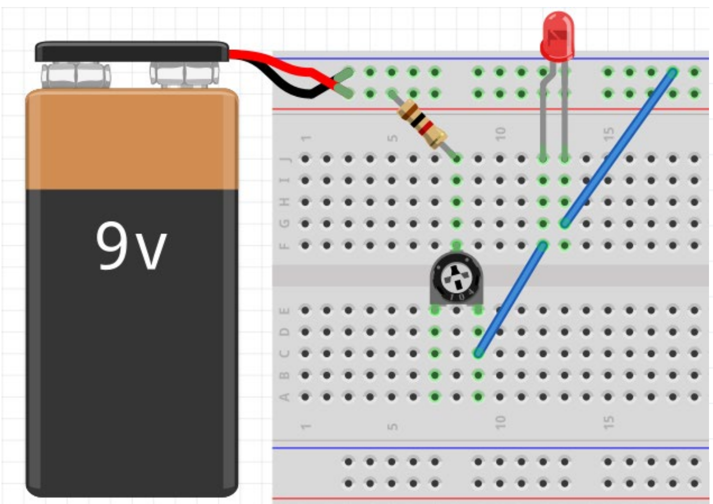


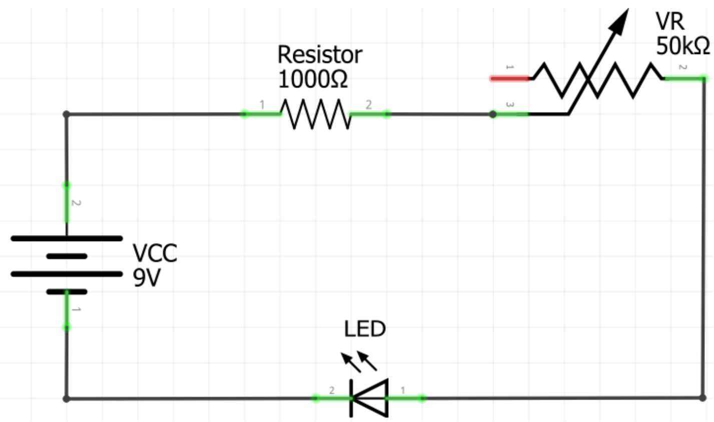
Each component is imitated by another part to respect the analogy, yet the functionality remains the same. Try thinking of it when looking at a schematic to gain a better understanding of how the circuit will work because the creation of schematics is vital when composing a circuit.

The purpose of this circuit is quite simple: to light up an LED. With this being the first circuit you've built, you now have an understanding of how to place components on the breadboard, what the word "polarity" means, what a short is, how resistance affects the circuit, how to find the resistance, and how to read schematics. Well done!

Experiment #2: Brightness Control

Before we jump into the experiment, let's analyze the newly added component. That is called a **variable resistor** and it behaves as a crane valve for turning on the faucet in your home. In the previous experiment, the LED would either be on or off depending on whether the switch would be pressed or not. In this case, as you may have guessed from the name of the experiment, the VR is used to control how bright or dim the LED could be and has three pins: the left pin, the center pin, the right pin. The center pin is used for voltage input and the other two pins are for feeding the current.



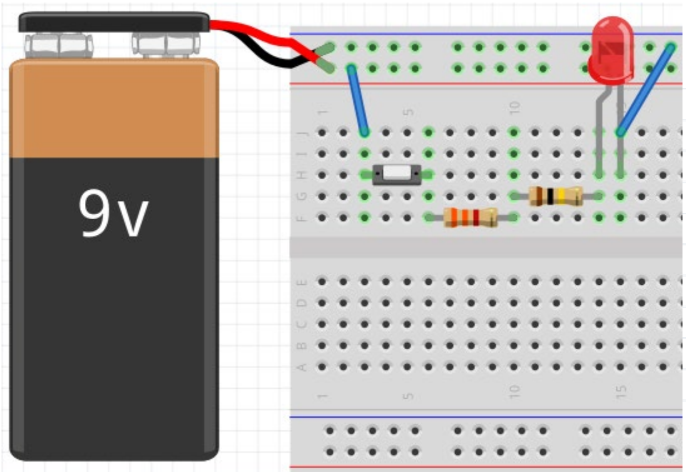


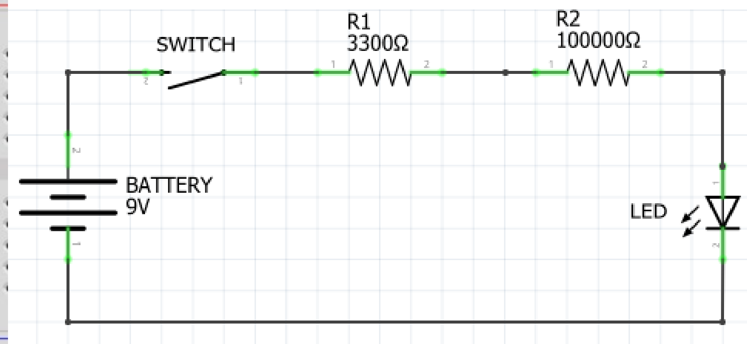
Parts Required:

- 9V battery or power supply.
- One variable resistor.
- One 1kΩ resistor.
- One LED.

In this experiment, the LED's state depends on how much current it is being fed with the variable resistor. As you turn the little knob clockwise, the LED becomes brighter, and turning it counterclockwise makes it become dim. Try taking the wire out of the right pin of the VR and plugging it into the left pin, see what happens when you start turning the knob again.

Experiment #3: Resistors in Series



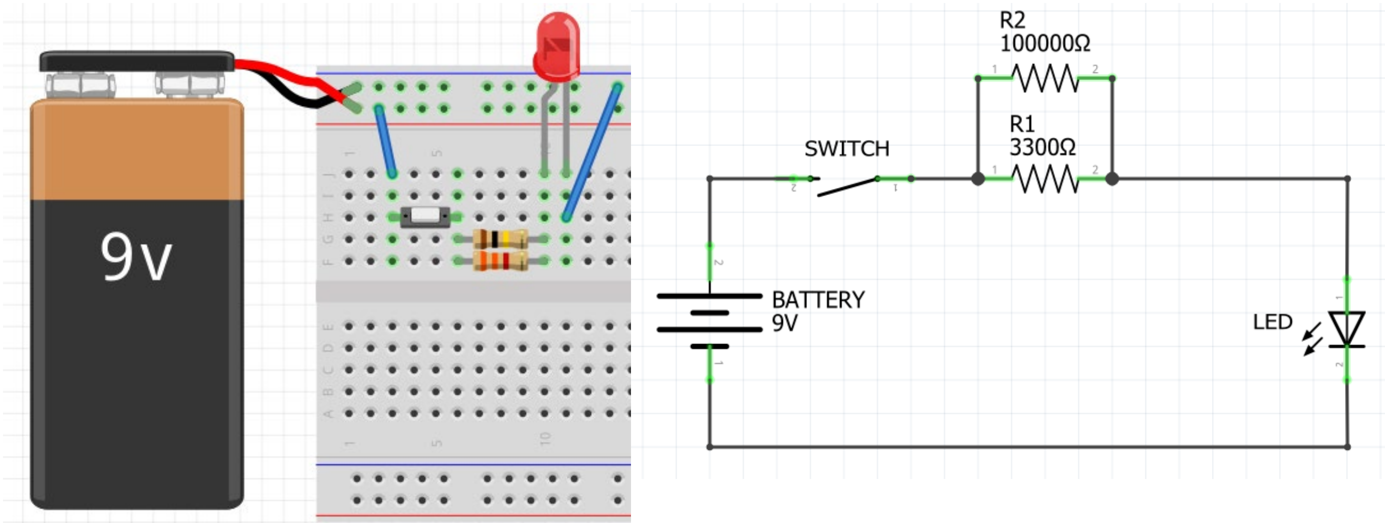


Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 100kΩ resistor.
- One LED.

This experiment looks quite like the very first one you've performed except there are two resistors in this circuit now and they are connected in how it's referred to as **series**. When two resistors are connected in series, their two resistances simply are added together and you may think of the result as if it's one big resistor. With a 3.3kΩ resistor and a 100kΩ resistor connected in series with one another, the total resistance becomes 103.3kΩ. The more resistors placed in series there are, the higher the total resistance becomes. This is useful if you require a specific resistance in the circuit but do not have the resistor with that value for it. Try replacing these resistors on the breadboard with other!

Experiment #4: Resistors in Parallel

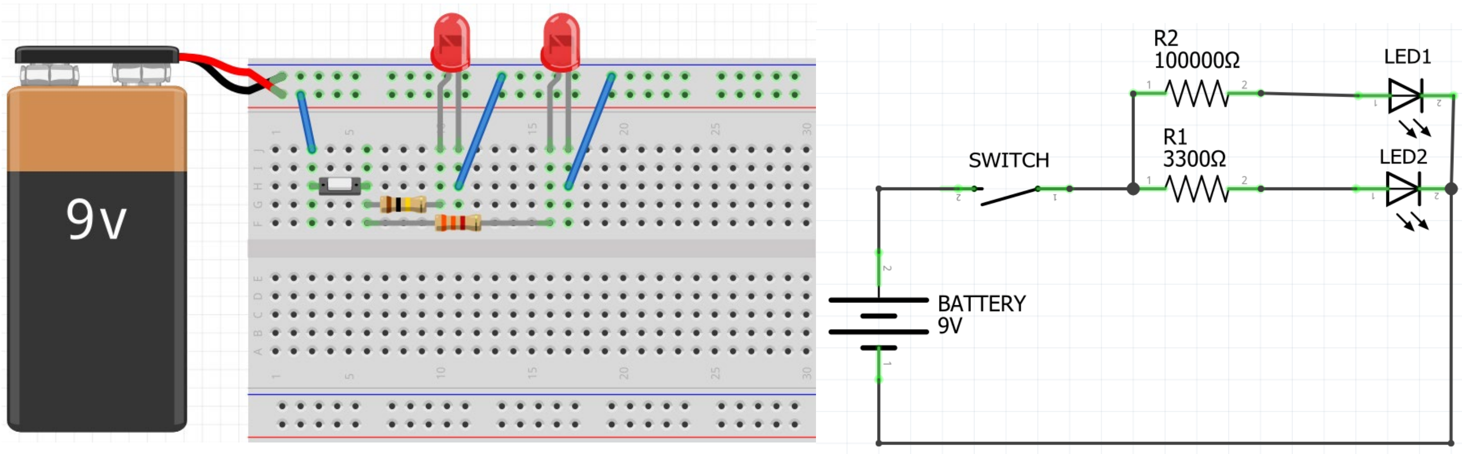


Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 100kΩ resistor.
- One LED.

There is only one difference between this experiment and the previous one. When resistors are placed in this manner, they're connected in **parallel**. When resistors are placed in parallel, their total resistance is reduced. However, it is more complicated than subtracting the values if that's what you may have assumed. The new resistance for resistors connected in parallel could be determined with the following formula: R[parallel] = (R1 * R2) / (R1 + R2). The more resistors placed in parallel there are, the lower the total resistance becomes.

Experiment #5: Parallel Currents Comparison

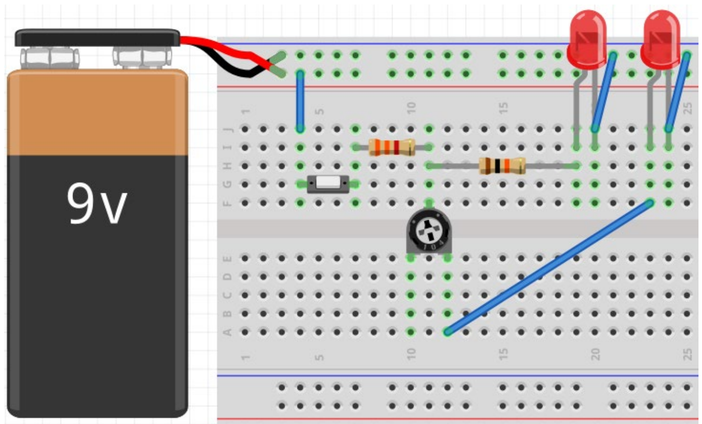


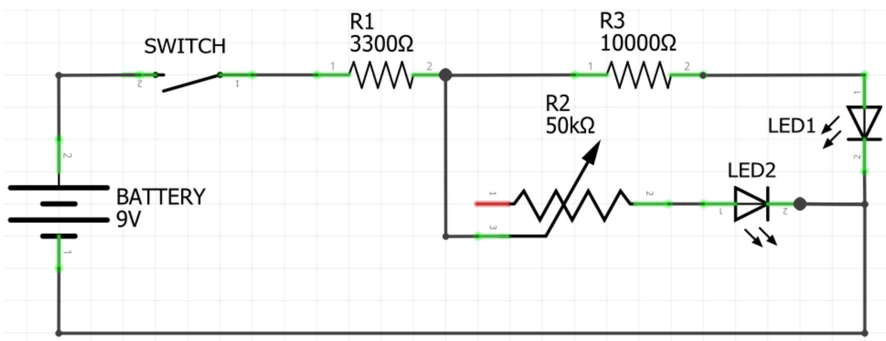
Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 100kΩ resistor.
- Two LEDs.

Using two LEDs, we can directly compare the difference between the two resistors with some visual indication. The brightness of an LED is determined through current the resistance allows to pass. This circuit is also useful if you wanted to turn on two LEDs at different brightnesses.

Experiment #6: Combined Circuit





Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One VR.
- Two LEDs.

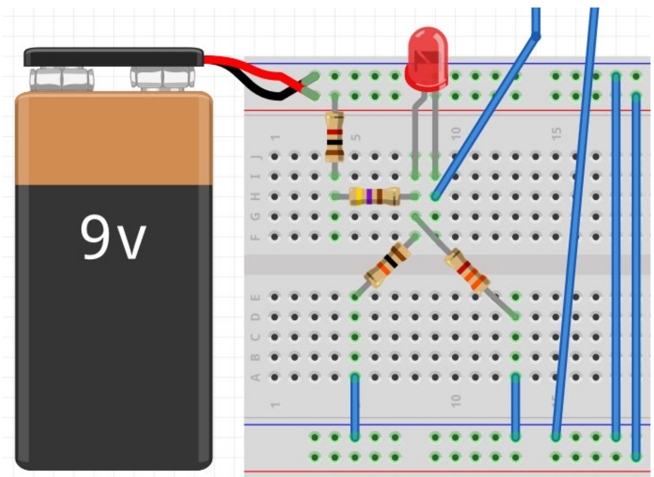
This circuit represents the previous five experiments and what you have learned from them. The variable resistor here controls which way the current will travel to light up an LED. If turned one way, it will brighten one while dimming the other in respect with the schematic. Turning the VR to 50% will divide the current equally and both LEDs will be equal in brightness. The switch plays the role of enabling such functionality, so it must be pushed down while turning the dial.

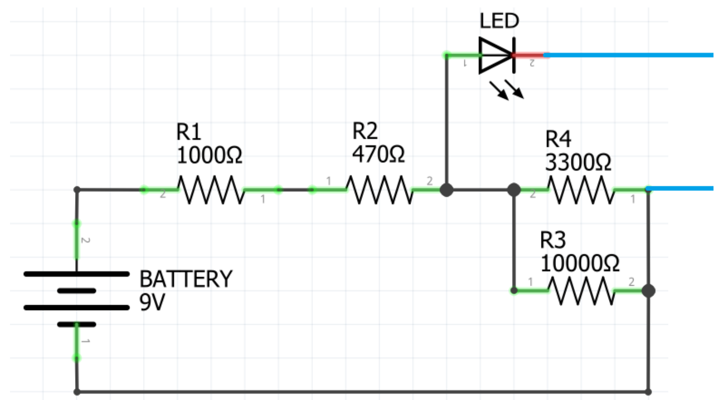
Experiment #7: Water Detector

Keywords:

Insulation: Very high resistance where electricity struggles to flow.

Conduction: Very low resistance where electricity can flow.





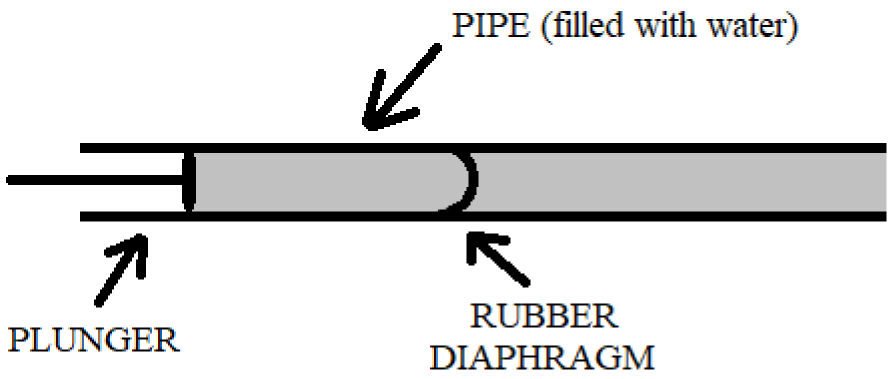
Parts Required:

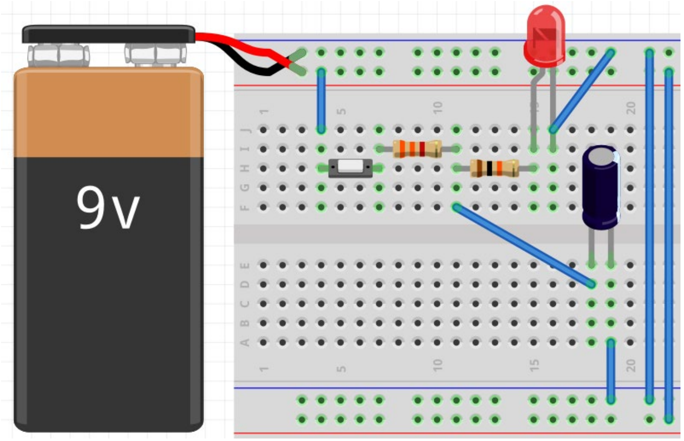
- 9V battery or power supply.
- One 470Ω resistor.
- One 1kΩ resistor.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One LED.
- Two loose wires.

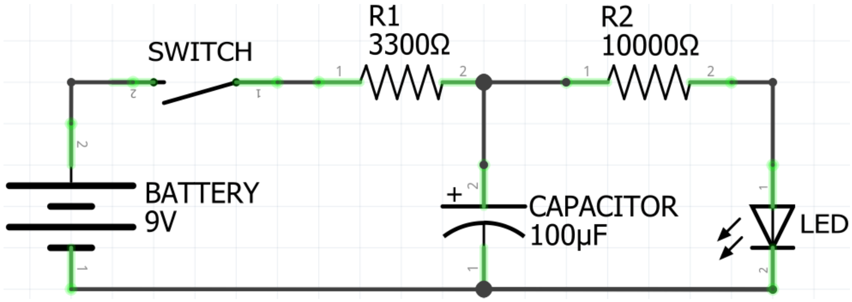
Grab a non-metal cup and fill it halfway with water. If both ends of the wires that are sticking out of the board touch each other, an appropriate short occurs and the LED will light up. Depending on your local water quality, the same result will occur if the wires are put in water, only dimmer. Upon adding more water to the cup, you should notice the LED becomes brighter thanks to the water's increased quantity of conduction. In cases if your tap water is quite distilled, its insulation will prevent the LED to light up. If such issue occurs, add some table salt and stir to dissolve it. This will lower the resistance in the water and make it more conductive!

Experiment #8: Slow Light Bulb

This experiment is using a component that is called a **capacitor**. Think of it as a rubber diaphragm inside a pipe sealing its center. A plunger is being used to stretch out the diaphragm until the force applied is ready to be returned and push the plunger away. Generally, the capacitors work the same way where they are being charged until the voltage is equal to the voltage applied, then they discharge. Upon completion of this experiment, you will see and understand how the capacitor works.







