Introduction to robotics

1st lab: Introduction to Basic Electronics and Measurement Tools

Introduction to Basic Electronics and Measurement Tools

Familiarization with basic electronics concepts and tools such as the multimeter, breadboard, and common components.

0. Resources

1. Basic electronics tutorials: how to use a breadboard, a multimeter, stripping wires etc (~ 17 min)
2. Does the resistor need to go before or after the LED? (~ 6 min)
3. How to Calculate the Correct Resistor for LEDs Light Emitting Diodes (~ 20 min)
4. How a breadboard works

1. Multimeter

1.1 Introduction: What is a multimeter?

A multimeter is a handy tool that you use to measure electricity, just like you would use a ruler to measure distance, a stopwatch to measure time, or a scale to measure weight. The neat thing about a multimeter is that unlike a ruler, watch, or scale, it can measure **multiple things** — kind of like a multi-tool. Most multimeters have a knob on the front that lets you select what you want to measure. Below is a picture of a typical multimeter, but there are many different multimeter models.

What can multimeters measure?

A. Measurable quantities

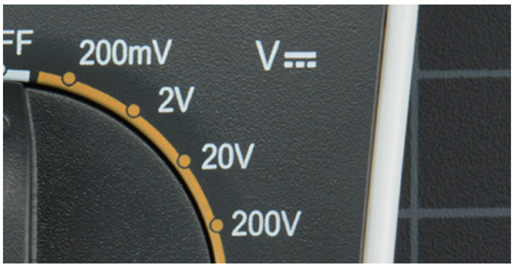
- **Voltage** is how hard electricity is being "pushed" through a circuit. A higher voltage means the electricity is being pushed harder. Voltage is measured in **volts**. The symbol for volts is **V**.
- **Current** is how much electricity is flowing through the circuit. A higher current means more electricity is flowing. Current is measured in **amperes**. The symbol for amperes is **A**.
- **Resistance** is how difficult it is for electricity to flow through something. A higher resistance means it is more difficult for electricity to flow. Resistance is measured in **ohms**. The symbol for ohms is **Ω** (the capital Greek letter omega).

> Ideally, with a multimeter, we would use alligator clips (short tutorial ~ 1 min) in order to ensure proper connection. For now, we unfortunately don't have them in the lab (but we will do so in the near future) so, when measuring the value of a component, make sure you press firmly on it with the 2 multimeter probes in order to ensure proper connectivity. Not doing so can yield incorrect value readings.

1.2 Measuring DC Voltage (V) with a Multimeter

Voltage, also known as electric pressure, electric tension, or (electric) potential difference, is the difference in electric potential between two points. In the International System of Units (SI), the derived unit for voltage is named volt (V).

Source: https://en.wikipedia.org/wiki/Voltage



When measuring voltage and current, make sure you select the settings for the **Direct Current (DC)** measurement **and not the** Alternating current (AC).
AC: ~ DC: ⎓

Short tutorial (~ 1 min)

Required components:

1. Multimeter
2. Source (in our case, a 9V battery)

How to measure the voltage of a battery (~ 3 min)

Steps:

1. Plug the black probe into the **COM** port on your multimeter
2. Plug the red probe into the **VΩmA** port
3. Turn the dial to one of the DC voltage settings: V⎓
4. For small, battery powered circuits, 20v is a good place to start. For first usage, start with the highest number
5. You can see that it is not that precise. Move down the values until you get the most accurate reading. Notice the movement of the decimal point (and thus, the increase in accuracy).

On a multimeter, the most accurate reading takes place when selecting the option with **the lowest value that is higher than the maximum value of the output.**
In the case of 9v batteries, you should set the multimeter to 20.

Keep in mind that 20m = 20miliVolts = 0.2V. Thus, when selecting “20” you will get the value in volts. When selecting “200m”, the values you will get will be in millivolts.

If you go lower than that, the multimeter will show a symbol meaning that you are outside the range you have selected. Many times, this symbol is “1”.

1.3 Measuring Resistance (Ω) with a Multimeter

The electrical resistance of an object is a measure of its opposition to the flow of electric current. It is denoted with “R” and in the International System of Units (SI), the unit of electrical resistance is the ohm (Ω)

Source: https://en.wikipedia.org/wiki/Electrical_resistance_and_conductance

Short tutorial (~ 1 min)

Required components:
1. Multimeter
2. A resistor (or better yet, multiple)

How to measure the value of a resistor (~ 2 min)

Why?
1. Can’t or don’t want to read the value of the resistor
2. You want to find out the actual value, not the theoretical rated value
3. Maybe you have multiple components and want to measure the resistance across them

When measuring the resistance of a resistor (or multiple components), make sure to disconnect them from the circuit (and more importantly, from the power supply) in order to get an accurate reading.

Steps:
1. Plug the black probe into the **COM** port on your multimeter
2. Plug the red probe into the **VΩmA** port
3. Turn the dial to the **lowest resistance settings**
4. Take the 2 probes and firmly press them against each end of the resistor
5. If the resistor value is too big for the value range you have selected, the multimeter will most likely show “1”
6. Increment the dial by one position and try reading again
7. Do this until you get the most accurate reading
8. Notice how the precision changes as you increase the value range

1.4 Measuring current (A) with a multimeter

An electric current is a flow of charged particles, such as electrons or ions, moving through an electrical conductor or space. It is defined as the net rate of flow of electric charge through a surface. It is denoted with "I" and in the International System of Units (SI), the unit of electric current is the ampere (A), or amp, which is the flow of electric charge across a surface at the rate of one coulomb (C) per second.

The conventional symbol for current, "I", originates from the French phrase intensité du courant, (current intensity), as it was used by André-Marie Ampère.

Source: https://en.wikipedia.org/wiki/Electric_current

Measuring the current in a circuit can be tricky, as we need to connect the multimeter probes **in series with the current we want to measure.** Thus, we need to create the circuit first. Return to this section **after finishing section 3 of this lab**. Short tutorial (~ 1 min)

Required components:

1. Multimeter
2. A functioning circuit

Improper use can damage the multimeter!

Depending on the multimeter, we have several extra ports rated for **10A, 20A** or some high value. If you don't know the approximate value of the current in the circuit you are going to measure, it is safer to start from the maximum possible value because that will allow you to measure a much higher current without damaging the multimeter fuse.

How to measure the current in a circuit (~ 4 min)

Steps:

1. Plug the black probe into the **COM** port on your multimeter
2. Plug the red probe into the **10A or 20A** port (or other maximum value)
3. Turn the dial to the **20A** or **10A for DC current**
4. Break the circuit that you want to measure
5. Connect the multimeter in series
6. If you get an inaccurate reading, it should be safe to move down to the port with the lower current range, that is going to be more accurate
7. Switch the red probe to the lower value port: **200mA**
8. Turn the dial to the rated value of the port: 200mA
9. Step down in order to get more and more accurate reading until the range is too low

When you are done with measuring current, switch the multimeter back to measuring voltage. That is because it is easier to blow the fuse of a multimeter when measuring current.

For example, while a **9V** battery usually has **600mA**, it can have up to **1.2A**.
Both values are higher than the rated **200mA**, meaning it will blow the fuse of the multimeter.

1.5 Continuity check