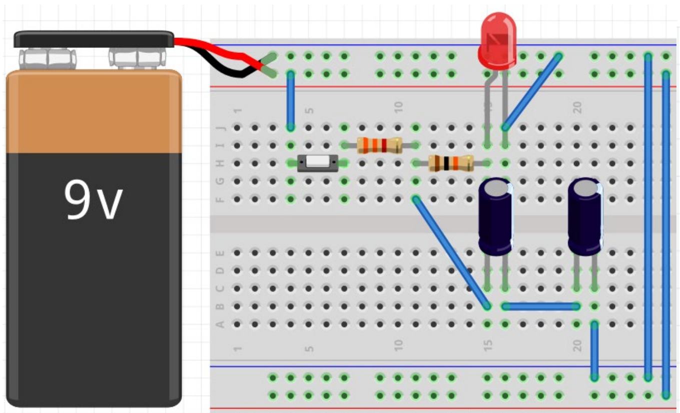
Parts Required:

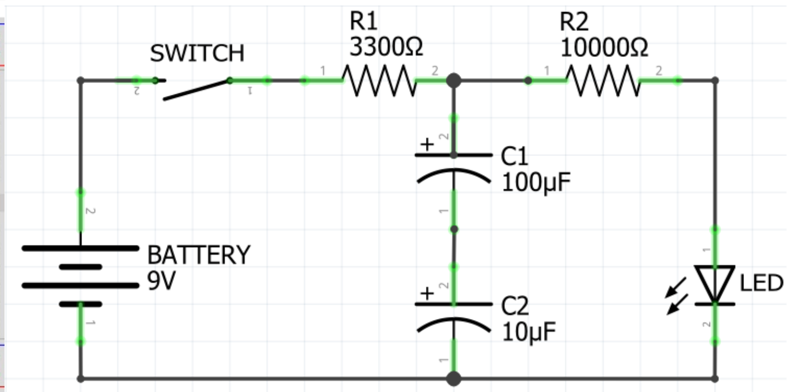
- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One 100 µF capacitor.
- One LED.

As you can already see, capacitance is measured in Farads (F, named after Michael Faraday whose work in electromagnetic induction brought the development of today's electric motors and generators). Mainly, however, you will see pico (p), nano (n), and micro (µ) prefixes in front when dealing with capacitance values because of how small they are. It's very important to note that electrolytic capacitors have a positive and a negative polarity, just like the LEDs. The negative polarity can be identified by seeing which side of the capacitor has a gray stripe.

Once you finish building this circuit and push the button, the LED demonstrates how the capacitor functions. When you close the switch, you're able to observe that the LED does not turn on immediately but takes some time to fully turn on. When you open the switch, the LED does not turn off immediately, but also takes some time to fully turn off. That is how the capacitor charges and discharges. If you were to replace the 100µF capacitor with a 10µF capacitor, you should notice that the LED is taking less time to fully activate. If you were to also experiment with the resistors, you might also figure out that the charge/discharge times are proportional to both the capacitance and the resistance in the charge/discharge path.

Experiment #9: Small Dominates Large



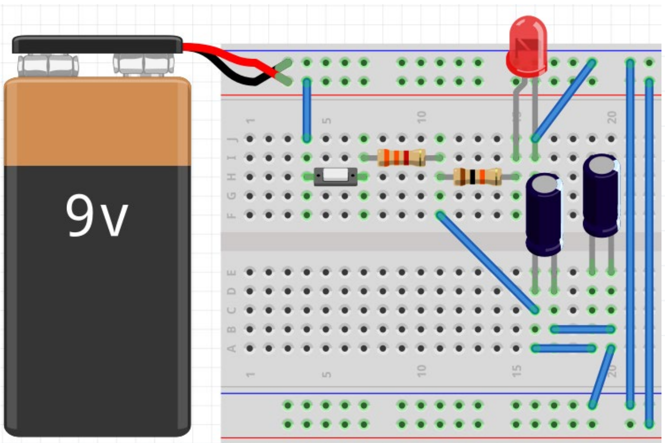


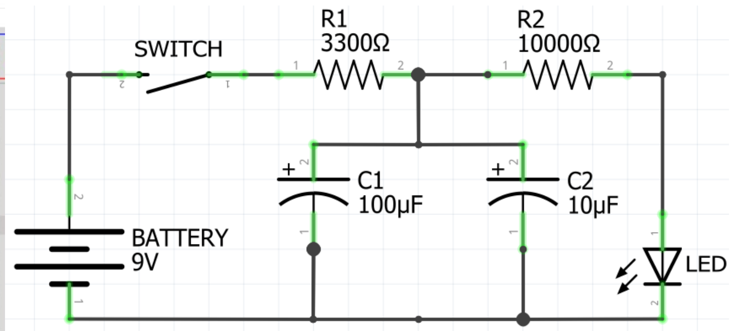
Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One 10uF capacitor.
- One 100 µF capacitor.
- One LED.

The capacitors do not have to be placed in the specified order. Now that there are two capacitors placed in series, the 10µF capacitor will dominate the 100µF capacitor. Specifically, the two capacitors are combined the same way resistors combine in parallel with the same formula, so if you refer to it with these two capacitors, the circuit will treat this as one 9.1uF capacitor. In summary, capacitors in series add the same way as resistors in parallel, which is why the LED turns on quickly.

Experiment #10: Large Dominates Small



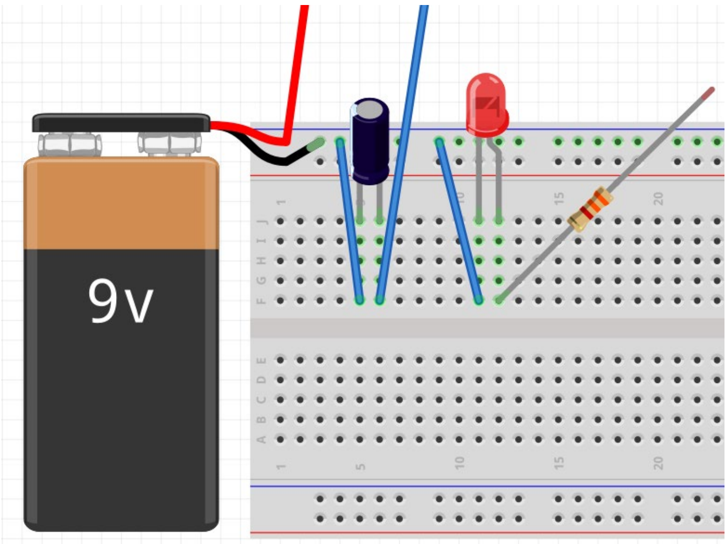


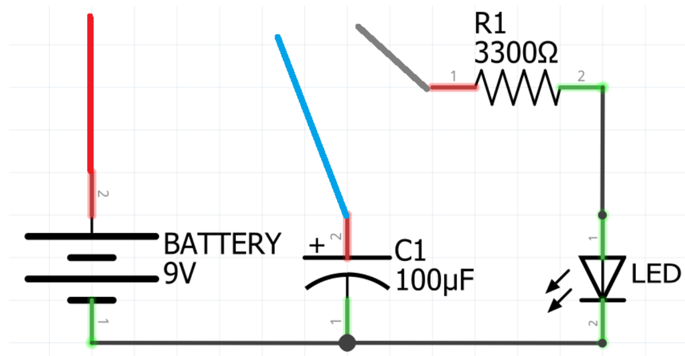
Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One 10uF capacitor.
- One 100 µF capacitor.
- One LED.

When putting capacitors in parallel right next to each other, be sure to pay attention to the polarities. As you power the circuit and press the button, you'll notice that the LED takes a while to charge and that's because capacitors in parallel add their values the same way as resistors in series, so the circuit treats these capacitors as one 110µF capacitor. Note that they can also be placed the same way as resistors in Experiment #4, only with respect to the polarities.

Experiment #11: Your Own Battery





Parts Required:

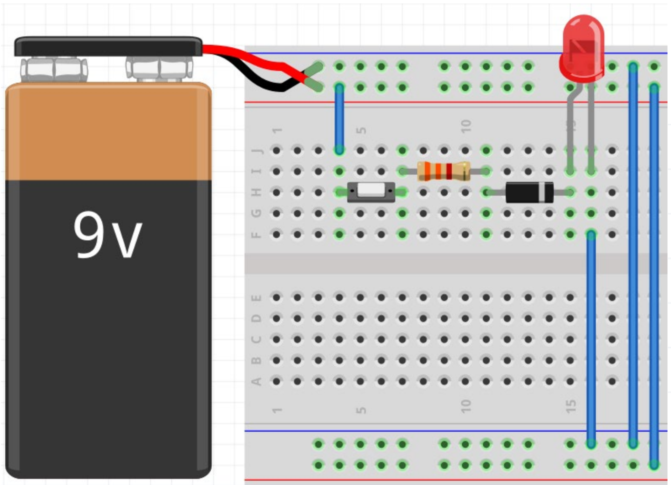
- 9V battery or power supply.
- One 3.3kΩ resistor.
- One 100 µF capacitor.
- One LED.
- One loose wire.

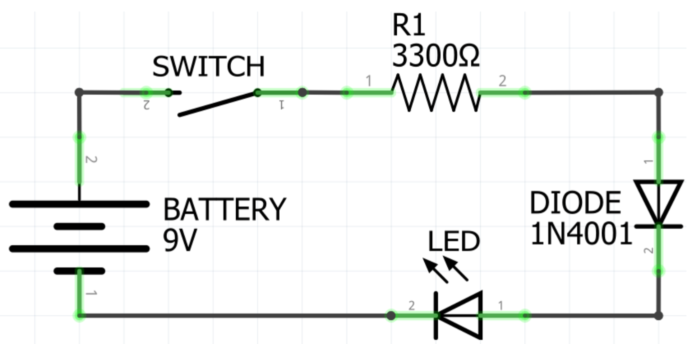
In this experiment, you will be seeing the capacitor discharge voltage and be able to interrupt and halt the process. First, some identification for the schematic to prevent confusion: red wire is the positive wire of the battery and will not be connected to the board, only the negative wire. Blue wire is the loose wire that will connect the capacitor with either the real battery or the LED. The gray wire is just the loose end of the resistor.

Now, take the end of the blue wire and touch the end of the red wire with it for several moments, then separate them. You have just charged the capacitor and it will not discharge until it makes a connection with something. Now, you will make that connection and touch the loose end of the resistor with the blue wire. You should see the LED immediately turn on and slowly turn off over time. If you separate the wires at any point and touch them again, the voltage crossing the LED will continue depleting from where it last stopped, just like with a real battery. As exciting as the title of this experiment might have sounded, this electrolytic capacitor of a battery is only good for several seconds.

Experiment #12: One-way Current

This is your introduction to the **diode**. Diodes only allow current to flow in one direction, so their polarity is very important. On the breadboard, you can see a white line towards the right end of the diode, meaning that the current will only be allowed to flow from left to right. The schematic symbol is identical to the LED symbol except it is missing the arrows.



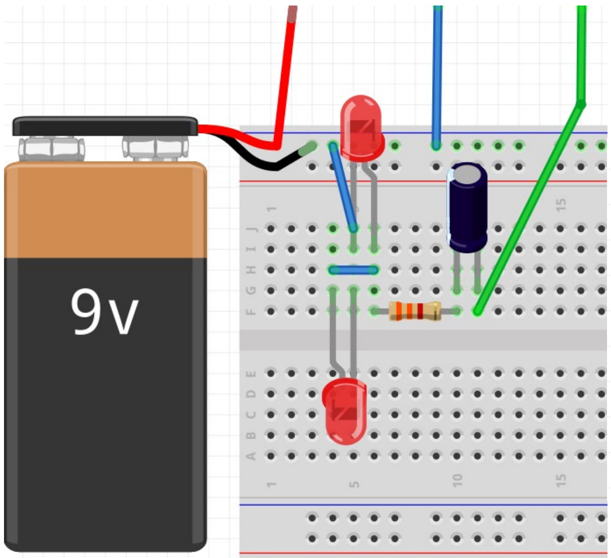


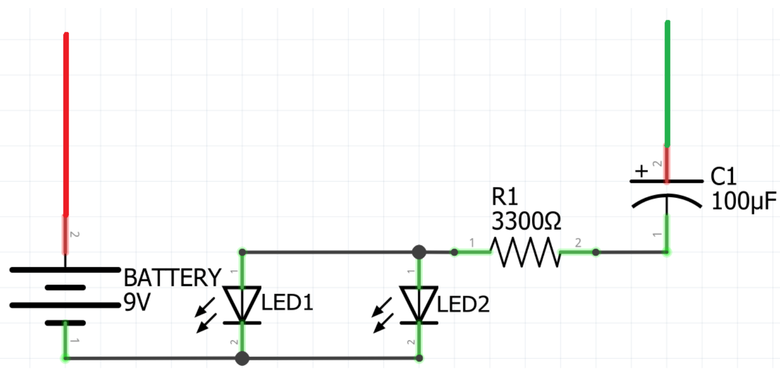
Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 1N4148 diode.
- One LED.
- One loose wire.

Your diode may appear slightly different in the package, but the line at the end of the component still marks the direction of where the current is going. In more complicated circuits, the wrong polarity placement of the diode could cause it to break down if the current is high enough and ruin the circuit. Now, by pressing the button, the LED would turn on as usual and that's not only because the diode is forward-biased (allows current to pass in desired direction) but because when it is, its resistance becomes very low and that's why the current can flow in that direction. Now if you were to flip the diode around, it'd become reverse-biased and no current would flow to the LED. In this case, it is safe to experiment with.

Experiment #13: One-way Light Bulbs





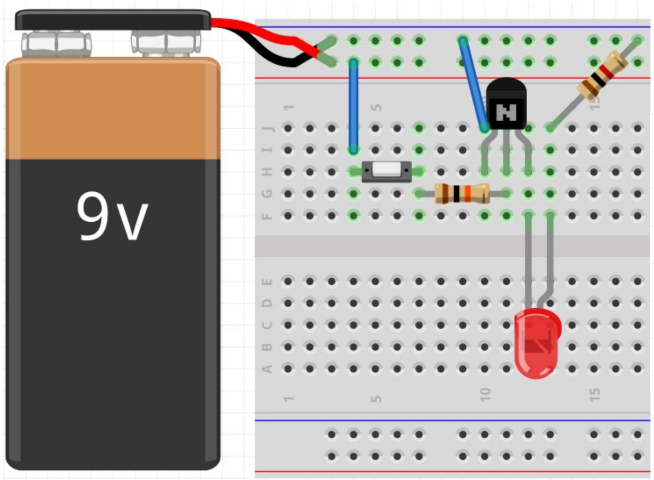
Parts Required:

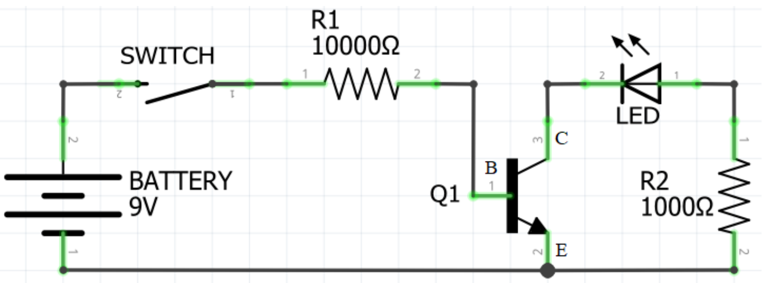
- 9V battery or power supply.
- One 3.3kΩ resistor.
- One 100µF capacitor.
- Two LEDs.
- Two loose wires.

The following circuit serves to illustrate the current flow between two LEDs (they will be referred to as “top” and “bottom”). If you were to touch the green loose wire to the battery’s red wire, you’d witness the top LED immediately turn on and then dim, that’s because the current no longer flows past the capacitor after it charges. The bottom LED is reverse-biased, meaning no current can flow through it and is why it won’t turn on. Now, if you were to touch the blue wire with the green wire, the bottom LED would turn on and go dim as the capacitor discharges. The top LED would not light this time since the current traveling from the other direction this time makes it reverse-biased. Make sure the polarities of components are correct before powering the circuit. Just like in Experiment #11, you may mess with other resistance values to try for different results.

Experiment #14: Electronic Switch

The **transistor** is one of the most revolutionary components that replaced vacuum tubes. The simplest way to describe it is as a current amplifier. The transistor's regions are as follow in order of the way the transistor is facing on the breadboard with the flat side (N) towards you: Emitter, base, collector. The order on the schematic symbol goes from bottom to top. The arrow on the symbol indicates in which direction the current will flow in the device.



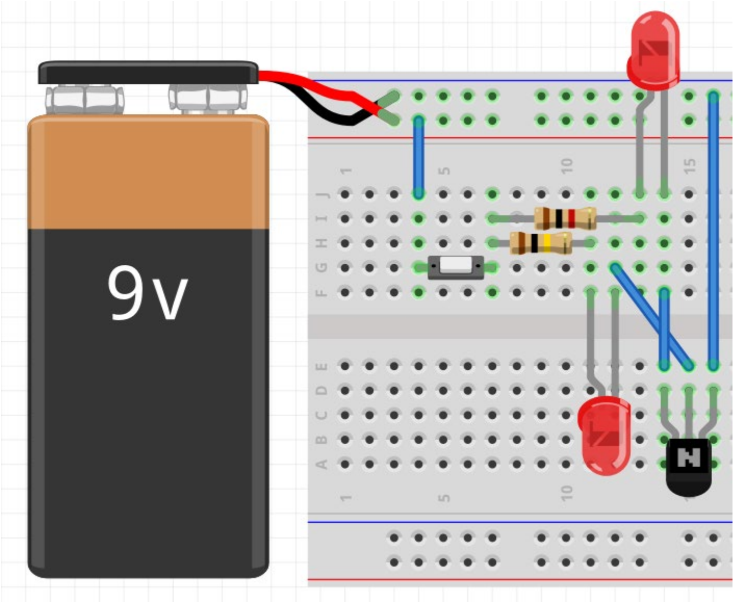


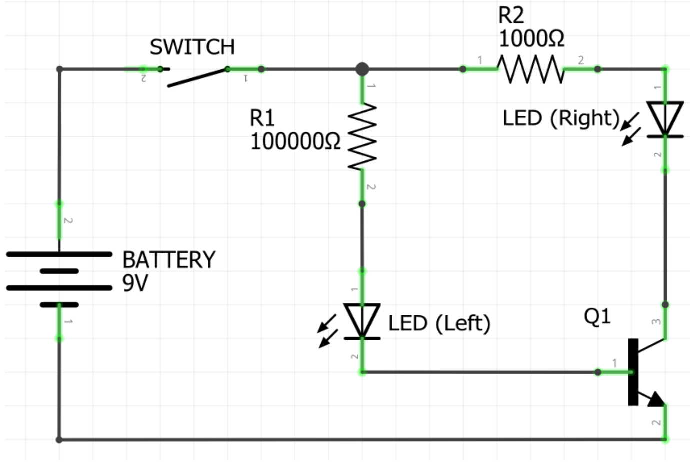
Parts Required:

- 9V battery or power supply.
- One switch.
- One 1kΩ resistor.
- One 10kΩ resistor.
- One 2N3904 transistor.
- One LED.

The transistor can behave as an electronic switch when current travels through it. Before you push the button, take note that the transistor currently behaves like an open circuit since has no current traveling through the base and needs at least 0.7V to function. Now, when you push the button, current flows through the base and the transistor behaves as a closed circuit, allowing the LED to light up. Despite needing a switch for the transistor switch to work, there are many switches that are controlled by one in electronics.

Experiment #15: Current Amplifier



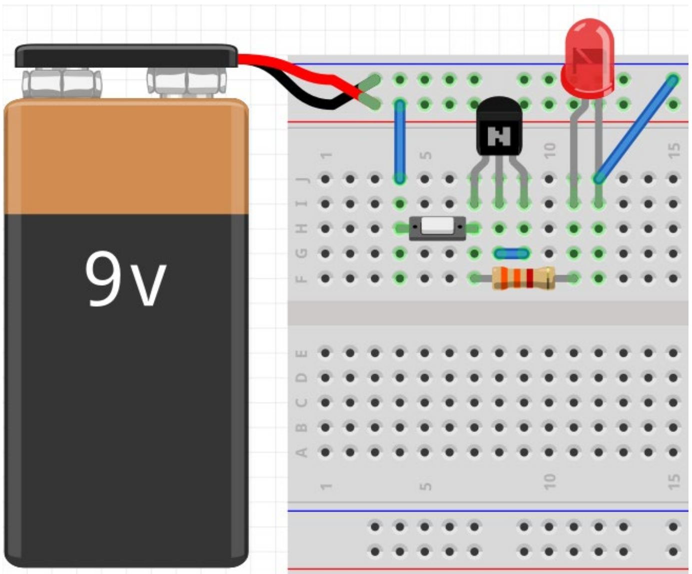


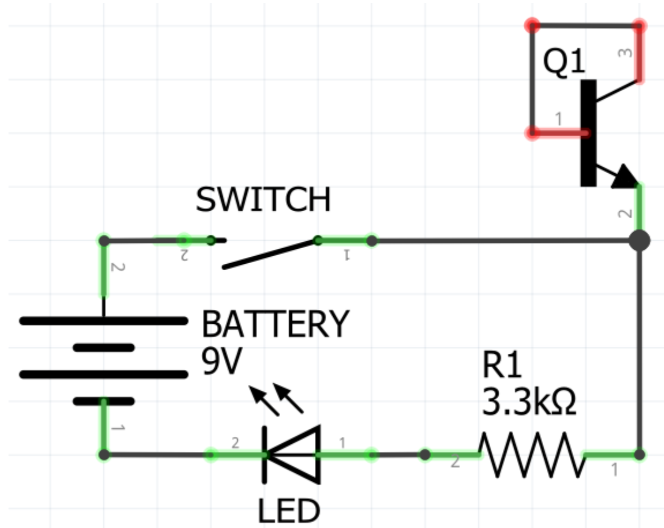
Parts Required:

- 9V battery or power supply.
- One switch.
- One 1kΩ resistor.
- One 100kΩ resistor.
- One 2N3904 transistor.
- Two LEDs.

This experiment's purpose is to portray the current at the base and at the collector of the transistor using LEDs. As you can see upon pushing the button, the left LED at the base is dim thanks to the heavy resistance in the circuit, but the right LED will be bright because it's at the collector where its current is amplified. In this transistor, the current gain is about 200. It's good to note that it isn't the transistor itself limiting the current gain but the resistance in the circuits. Be sure to pay attention to the way the components are faced on the breadboard when creating the circuit.

Experiment #16: The Substitute



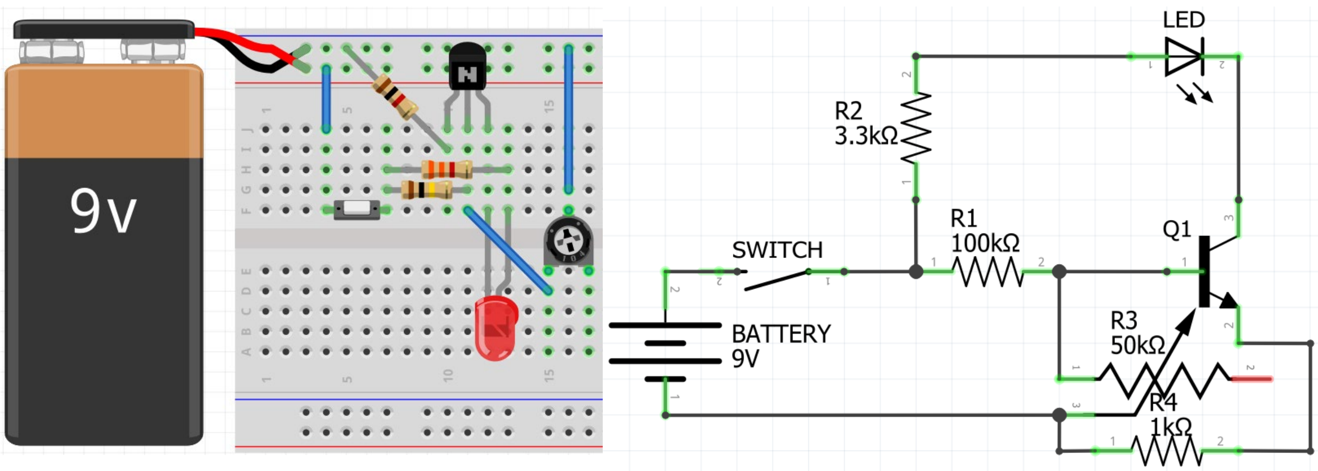


Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ resistor.
- One 2N3904 transistor.
- One LED.

The thought may or may not have crossed your mind – what would happen if the base and the collector were connected? The transistor's resistance would become very small and the current gain becomes obsolete, mocking the description of a diode. To be clearer, the transistor becomes a diode. This experiment is taken from Experiment #12, but the diode is replaced. The functionality of both experiments is the same. As a matter of fact, this occurs sometimes in the manufacturing of devices.

Experiment #17: Transistor Biasing Circuit

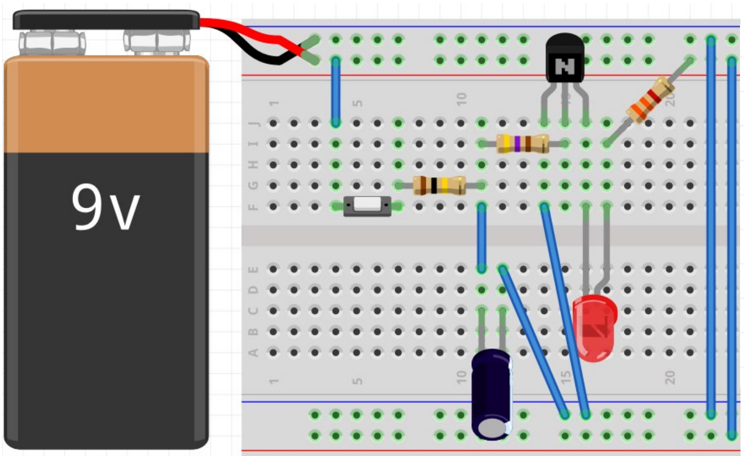


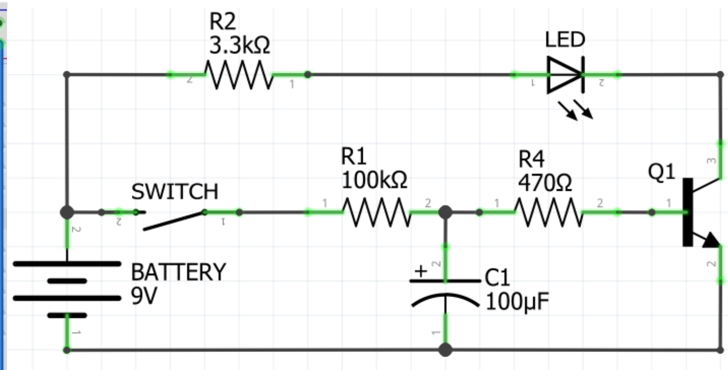
Parts Required:

- 9V battery or power supply.
- One switch.
- One 1kΩ resistor.
- One 3.3kΩ resistor.
- One 100kΩ resistor.
- One 50kΩ variable resistor.
- One 2N3904 transistor.
- One LED.

This circuit resembles a voltage divider that sets the voltage at the base of the transistor with the help of the variable resistor. If the voltage is less than 0.7V, no current will pass through the transistor. As you turn the variable resistor to increase the voltage, at some point the LED's brightness will stop increasing despite the valve being able to still turn. That's because with enough voltage, the transistor becomes saturated and cannot amplify current further.

Experiment #18: Very Slow Light Bulb



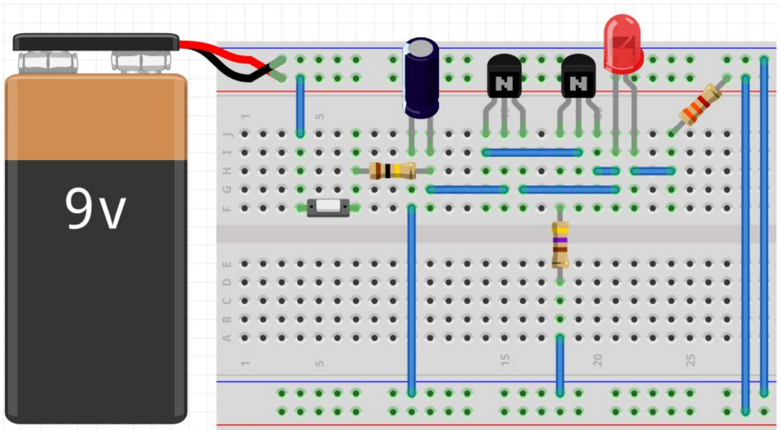


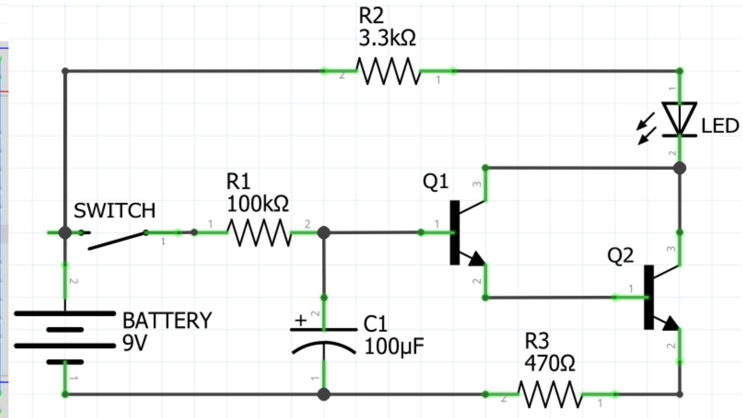
Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω resistor.
- One 3.3kΩ resistor.
- One 100kΩ resistor.
- One 100uF capacitor.
- One 2N3904 transistor.
- One LED.

Press the switch and observe the speeds at which the LED lights up and dims. At first, all the current flows through the 100kΩ resistor to charge the capacitor, then when the switch is released, the LED very slowly begins to dim as the capacitor discharges through the 470Ω resistor. You may change those values to experiment with the charge and discharge speeds. The capacitor is also responsible for both.

Experiment #19: The Darlington



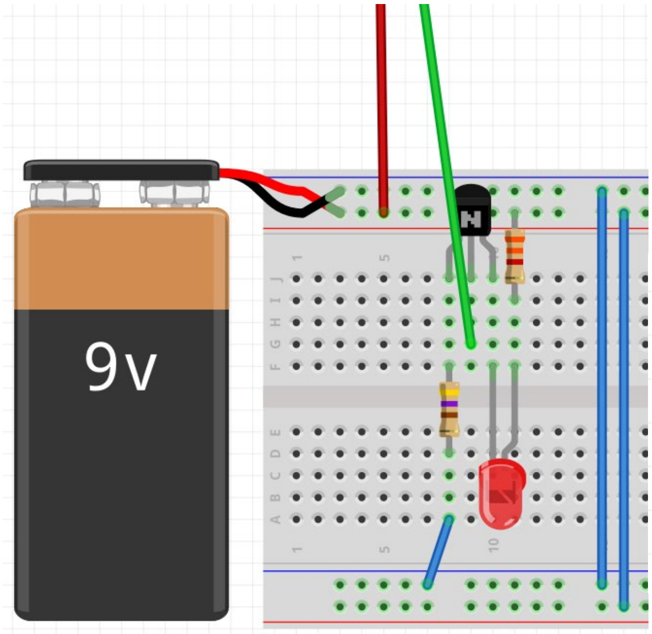


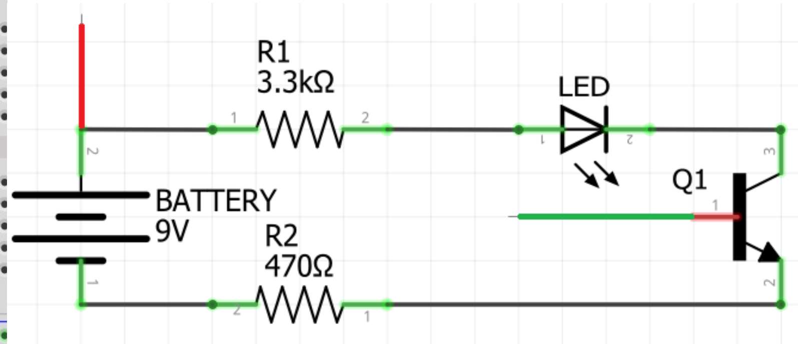
Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω resistor.
- One 3.3kΩ resistor.
- One 100kΩ resistor.
- One 100uF capacitor.
- Two 2N3904 transistors.
- One LED.

This circuit is similar to the one in Experiment #18. The difference is that here, the current going to the base of Q1 (left transistor) is amplified twice because of Q2 (right transistor). This is called the **Darlington configuration**. This configuration has very high current gain and very high input resistance at the base of the transistor. Also, because there are two transistors to turn on, the capacitor voltage must exceed 1.4V before the LED will begin to light up. The LED will dim even slower because of the low input current at the base, it will take a while.

Experiment #20: Two Finger Touch Lamp



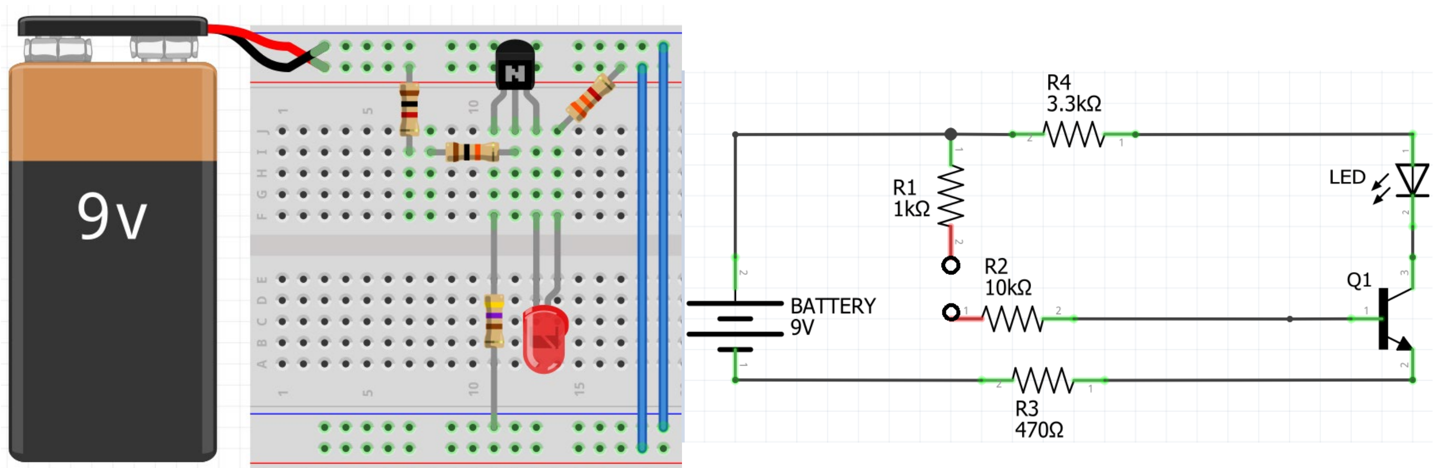


Parts Required:

- 9V battery or power supply.
- One 470Ω resistor.
- One 3.3kΩ resistor.
- One 2N3904 transistor.
- One LED.
- Two loose wires.

This circuit will not work because as you can see, there is nothing connected to the base of the transistor. That, however, can change if you provide a connection. Put one finger on the red wire and another on the green wire. The LED will probably be dimly lit since this experiment will vary from person to person depending on the resistance your body contains. You can improve this by dipping your fingertips in some water since, as tested in Experiment #7, it can conduct electricity and your body is mostly made up of water.

Experiment #21: One Finger Touch Lamp



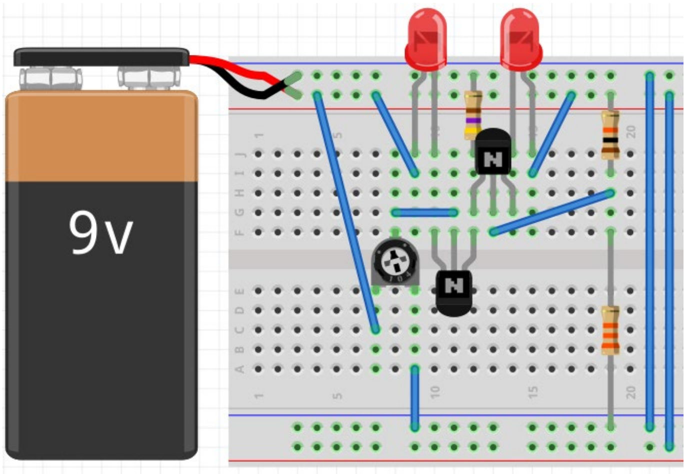
Parts Required:

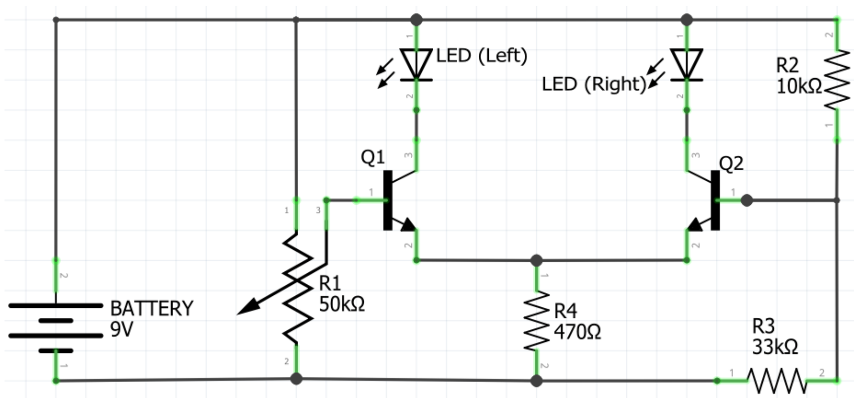
- 9V battery or power supply.
- One 470Ω resistor.
- One 1kΩ resistor.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One 2N3904 transistor.
- One LED.

You will need your fingers for this experiment also, or rather just one. You'll notice upon creating this circuit that the 1kΩ and the 10kΩ resistors are plugged into the board adjacently from each other rather than being connected directly in series. This is done for the purpose of you placing your fingertip against the two resistors simultaneously to create the connection towards the LED to light it up. If the LED barely or does not light up, wet your finger with water or saliva and try again.

Experiment #22: The Voltmeter

It's preferred to have a fully charged 9V battery for this experiment.





Parts Required:

- 9V battery or power supply.
- One 470Ω resistor.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One 33kΩ resistor.
- One 50kΩ variable resistor.
- Two 2N3904 transistors.
- Two LEDs.

The 10kΩ (upper) and the 33kΩ (lower) resistors will be replaced occasionally by you when measuring the voltage. Instead of using a real voltmeter, you will calculate the voltage using the following formula:

Calculated Voltage = (R lower / (R upper + R lower)) * Battery Voltage

After obtaining the calculated voltage, you'll have to find the measured voltage. To do that, you must turn the variable resistor until both left and right LEDs are equally bright. Consider the percentage of how much you have turned the dial from 0 and multiply it by 0.09. For example, my calculated voltage is 6.9V for the resistor values of 10kΩ and 33kΩ:

Calculated Voltage = (33kΩ / (10kΩ + 33kΩ)) * 9V

Calculated Voltage = 6.9V

I turn the dial approximately 75% until both LEDs were equally bright.

Measured Voltage = 75 * 0.09

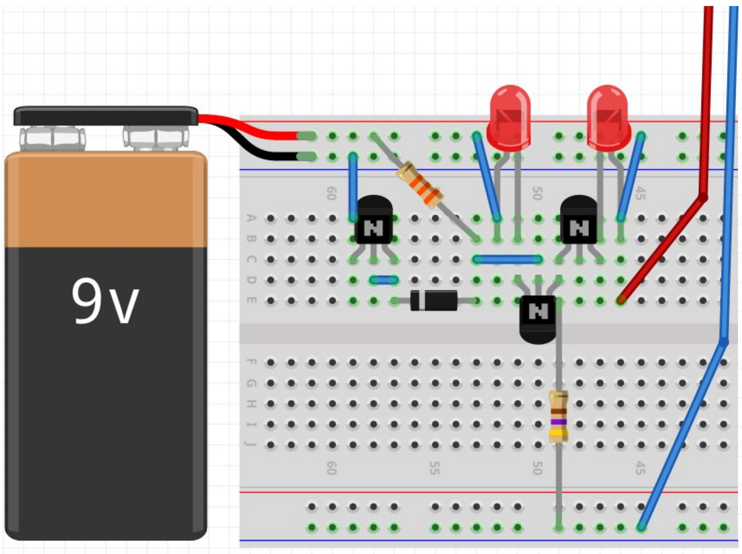
Measured Voltage = 6.75V

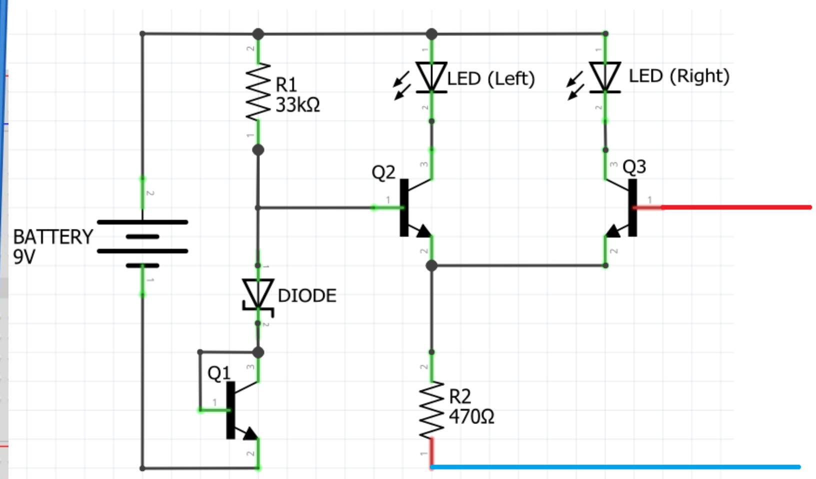
There may be a slight difference between the measured and calculated voltages due to tolerances in the resistors as well as how far you have turned the dial. The following table lists different combinations of resistor values of which you can measure. Some resistors will be replaced with a pair either in series or in parallel to obtain new values. Remember to unplug the battery from the circuit board when you're not using it to avoid draining your battery.

Upper Resistor	Lower Resistor	Calculated Voltage	Measured Voltage
10kΩ	33kΩ	6.9V	
33kΩ	10kΩ	2.1V	
33kΩ	100kΩ	6.8V	
100kΩ	33kΩ	2.2V	
3.3kΩ	10kΩ	6.8V	
10kΩ	3.3kΩ	2.2V	
1kΩ	3.3kΩ	6.9V	
3.3kΩ	1kΩ	2.1V	
10kΩ	Parallel 33kΩ, 100kΩ	6.4V	
Parallel 33kΩ, 100kΩ	10kΩ	2.6V	
Series 10kΩ, 33kΩ	100kΩ	6.3V	
100kΩ	Series 10kΩ, 33kΩ	2.7V	
1kΩ	Parallel 3.3kΩ, 10kΩ	6.4V	
Parallel 3.3kΩ, 10kΩ	1kΩ	2.6V	
Series 1kΩ, 3.3kΩ	10kΩ	6.3V	
10kΩ	Series 1kΩ, 3.3kΩ	2.7V	

Experiment #23: 1.5V Battery Tester

It's preferred to have a fully charged 9V battery for this experiment.





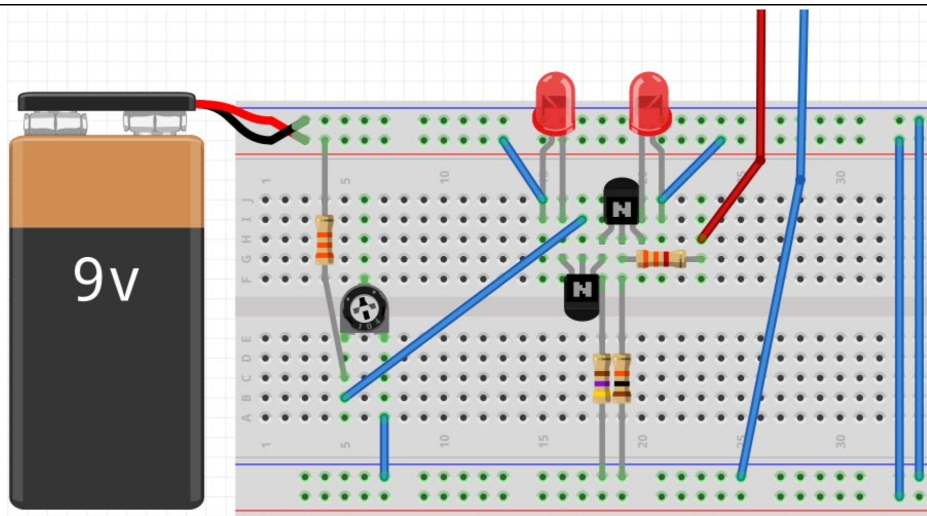
Parts Required:

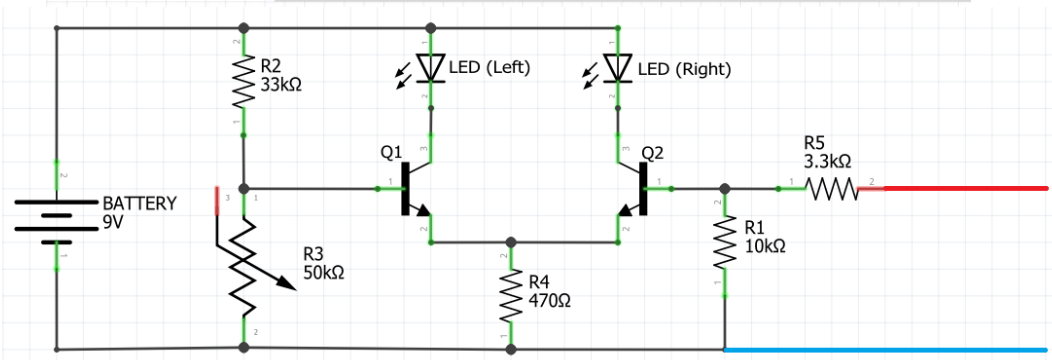
- 9V battery or power supply.
- One 470Ω resistor.
- One 33kΩ resistor.
- One 1N4148 diode.
- Three 2N3904 transistors.
- Two LEDs.
- Two loose wires.
- 1.5V battery.

This circuit is a good for testing the life of a 1.5V battery. Take any 1.5V battery (AAA, AA, A, B, C or D cells) and hold it between the two loose wires after you have plugged in your 9V battery / power supply. The red wire marks the positive the positive side of the battery and the blue wire marks the negative side. If the right LED turns on when the battery touches the two wires, it means the 1.5V battery is good. Otherwise, the battery is weak and should be replaced. Remember to unplug the battery from the circuit board when you're not using it to avoid draining your battery.

Experiment #24: 9V Battery Tester

It's preferred to have a fully charged 9V battery for this experiment.



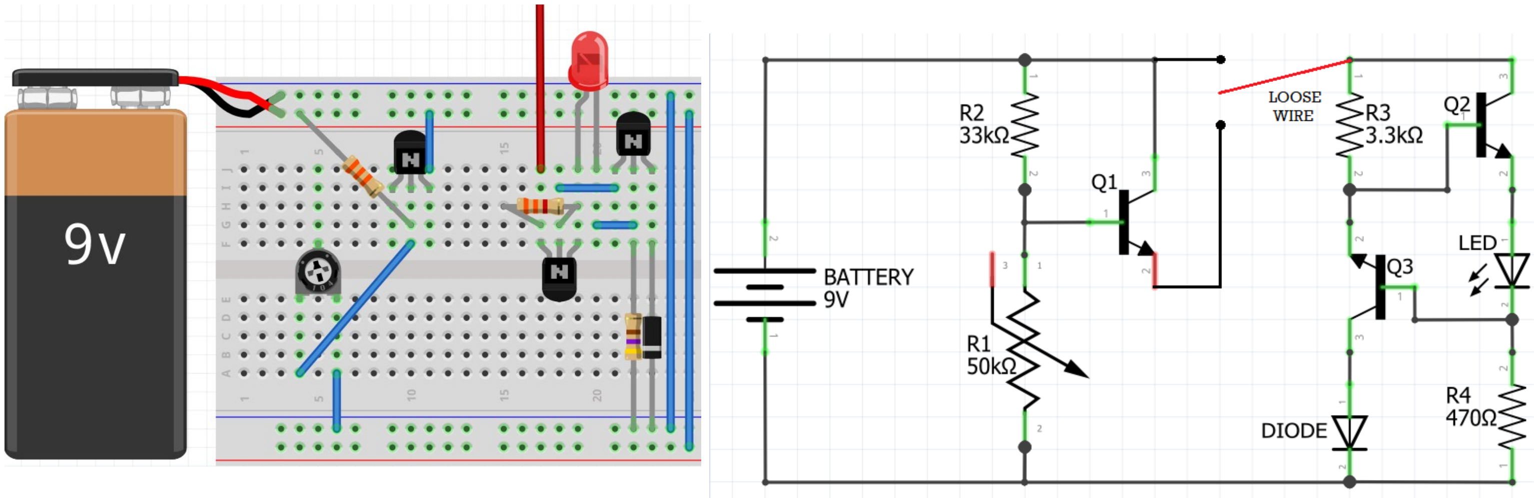


Parts Required:

- Two 9V batteries or power supply with a 9V battery.
- One 3.3kΩ resistor.
- One 10kΩ resistor.
- One 470Ω resistor.
- One 33kΩ resistor.
- One 50kΩ variable resistor.
- Two 2N3904 transistors.
- Two LEDs.
- Two loose wires.

This circuit is similar to the one in Experiment #23 and the procedure is the same – red wire to the positive of the battery and the blue to the negative. When measuring the battery, the right LED states the battery is good, otherwise not. Remember to unplug the battery from the circuit board when you're not using it to avoid draining your battery.

Experiment #25: Battery Immunizer



Parts Required:

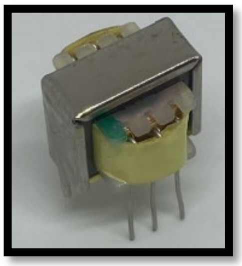
- 9V battery or power supply.
- One 470Ω resistor.
- One 3.3kΩ resistor.
- One 33kΩ resistor.
- One 50kΩ variable resistor.
- Three 2N3904 transistors.
- One 1N4148 diode.
- One LED.
- One loose wire.

The left side of this circuit's voltage is reduced to 4.7V. If the loose wire were to be connected to the collector of Q1 (left transistor), the performance of the overall circuit to light up the LED will not be any different if it were to be connected to the 9V battery source (positive power rail). This circuit's useful if you don't want its performance affected by the voltage drop in your weakening battery.

Experiment #26: Anti-Capacitor

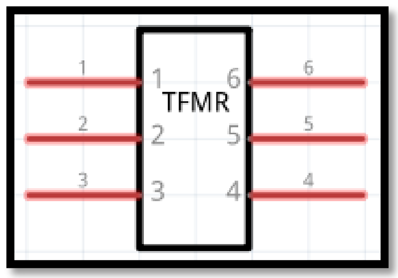
The **transformer** is two wires wrapped around different ends of an iron bar with different amounts of turns that invokes inductance (expressed in henrys, H). Essentially, an inductor in this case could be thought of as a long hose wrapped around itself many times. In reality, it is made by coiling a wire, so they can also be referred to as coils. The transformer's inductors lie within its primary (1kΩ impedance) and secondary (8Ω impedance) sides. Primary side is marked with a green sticker and its pins range from 1-3.

Transformer

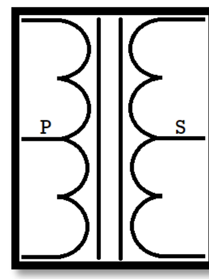


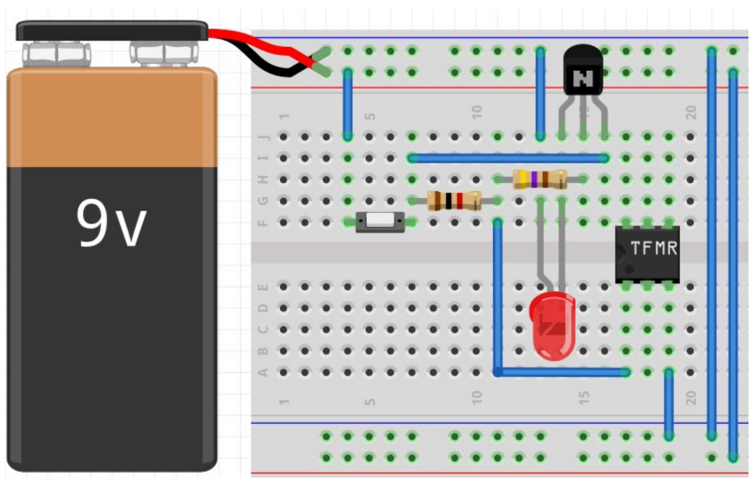
Symbols

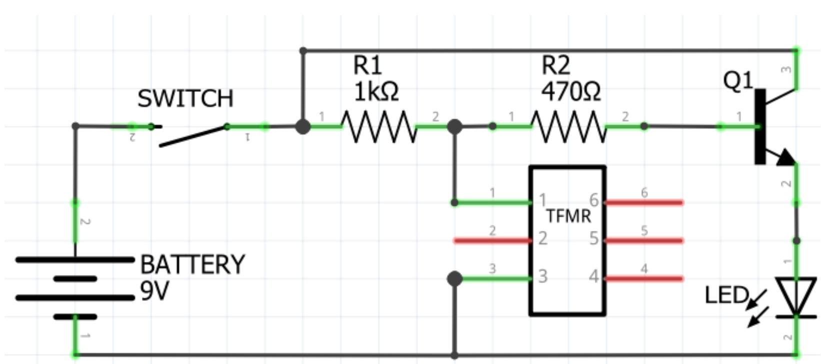
(unofficial)



(official)





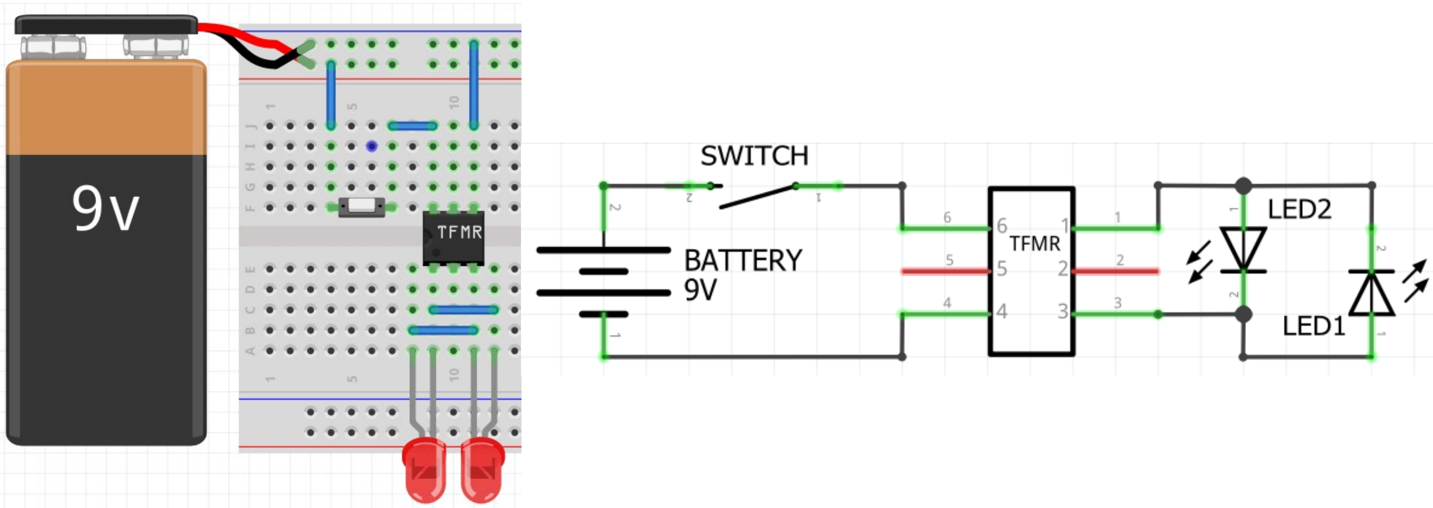


Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω resistor.
- One 1kΩ resistor.
- One 2N3904 transistor.
- One 42TL013 transformer.
- One LED.

One thing to note about the inductors is that they block alternating current (AC) but pass direct current (DC), while the capacitor does the opposite. It's now important to know about the fundamental differences between the two types of current: AC changes its direction periodically (constantly changing) while DC only flows in one direction (unchanging) and they're used for different applications. When you power your circuit and press the switch, you'll notice that the LED only blinked once. While it took time for the capacitor to charge to light up an LED, the transformer causes the LED to blink for a moment before turning off as the switch is still pressed.

Experiment #27: Magnetic Bridge



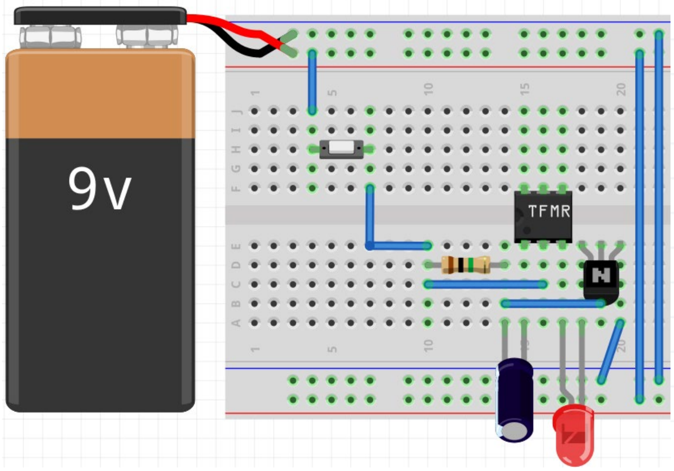
Parts Required:

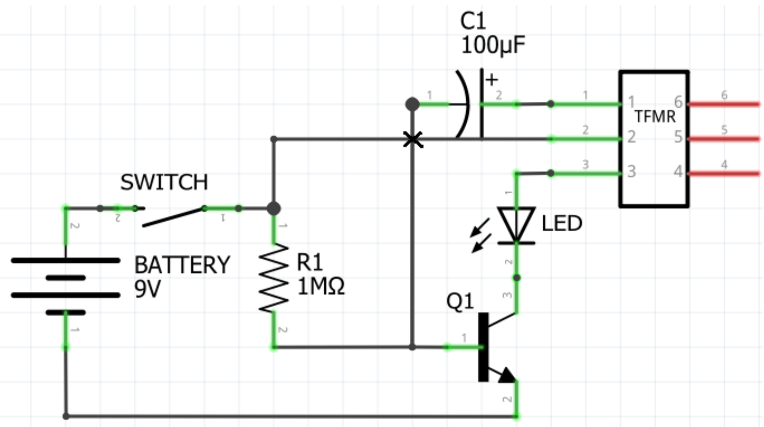
- 9V battery or power supply.
- One switch.
- One 42TL013 transformer.
- Two LEDs.

The reason you'd call the transformer a "magnetic bridge" involves reasoning that partly abolishes the water pipe analogy used earlier. Electric current doesn't entirely flow like water. It's rather a flow of sub-atomic particles called **electrons** that contain not only electric properties but also magnetic, and the coils are what express these magnetic effects. Now, when you power the circuit and press the switch, you'll obtain similar results as the previous experiment but with different method. Upon pressing that switch, there is a sudden surge of alternating current that lights up the left LED for only a brief moment due to the stabilization of the current and turning it to direct current. Once the switch is released, the drop in current through the transformer magnetically creates another current on the other side of the transformer except in the opposite direction, hence lighting up the right LED for a brief moment. If you were you to flip the transformer to change its sides, the LEDs would not turn on due to the secondary side lacking the proper inductance.

Experiment #28: The Lighthouse

The "x" marked on the schematic indicates that the intersecting wires do not actually create a connection and are just going over each other, e.g., the C1 100µF capacitor does not directly connect to the switch.





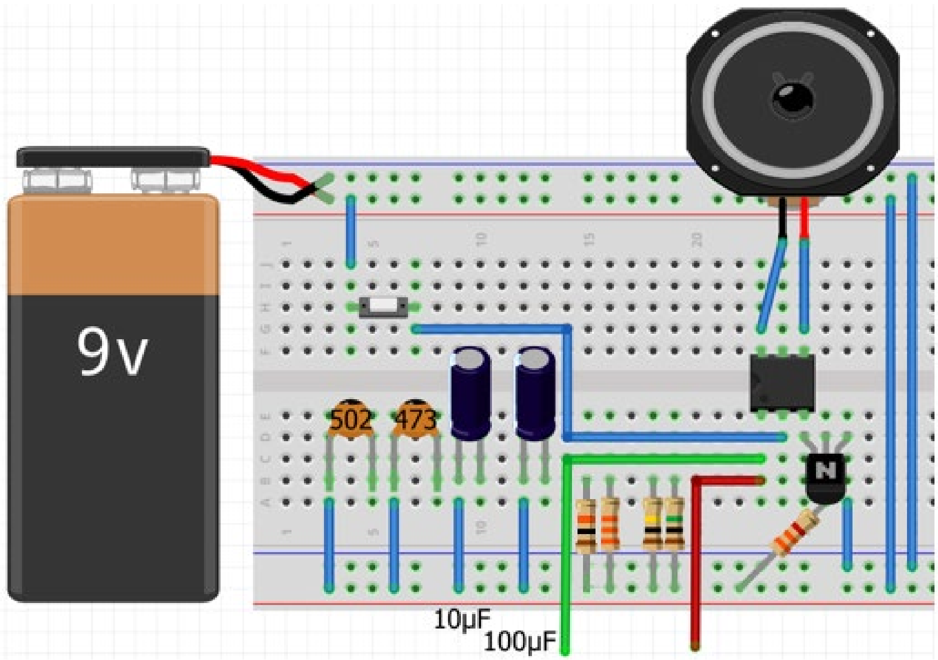
Parts Required:

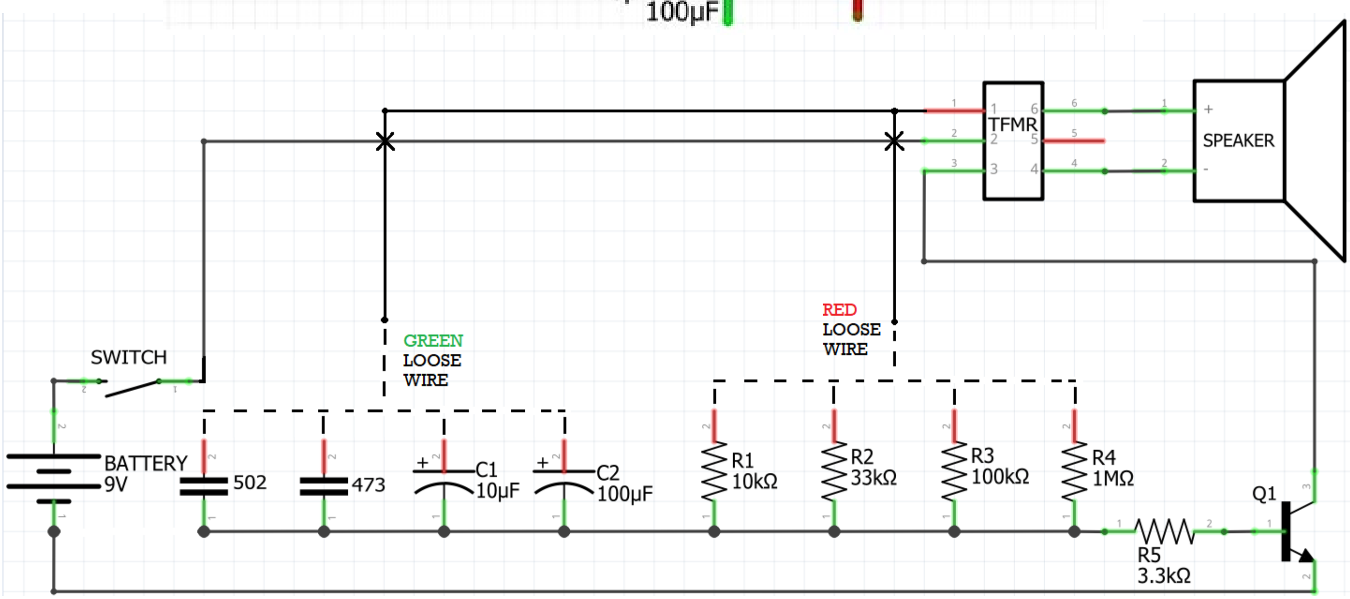
- 9V battery or power supply.
- One switch.
- One 1MΩ resistor.
- One 100µF capacitor.
- One 2N3904 transistor.
- One transformer.
- One LED.

As you push and hold the switch, the LED blinks at a fixed frequency. This is due to the circuit simulating the behavior of an **oscillator.** Oscillators use feedback, and feedback is when the input is being adjusted based on what the output is. In this circuit, the oscillator's frequency is controlled by the resistor, capacitor and the transformer. If you were to replace the 1MΩ with a 10kΩ, you'd be able to witness the LED blink at a much faster frequency due to lower resistance. Feedback is useful and necessary, but it can often be dangerous. For instance, you're at a concert and you hear a high pitch come from the speakers when somebody speaks into the microphone. That's because the sound from speaker has been fed back into the microphone.

Experiment #29: Electronic Sound

A **speaker** plays sound and the way it does so is through converting electrical energy into sound by creating vibrations caused by signal in alternate current. Such vibrations travel through the air in sound waves that our ears can pick up.





Note: In all experiments, replace the 502 disc capacitor with a 472 disc capacitor.

Parts Required:

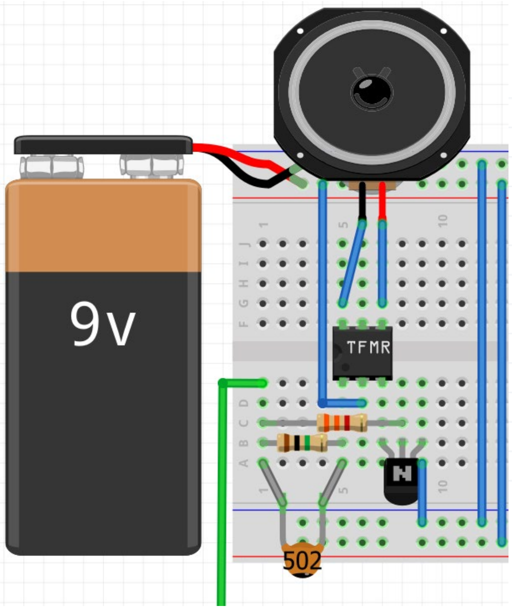
- 9V battery or power supply.
- One switch.
- One 3.3kΩ, 10kΩ, 33kΩ, 100kΩ, 1MΩ resistor.
- One 4.7nF (472), 0.047µF (473), 10µF, 100µF capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.
- Two loose wires.

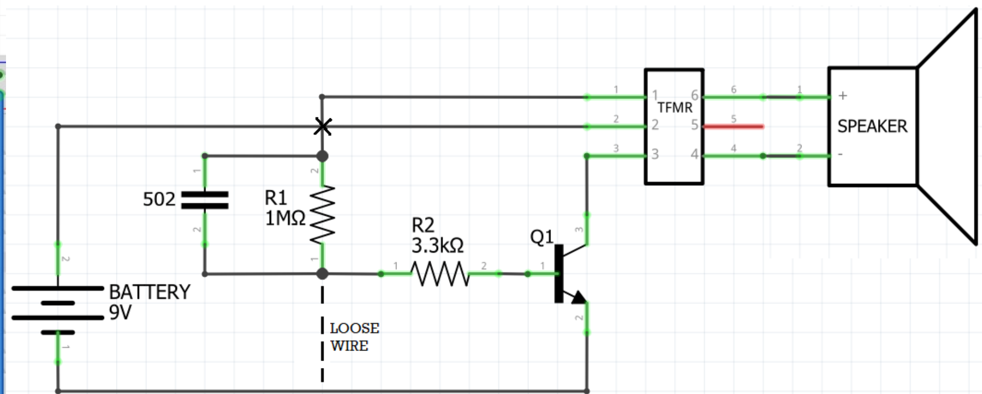
You might have noticed a pair of disc capacitors in the diagram. They behave like regular capacitors except they do not have a polarity and can be placed in whichever direction. They are used for even smaller capacitances. You may also have noticed that the speaker in the diagram has a positive and a negative polarity – those placements do not matter as the speaker in your kit lacks polarities.

The reason most of the resistors and all capacitors are being used in this experiment is because you'll be trying out different combinations of Farads and Ohms to achieve a specific sound. Using the table below, write some comments about the pitch of the sound you hear.

Farads / Ohms	10kΩ	33kΩ	100kΩ	1MΩ
4.7nF				
0.047µF				
10µF				
100µF				

Experiment #30: The Alarm





Parts Required:

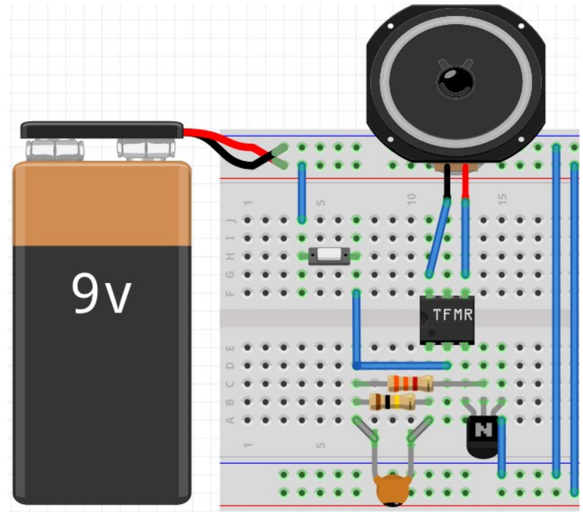
- 9V battery or power supply.
- One 3.3kΩ, 1MΩ resistor.
- One 4.7nF (472) capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.
- One loose wire.

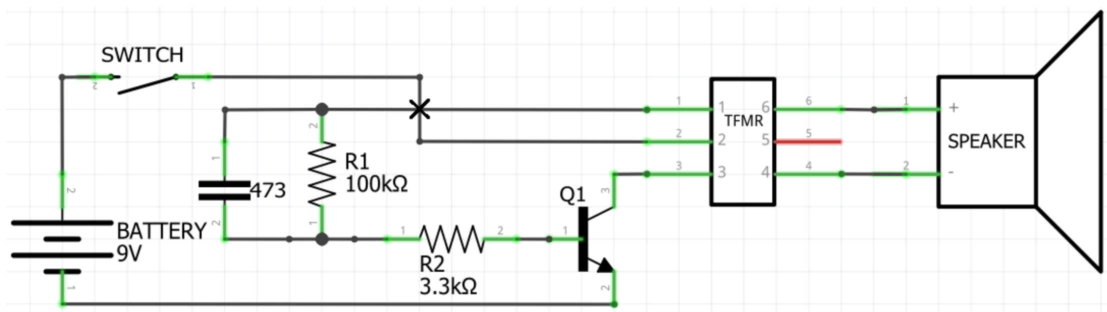
Connect the loose wire as indicated in the schematic and you won't be hearing any sound. That's because that wire creates a short across the base of the transistor and the current flow there is restricted. If you disconnect the trip wire, you will hear the alarm go off. This circuit is used to detect intruders and burglars that try breaking into homes by tripping on the wire and disconnecting it as demonstrated in this experiment.

Experiment #31: Morse Code

Parts Required:

- 9V battery or power supply.
- One switch.
- One 3.3kΩ, 10kΩ resistor.
- One 0.047µF (473) capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.

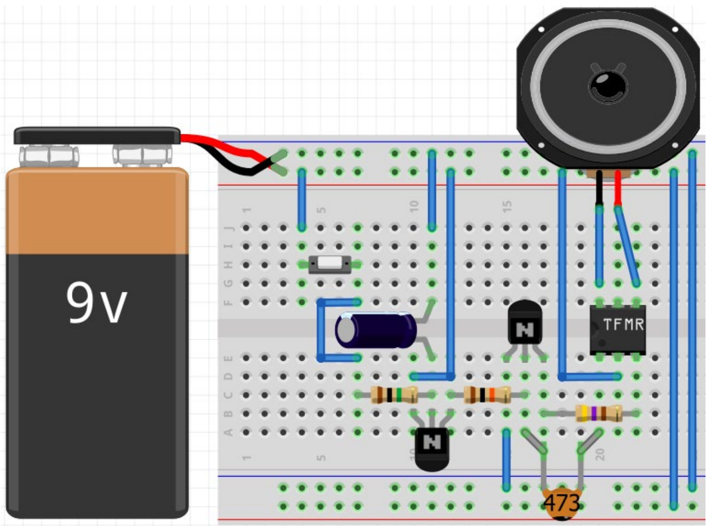


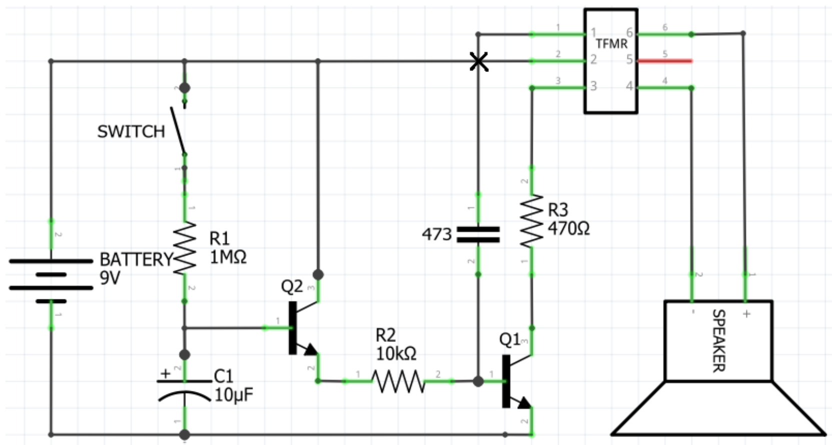


MORSE CODE					
A: . _	H:	O: _ _ _	V: . . . _	Question: . . _ _ . .	7: _ _ . . .
B: _ . . .	I: . .	P: . _ _ .	W: . _ _	1: . _ _ _ _	8: _ _ _ . .
C: _ . _ .	J: . _ _ _	Q: _ _ . _	X: _ . . _	2: . . _ _ _	9: _ _ _ _ .
D: _ . .	K: _ . _	R: . _ .	Y: _ . _ _	3: . . . _ _	0: _ _ _ _ _
E .	L: . _ . .	S: . . .	Z: _ _ . .	4: . . . . _	
F . . _ .	M: _ _	T: _	Period: . _ . _ . _	5:	
G: _ _ .	N: _ .	U: . . _	Comma: _ _ . . _ _	6: _	

This experiment is pretty straightforward – use the above chart to try and compose a series of characters with the use of this experiment's circuit. Morse code was widely used in the second half the 19th century to communicate, usually encrypted, information through the use of dots and dashes. This can be done by pressing the circuit's switch to imitate a short beep (dot) or a long beep (dash) and leave a short pause in between to compose a character. When starting the next character, begin with a slightly longer pause so it can be heard when it begins.

Experiment #32: Siren



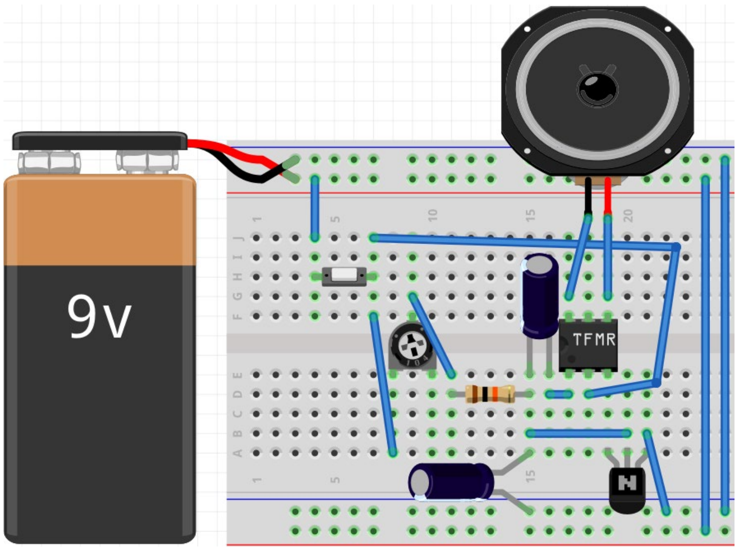


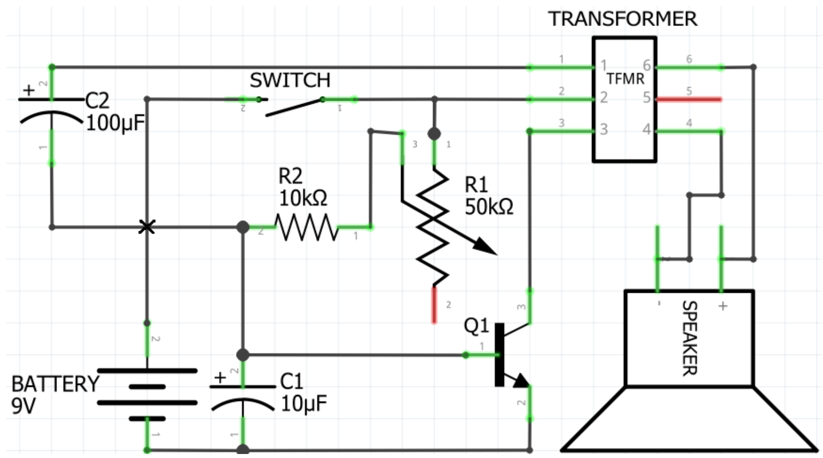
Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω, 10kΩ, 1MΩ resistor.
- One 0.047µF (473), 10µF capacitor.
- Two 2N3904 transistors.
- One transformer.
- One speaker.

By pressing the switch, this circuit imitates the sound of a siren that comes from the speaker. The 1MΩ resistor and 10µF capacitor connected to the base of the left transistor cause the current to slowly increase. When the switch is released, the capacitor, of course, discharges, and that's how this sounds like a siren. The sound can get louder by adding a 1kΩ resistor in series with the base of the right transistor if you'd like that.

Experiment #33: Electronic Rain



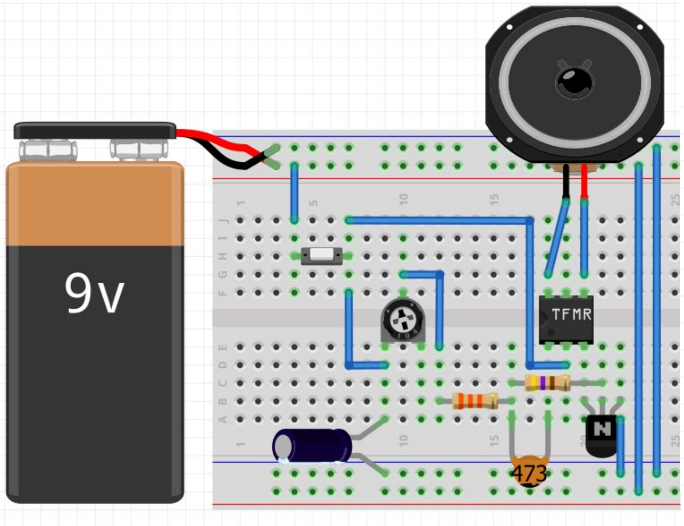


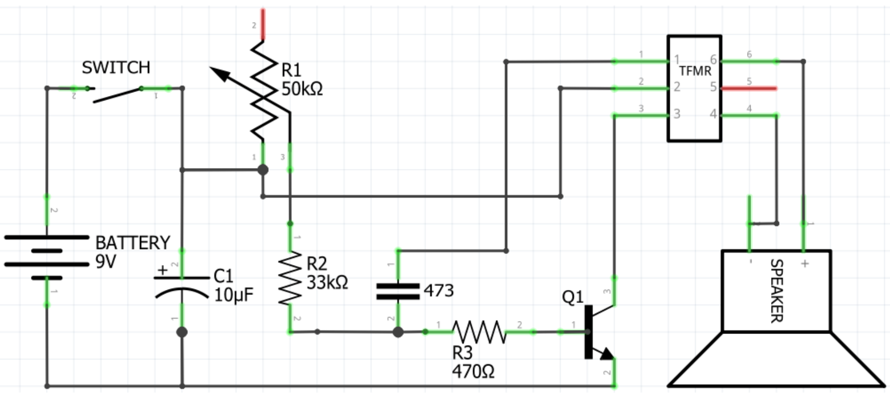
Parts Required:

- 9V battery or power supply.
- One switch.
- One 10kΩ resistor.
- One 50kΩ variable resistor.
- One 10µF, 100µF capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.

Press the switch when the circuit is connected, and you'll hear what sounds like raindrops. The VR controls the speed of the rain, turning it one way will speed it up and the other way will slow it down. As you already know, this happens because the VR controls the resistance that affects how much current comes through. If you were to replace the 10kΩ resistor with a 100kΩ, the rain would be very slow and will sound more like a leaky faucet.

Experiment #34: The Space Gun



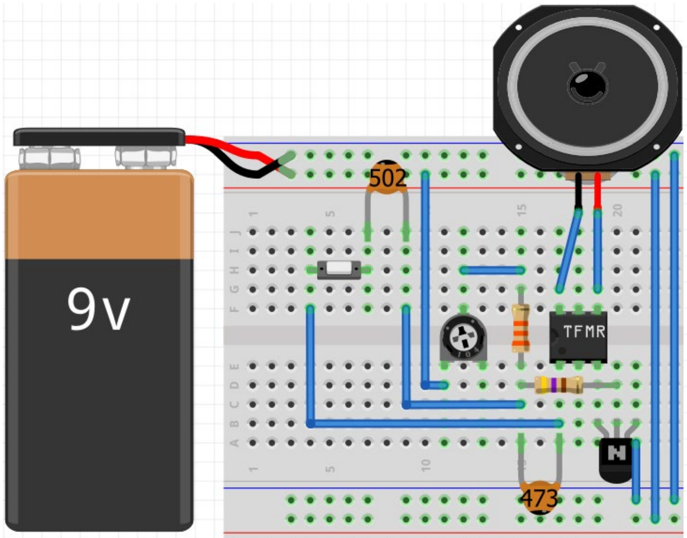


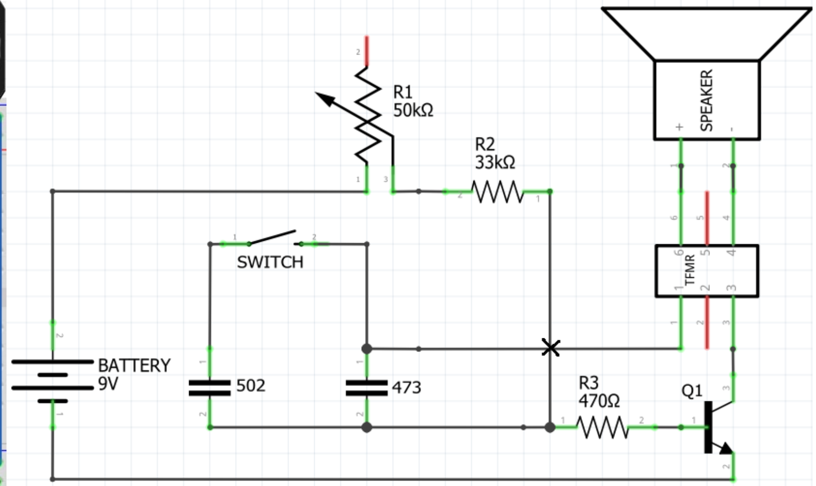
Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω, 33kΩ resistor.
- One 50kΩ variable resistor.
- One 0.047µF (473), 10µF capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.

By pressing the switch repeatedly, you'll hear what sounds like a sound effect used in sci-fi movies for space guns that shoot lasers. This circuit works similarly as to the one in the previous experiment except for the 10µF capacitor. It charges instantly and discharges when the switch is released.

Experiment #35: Electronic Noisemaker



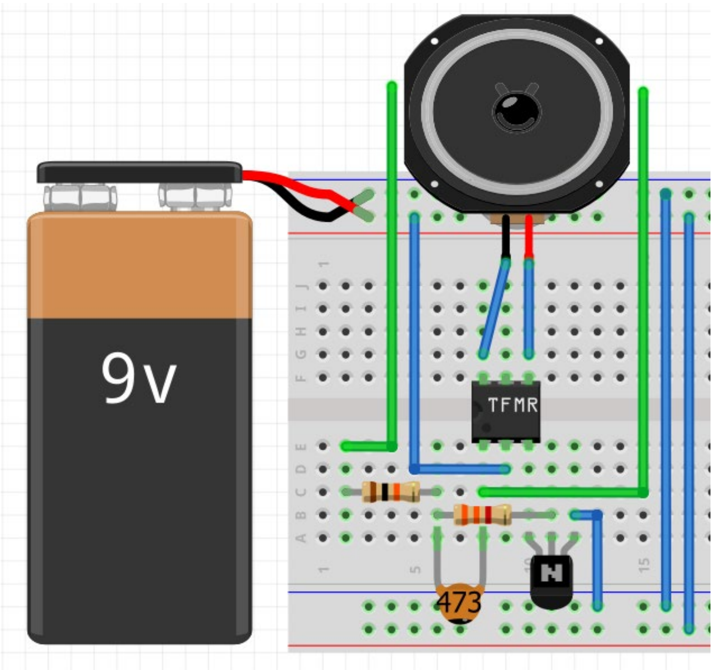


Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω, 33kΩ resistor.
- One 50kΩ variable resistor.
- One 0.047µF (473), 4.7nF (472) capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.

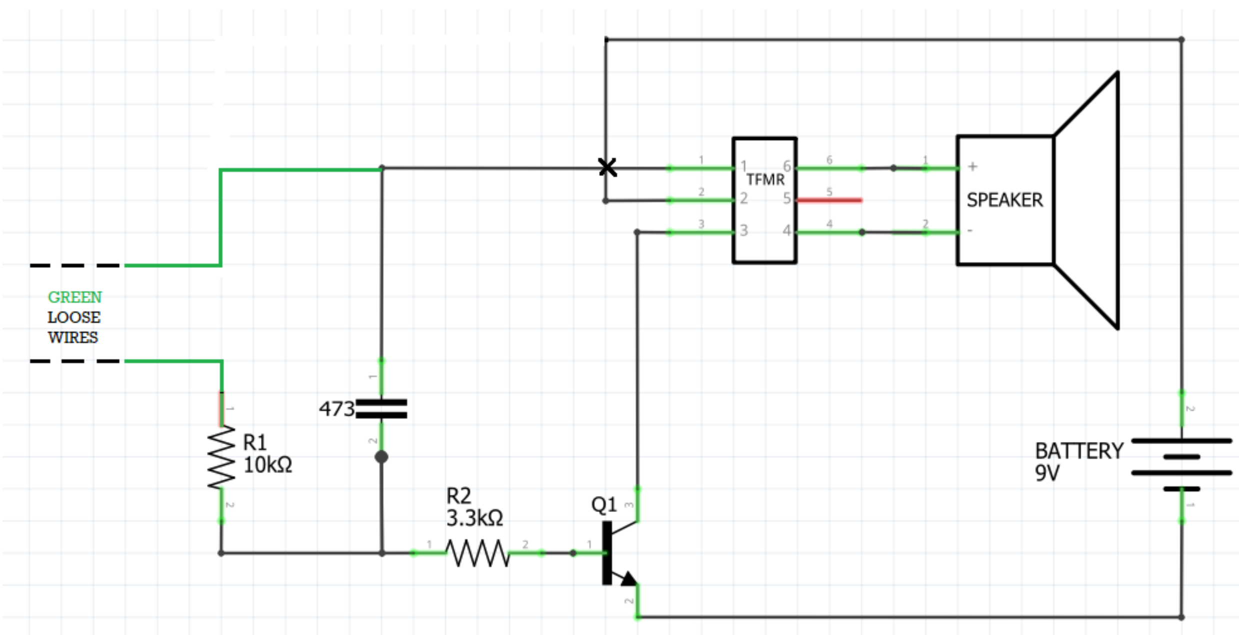
Connecting the battery will turn the circuit on. Press the switch a few times quickly and turn the VR knob to change the frequency of the sounds. What's happening is that you're increasing the oscillator capacitance by putting the two capacitors in parallel, and that lowers the frequency. You can experiment with changing the components on the breadboard if you'd like.

Experiment #36: Drawing Resistors

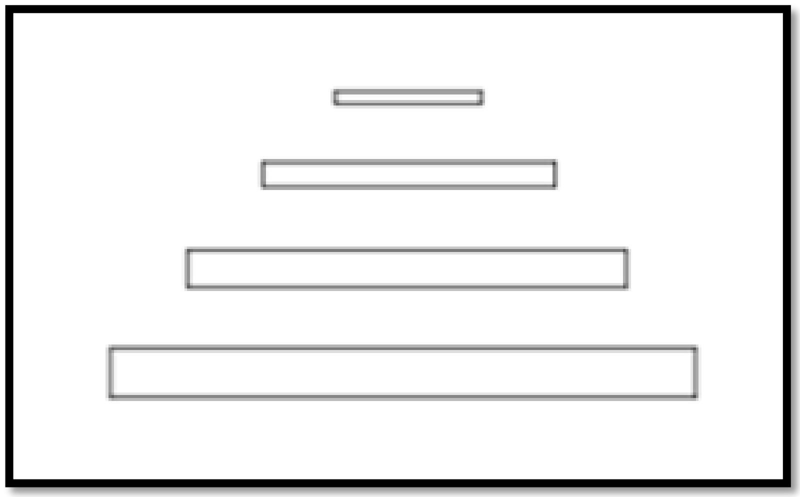


Parts Required:

- 9V battery or power supply.
- One 3.3kΩ, 10kΩ resistor.
- One 0.047µF (473) capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.
- Two loose wires.
- A pencil.



For this experiment, you'll be needing a pencil to literally draw the required components. Make sure it's sharpened. No. 2 lead pencil is preferred, but other types of pencils should also work.



For above rectangles, you need to color them in with your lead pencil. Place a hard flat surface between this page and the rest of the booklet. Press hard but pay mind to the paper to avoid ripping it. Try to not cross the boundaries when coloring to achieve better results. Color each rectangle in more than once if you must.

Even though your pencils are referred to as "lead pencils", the so-called "lead" is really a form of carbon – the same material that resistors are made of. You are essentially creating resistors by coloring in rectangles!

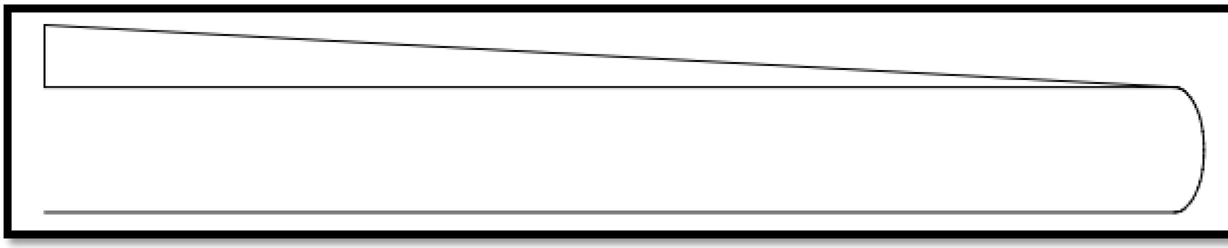
Connect the circuit and touch the opposite ends of a rectangle with the loose green wires upon powering the circuit. You should hear a sound, which means that your handmade resistors worked. If not, you may try wetting the wires with water or saliva for better electrical contact. Make sure your rectangles are done as instructed. Now try another rectangle and you should hear the sound that plays be similar to the previous rectangle. Try another rectangle.

To explain, the length and width of the rectangle determines its resistance. Making the rectangle longer (resistors in series) increases the resistance while making it wider (resistors in parallel) decreases it.

Wash your hands when done, unless you're advancing to the experiment on the next page.

Experiment #37: Electronic Kazoo

For this experiment, you'll be needing a pencil to literally draw the required components. Make sure it's sharpened. No. 2 lead pencil is preferred, but other types of pencils should also work. This experiment also uses the same circuit as in Experiment #36, you will just draw a new shape.



For above picture, you need to color it in with your lead pencil. Place a hard flat surface between this page and the rest of the booklet. Press hard but pay mind to the paper to avoid ripping it. Try to not cross the boundaries when coloring to achieve better results. Color the image in more than once if you must. Where this shape is just a line, trace a thick line over it a few times because the black ink on this paper is insulative and will not pass electricity.

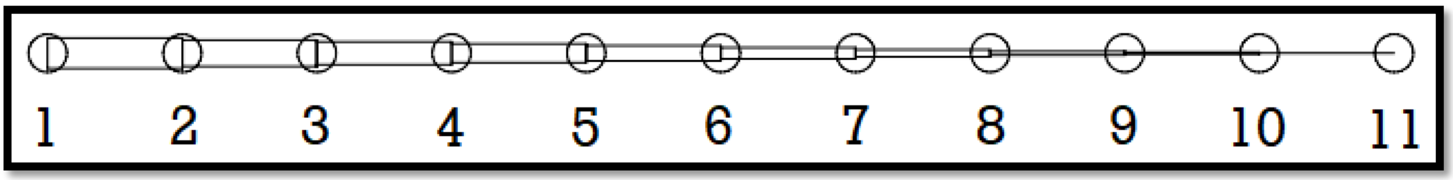
Take one of the two loose wires and touch it against the widest part of the shape (upper left). Touch the other loose wire to the right of the first wire near it and you should hear a high-pitch sound. As you slide the second wire further to the right, the pitch of the sound will change and become lower, just like a real kazoo. If not, you may try wetting the wires with water or saliva for better electrical contact. Make sure the "kazoo" is done as instructed.

As mentioned in Experiment #36, the resistance is determined by the length and width of the shape.

Wash your hands when done, unless you're advancing to the experiment on the next page.

Experiment #38: Electronic Keyboard

For this experiment, you'll be needing a pencil to literally draw the required components. Make sure it's sharpened. No. 2 lead pencil is preferred, but other types of pencils should also work. This experiment also uses the same circuit as in previous two experiments, you will just draw a new shape.



For above picture, you need to color it in in with your lead pencil. Place a hard flat surface between this page and the rest of the booklet. Press hard but pay mind to the paper to avoid ripping it. Try to not cross the boundaries when coloring to achieve better results. Color the image in more than once if you must. Where this shape is just a line, trace a thick line over it a few times because the black ink on this paper is insulative and will not pass electricity.

Take a loose wire and put it on circle 1. Take the other loose wire and touch it to each of every other circle. Specific pitched sounds are made at each circle like notes, making this a keyboard. If a sound isn't made, you may try wetting the wires with water or saliva for better electrical contact. Make sure the "keyboard" is done as instructed.

Now, put one wire to circle 11 and touch the other wire to the circles in the following sequence:

7 – 5 – 1 – 5 – 7 – 7 – 7

5 – 5 – 5

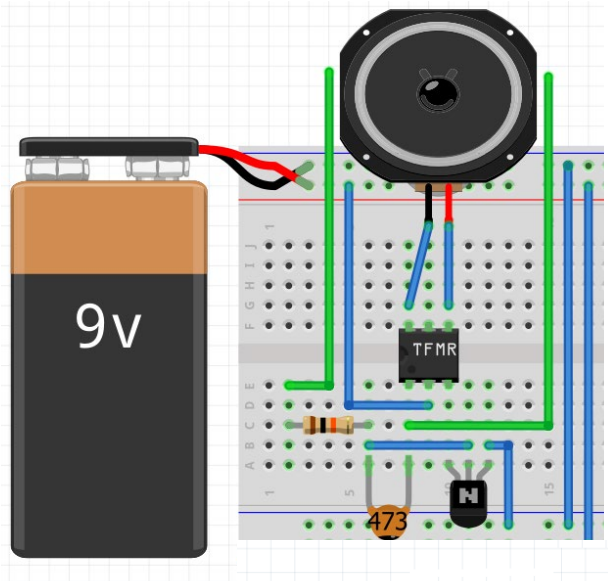
7 – 7 – 7

7 – 5 – 1 – 5 – 7 – 7 – 7 – 7 – 5 – 5 – 7 – 5 – 1

If you are able to recognize this nursery rhyme, you've just played "Mary Had a Little Lamb". At this point, you've realized that you can draw any shape you can imagine and make electronic sounds with it.

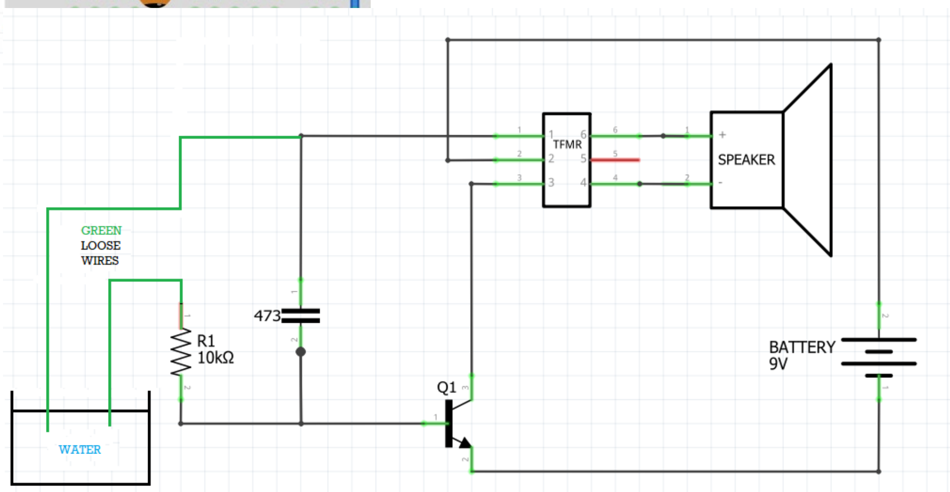
Be sure to wash your hands after this experiment.

Experiment #39: Fun with Water



Parts Required:

- 9V battery or power supply.
- One 10kΩ resistor.
- One 0.047µF (473) capacitor.
- One 2N3904 transistor.
- One transformer.
- One speaker.
- Two loose wires.

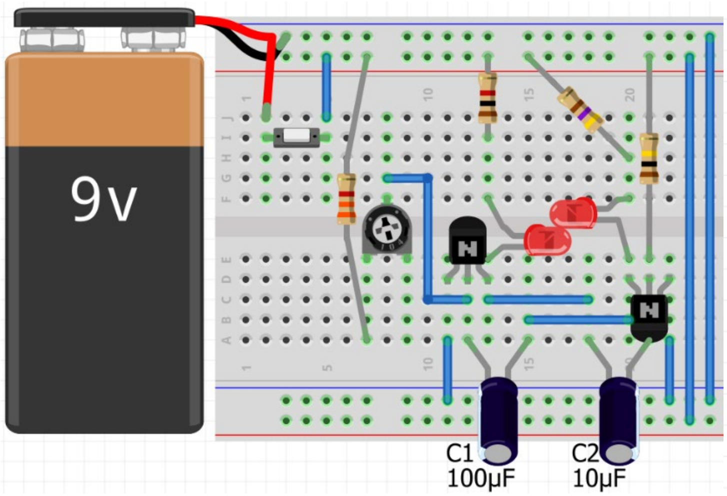


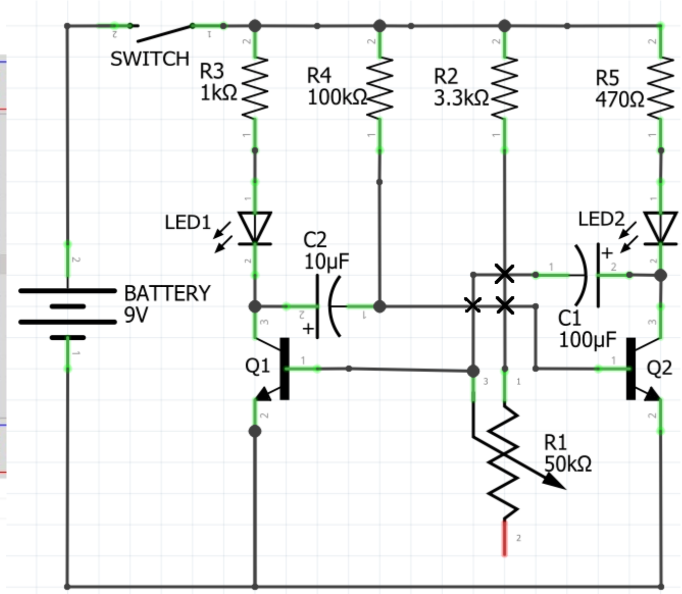
With the two loose wires being initially unconnected in this circuit, there will be no sound. If you were to touch two wires with different hands, however, you'd be able to hear a low frequency sound. As usual, wetting your fingers will improve electrical conduct. This works because your body is already made up of mostly water.

Take a small non-metal cup and fill it halfway with water. Place the two wires in the water but don't let them touch each other. You'll be able to hear a sound with a much higher frequency because the water in the cup has less resistance than the water in your body. For this next step, get some table salt.

While keeping the wires in the water, add salt to it and stir. Doing so will increase the frequency more. What's happening is that when salt breaks down, its electrically charged ion particles allow conductivity in the water. Now you know that sea water has little to no resistance while distilled (pure) water has very high resistance due to lack of minerals being mixed in it. This was also mentioned in Experiment #7.

Experiment #40: Blinking Lights



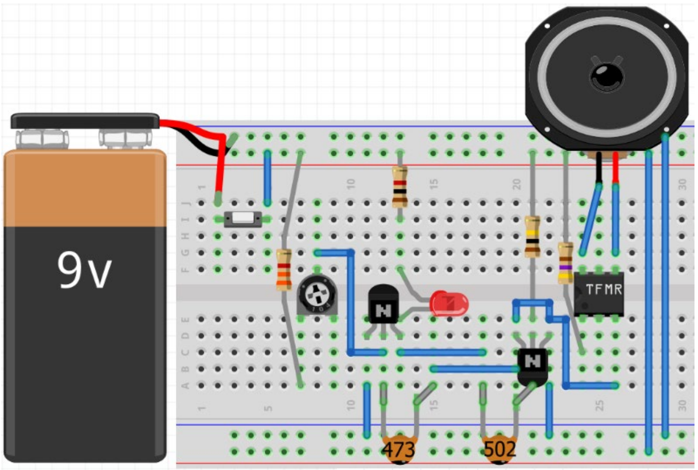


Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω, 1kΩ, 3.3kΩ, 100kΩ resistor.
- One 50kΩ variable resistor.
- One 10µF, 100µF capacitor.
- Two 2N3904 transistors.
- Two LEDs.

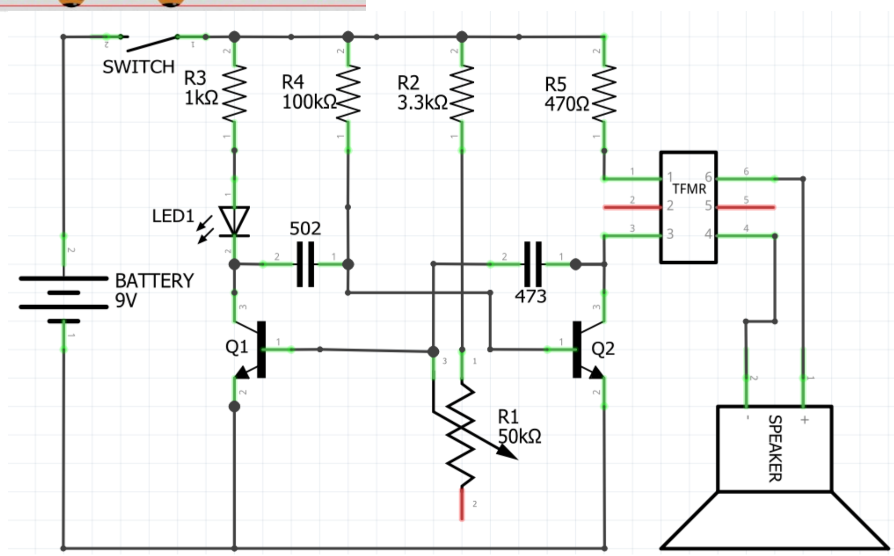
This circuit is a type of oscillator called **an astable multivibrator**. Take note of the battery's red wire and its new location. Press and hold down the switch and the LEDs will toggle based on the variable resistor's knob position. Try turning the knob so that both LEDs toggle alternatively at the same frequency. The functionality of the LEDs is based on the transistors they're connected to. The left transistor for its LED (LED1) is controlled by the 100kΩ resistor and 10µF capacitor, while the right transistor for its LED (LED2) is controlled by the 3.3kΩ resistor, 100µF capacitor and the VR. You may experiment with different components, but do not switch out the capacitors for disc capacitors. The next experiment will explain why.

Experiment #41: Noisy Blinker



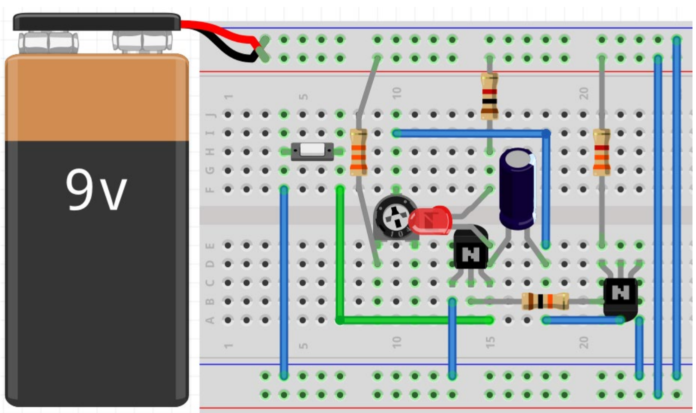
Parts Required:

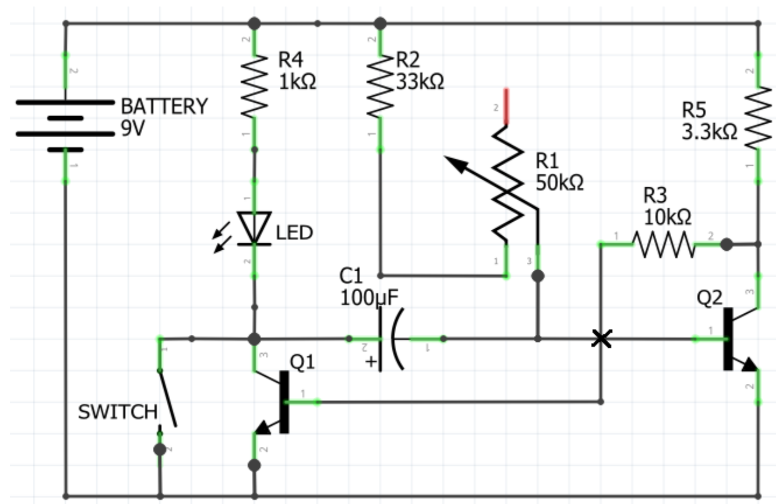
- 9V battery or power supply.
- One switch.
- One 470Ω, 1kΩ, 3.3kΩ, 100kΩ resistor.
- One 50kΩ variable resistor.
- One 0.047µF (473), 4.7nF (472) capacitor.
- Two 2N3904 transistors.
- One LEDs.



This circuit is similar to Experiment #40 except the electrolytic capacitors are replaced with disc capacitors and the right LED is replaced with a transformer that's connected to a speaker. By pushing down the switch, you'll see the LED light up and sound will come out of the speaker. In this experiment, despite the LED appearing as if it's not blinking, it actually does blink for about 500 times per second, it's just your eyes cannot keep up. That is the reason why you were asked not to switch for disc capacitors in the previous experiment.

Experiment #42: One-Shot



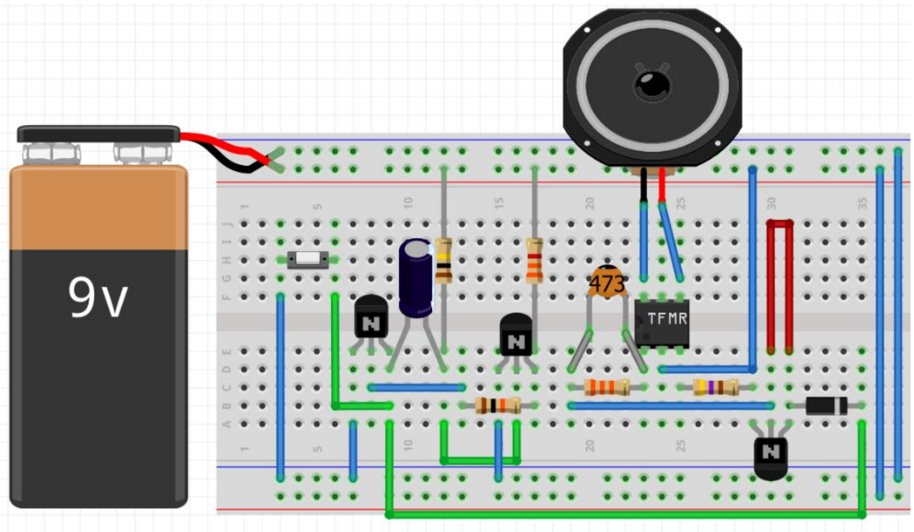


Parts Required:

- 9V battery or power supply.
- One switch.
- One 1kΩ, 3.3kΩ, 10kΩ, 33kΩ resistor.
- One 50kΩ variable resistor.
- One 100µF capacitor.
- Two 2N3904 transistors.
- One LEDs.

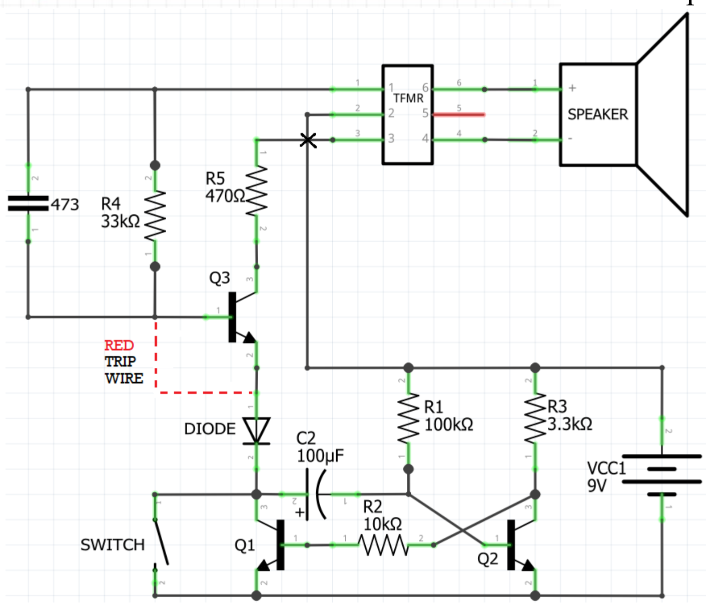
By pressing the switch and releasing it, the LED will turn on and remain on for a few seconds before turning off. That short delay for keeping the LED on is determined by the 33kΩ resistor, the variable resistor and the 100µF capacitor. This circuit would be useful as a timer. Perhaps you already own electronics that use this circuit and share the procedure of turning the electronic on and adjusting the VR to determine how long it should stay on. Also, this circuit is a variation of the astable multivibrator that's called **a one-shot multivibrator**.

Experiment #43: Shut-Off Timer Alarm



Parts Required:

- 9V battery or power supply.
- One switch.
- One 470Ω, 3.3kΩ, 10kΩ, 33kΩ, 100kΩ resistor.
- One 0.047µF (473), 100µF capacitor.
- Three 2N3904 transistors.
- One 1N4148 diode.
- One transformer.
- One speaker.

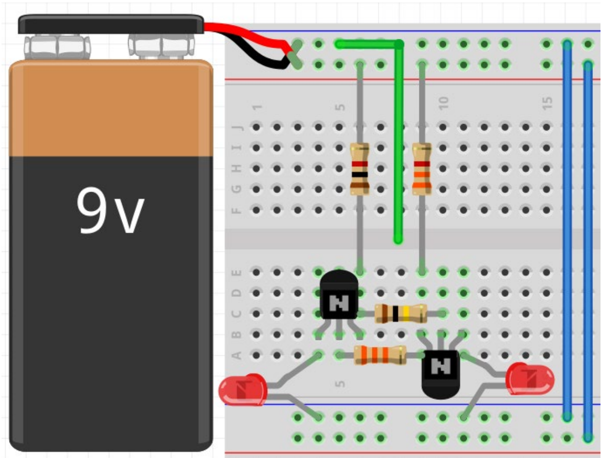


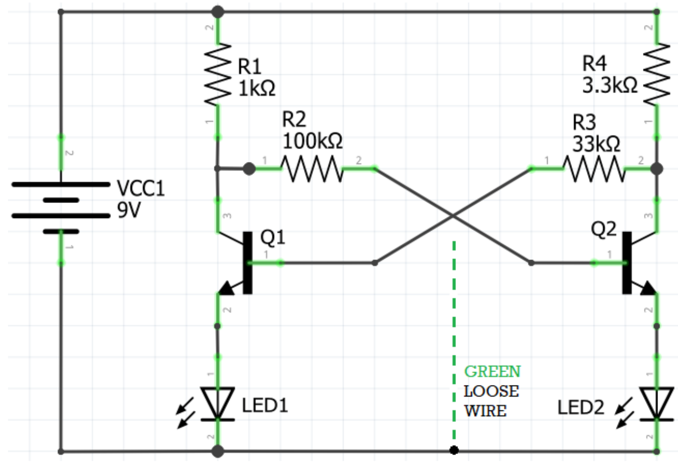
The schematic shows two wires diagonally crossing over each other. They do not connect or physically intersect with each other.

The red wire is a “trip” wire that will turn the speaker on and play the alarm upon disconnection. Before disconnecting the wire, press the switch to reset the timer of the alarm. After following the instructions, you should hear the speaker play the alarm for a few seconds before going quiet. To do this again, you must reconnect the wire and press the switch to reset the alarm. If the wire is connected and disconnected without resetting the timer, it will not work.

Side note: If this circuit does not work properly, try flipping the electrolytic capacitor.

Experiment #44: Flip-Flop





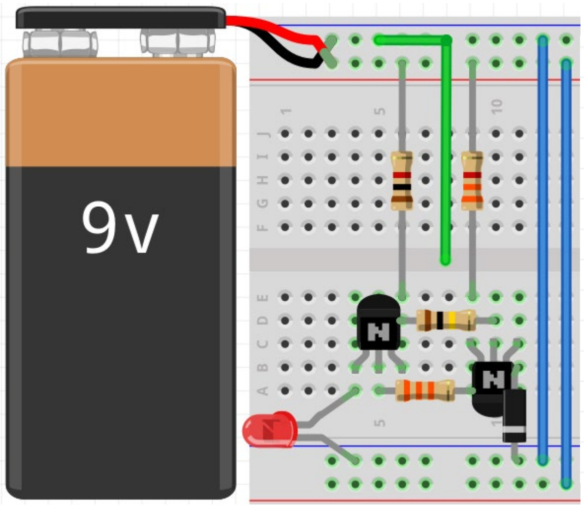
Parts Required:

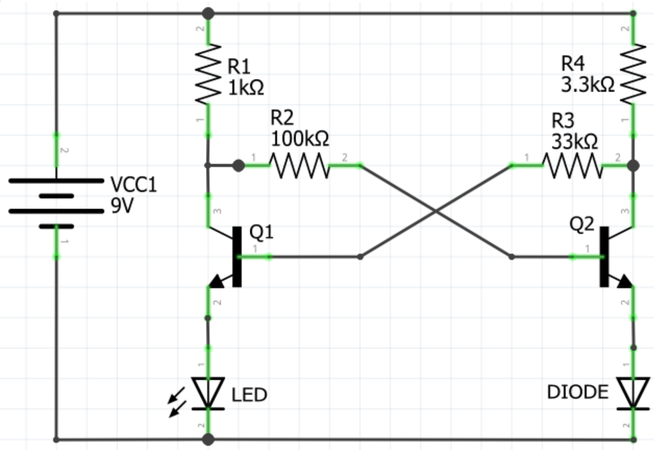
- 9V battery or power supply.
- One 1kΩ, 3.3kΩ, 33kΩ, 100kΩ resistor.
- Two 2N3904 transistors.
- Two LEDs.

This circuit is also another form of a basic multivibrator configuration. With the green loose wire unconnected, power the circuit and you will see that one of the LEDs will be on while the other will be off. Now, take the loose wire, connect it to the base of the transistor that is currently on, and you will see the LED turn off while the other LED turn on. It seems that the transistor turning on "flips" and the transistor turning off "flops".

A circuit like this is formally known as the bistable switch but is nicknamed "flip-flop" because of the way that it functions. Many variations of this circuit compose the fundamentals for computers despite its silly name. This circuit could also be considered as a form of memory because even though you remove that loose wire after lighting up an LED, it remains on because it "remembered" its purpose.

Experiment #45: FTL With Memory



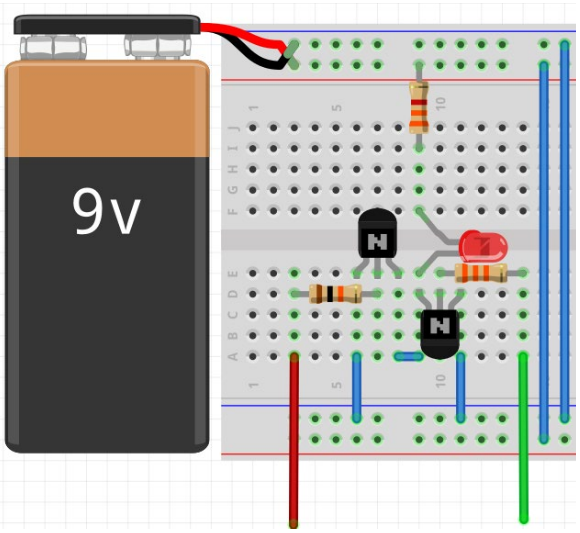


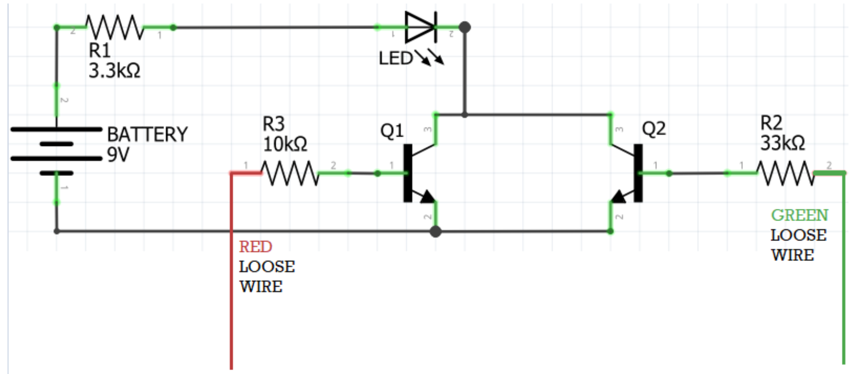
Parts Required:

- 9V battery or power supply.
- One 1kΩ, 3.3kΩ, 33kΩ, 100kΩ resistor.
- Two 2N3904 transistors.
- One 1N4148 diode.
- One LED.

The finger touch lamp circuit in this experiment is the same as the in the previous, except the right LED is replaced with a diode and the loose wire is not used, so it may be removed. Power the circuit and wet two fingers. Put one finger on the positive row of the breadboard (+) while putting the other finger on one of the transistor bases. This can be done easily by sticking a loose wire in a positive row hole and in the column that shares a transistor base. You must alternate between transistors to turn them on or off based on what was discussed in the previous experiment.

Experiment #46: This OR That





Parts Required:

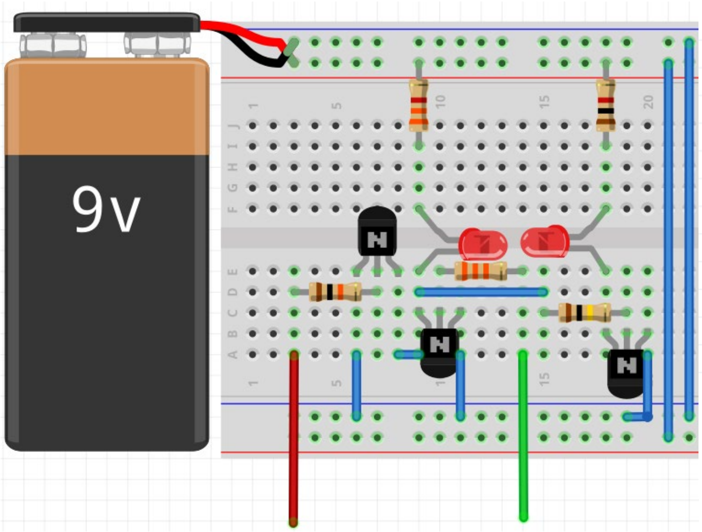
- 9V battery or power supply.
- One 3.3kΩ, 10kΩ, 33kΩ resistor.
- Two 2N3904 transistors.
- One LED.
- Two loose wires.

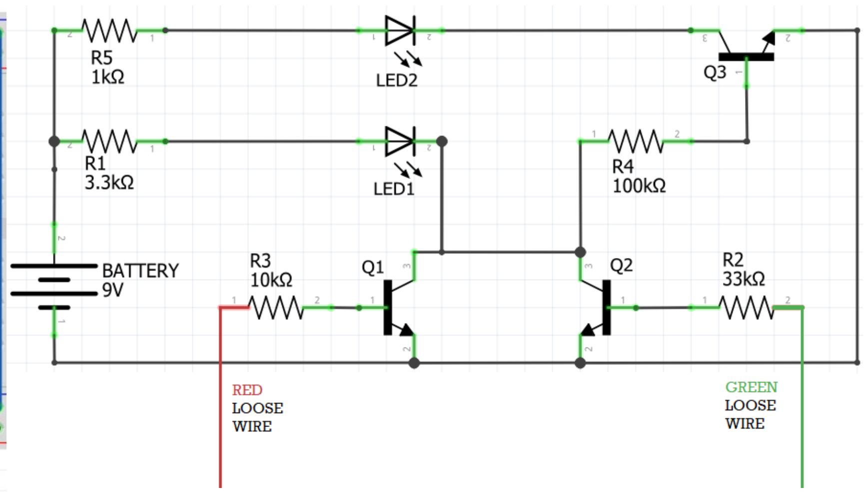
After performing a few experiments involving the flip flops, you're ready to be introduced to digital circuits. Digital, in this case, usually refers to two outputs: High and low, one and zero, true or false - the same as the LED being on and off. The two loose wires are going to contribute to the results of the output, and they are referred to being its inputs. Connect the loose wires to either the power (HIGH) or the ground (LOW) rail in any order you like and mark whether the LED is on or off in the truth table provided below based on how both wires are connected:

RED WIRE	GREEN WIRE	LED
LOW	LOW	
LOW	HIGH	
HIGH	LOW	
HIGH	HIGH	

The purpose of the **truth table** is to provide information about the output's state based on the set of input combinations. If your results are correct, you will learn that this circuit's logic is based on an OR gate, which the next experiment will go more in-depth about. The OR gate requires at least one input to be high for the output to also be high - similar as to adding a bunch of ones. If there is a zero in the operation, the result will ultimately be one. Gates can have more than two inputs.

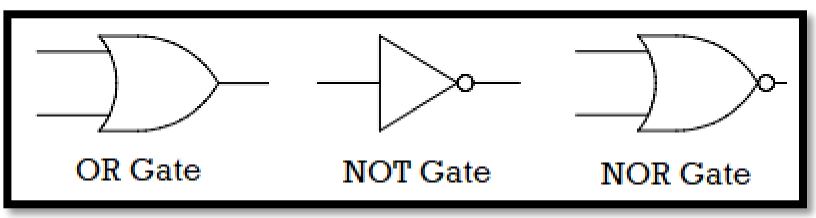
Experiment #47: Neither This NOR That





Parts Required:

- 9V battery or power supply.
- One 1kΩ, 3.3kΩ, 10kΩ, 33kΩ, 100kΩ resistor.
- Three 2N3904 transistors.
- Two LEDs.
- Two loose wires.

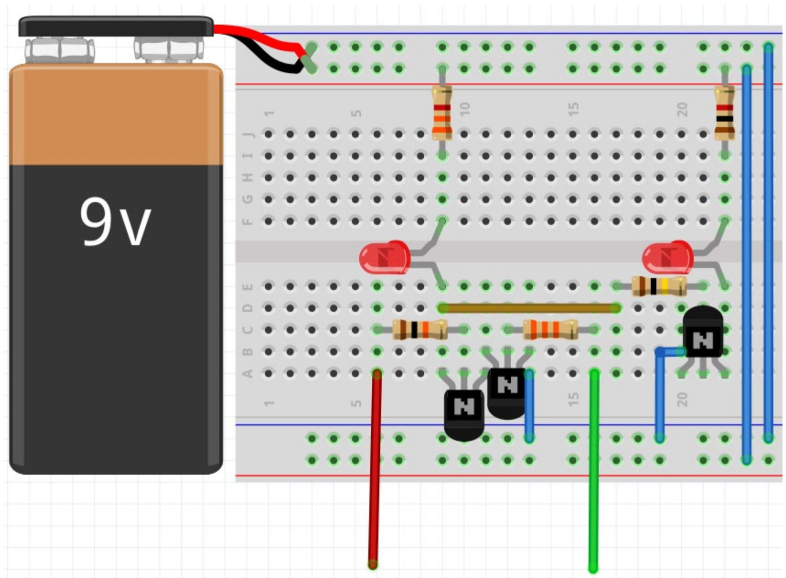


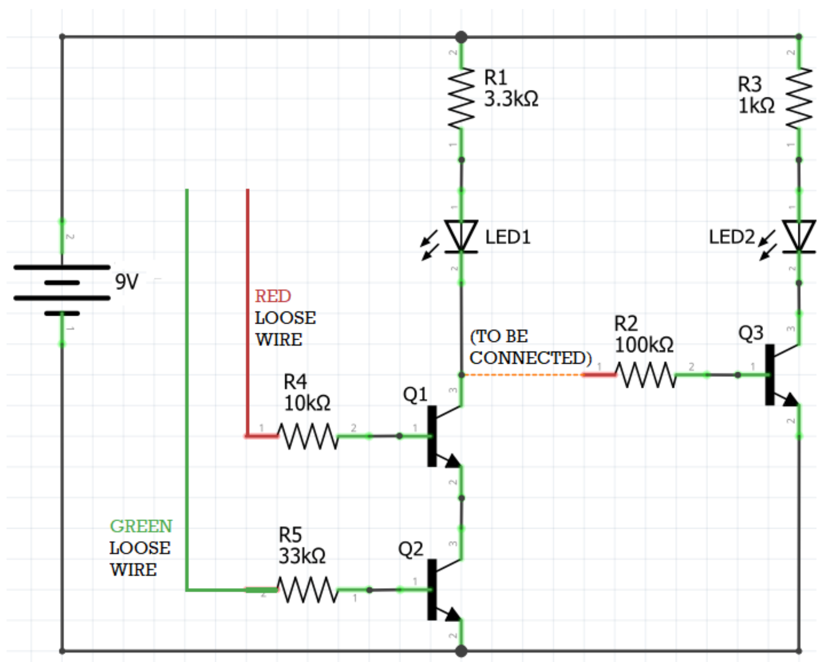
As discussed how the OR gate functions in the previous experiment, let's introduce other gates. The NOT gate inverses the state of the input / output, meaning if it's high and goes through the NOT gate, that input becomes a low input. The NOR gate inverses the output of the OR logic, and it can be identified by taking note of the circle that it shares with the NOT gate.

RED WIRE	GREEN WIRE	LED
LOW	LOW	
LOW	HIGH	
HIGH	LOW	
HIGH	HIGH	

As explained, the output is inversed – its states are a complete opposite from the OR gate because of the implementation of NOT logic. In order for the LED to be turned on, there must be at least one low input.

Experiment #48: This AND That



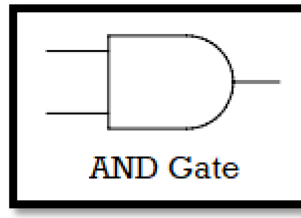


Parts Required:

- 9V battery or power supply.
- One 1kΩ, 3.3kΩ, 10kΩ, 33kΩ, 100kΩ resistor.
- Three 2N3904 transistors.
- Two LEDs.
- Two loose wires.

Do not connect the brown wire yet when powering the circuit. Experiment with the loose wires to see what kind of output results you get.

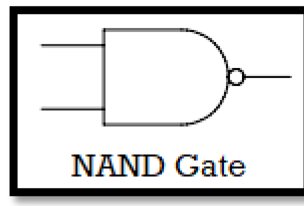
RED WIRE	GREEN WIRE	LED
LOW	LOW	
LOW	HIGH	
HIGH	LOW	
HIGH	HIGH	



This type of logic is called AND Gate logic. As you may have analyzed, all inputs must be high for the LED to be turned on – like multiplying a bunch of ones but if there is a single zero in the operation, the result will ultimately be zero.

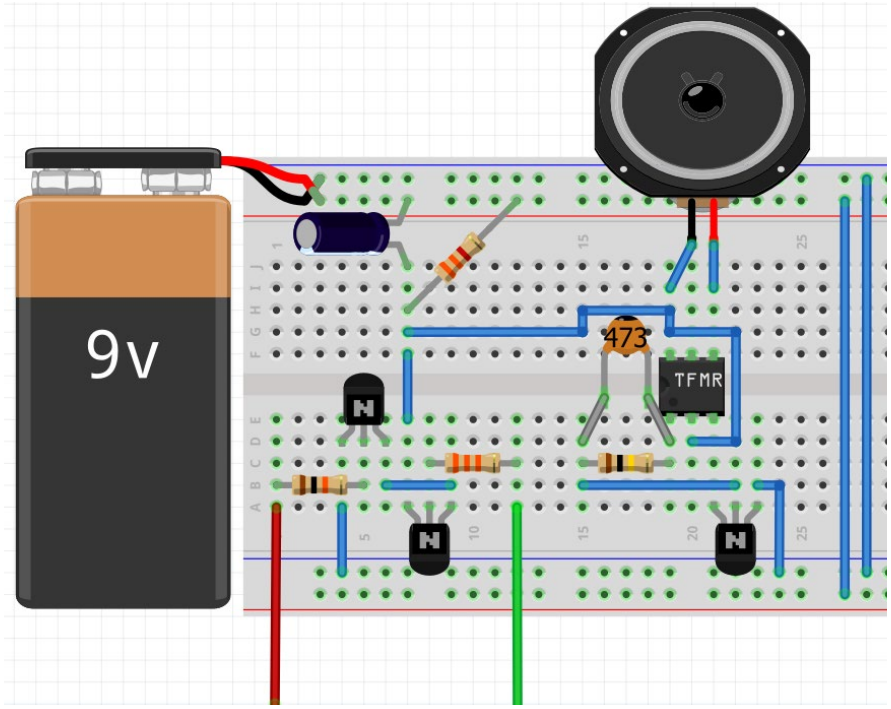
Now that you know how AND gate logic works, you may connect the brown wire mentioned earlier into the circuit to complete the connection to the transistor base. What you're essentially doing is adding a NOT gate to the AND gate, which should give you a relative idea as to what the output results should be. Do experiment with the loose wires to verify.

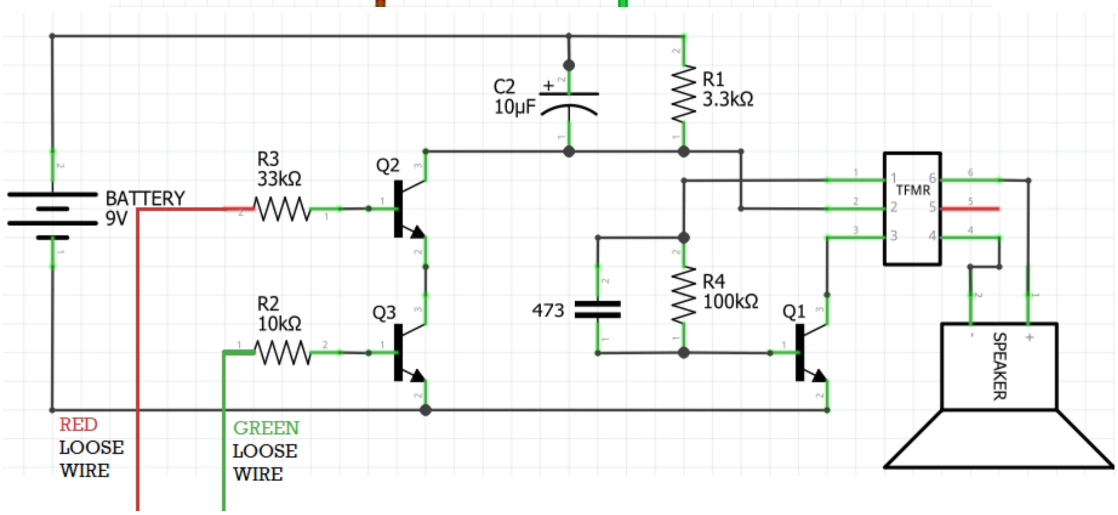
RED WIRE	GREEN WIRE	LED
LOW	LOW	
LOW	HIGH	
HIGH	LOW	
HIGH	HIGH	



This type of logic is called NAND Gate logic. All inputs must be low for the LED to be turned on but if one input is high, the LED will be turned off. All this logic is important because today's computers use these gates to add and multiply numbers with the help of flip-flops.

Experiment #49: Audio AND, NAND





Parts Required:

- 9V battery or power supply.
- One 3.3kΩ, 10kΩ, 33kΩ, 100kΩ resistor.
- One 0.047µF (473), 10µF capacitor.
- Three 2N3904 transistors.
- One transformer.
- One speaker.
- Two loose wires.

Instead of using the LEDs, how about using the speaker? By looking at the title of the experiment, you already know that this circuit is either an AND or a NAND gate, but are you capable of understanding just by looking at the schematic? As always, you may fill out the truth table to verify your educational guess. You may also draw the gate in the box to the right.

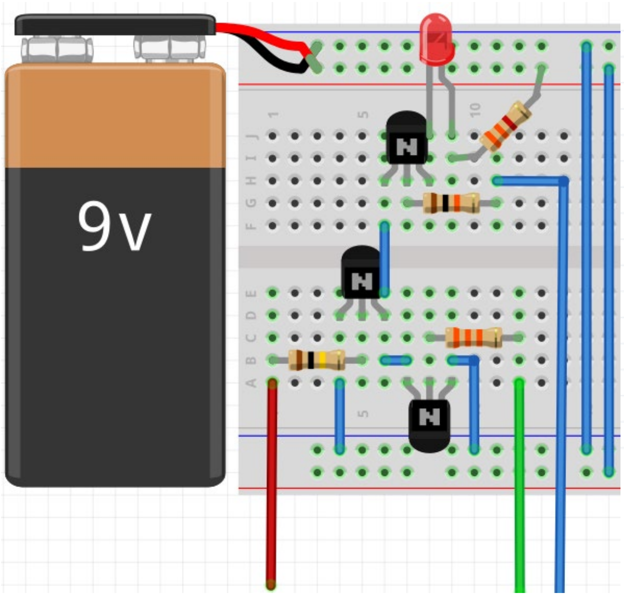
RED WIRE	GREEN WIRE	LED
LOW	LOW	
LOW	HIGH	
HIGH	LOW	
HIGH	HIGH	

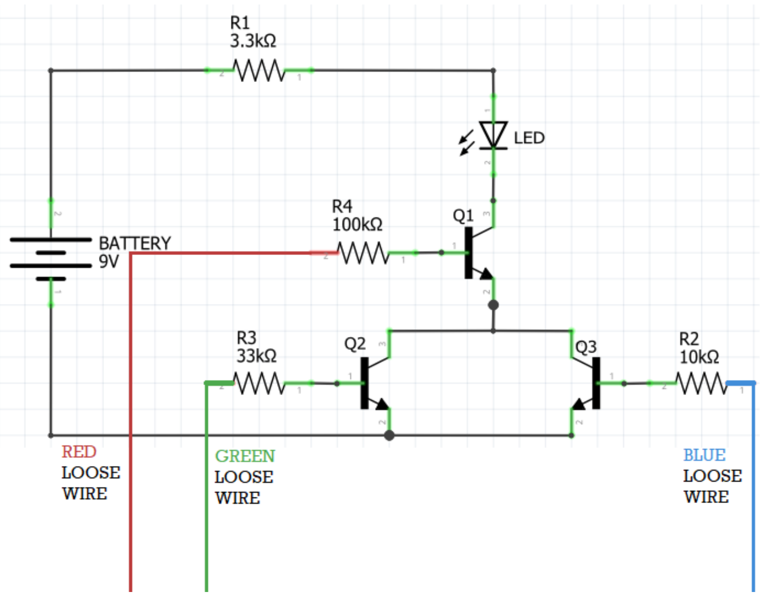
The circuit is a NAND gate, but you can modify it to be an AND gate. To do that, remove the $3.3k\Omega$ resistor, the $10\mu F$ capacitor, wires E7-F7, G7-D20, B23-GND. Now add wires B23-E7, D20-9V.

Verify the newly established with the truth table below and draw the gate:

RED WIRE	GREEN WIRE	LED
LOW	LOW	
LOW	HIGH	
HIGH	LOW	
HIGH	HIGH	

Experiment #50: Logic Combination





Parts Required:

- 9V battery or power supply.
- One 3.3kΩ, 10kΩ, 33kΩ, 100kΩ resistor.
- Three 2N3904 transistors.
- One LED.
- Three loose wires.

This circuit is a combination of some logic gates and this one has three inputs instead of two. Fill the truth table below to verify your predicted output states for the LED.

RED	GREEN	BLUE	LED
LOW	LOW	LOW	
LOW	LOW	HIGH	
LOW	HIGH	LOW	
LOW	HIGH	HIGH	
HIGH	LOW	LOW	
HIGH	LOW	HIGH	
HIGH	HIGH	LOW	
HIGH	HIGH	HIGH	

Do you know why the LOWs and HIGHs are written in that particular order? It's an imitation of counting in binary where LOW is zero and HIGH is one. In binary, 000 indicates number zero, 001 indicates number one, 010 indicates number two and so on. It's the easiest way to stay organized when testing out many combinations of inputs and keep track of their outputs.

Troubleshooting Guide

If your circuit does not seem to properly function during an experiment, you may try suggested fixes below:

- Make sure that your connections on the breadboard match with the designs on the diagrams. It may be a wiring error.

- When there is power in your circuit, prevent the components' metals from coming in physical contact with each other to prevent shorts. It is also possible that you may short components by touching them with your fingers.

- Remember that electrolytic capacitors, diodes, and LEDs have positive and negative polarities. Failure to place component by correct polarity when the circuit is powered could cause the component to break and prevent the whole circuit from functioning properly. Refer to the experiments introducing the component if you are unsure about polarities.

- It is possible that you may require a new 9V battery.

- When working with wires to make connections, make sure the metal is not scratched or damaged after stripping them. Try another wire if you think a damaged wire could be the source of the problem.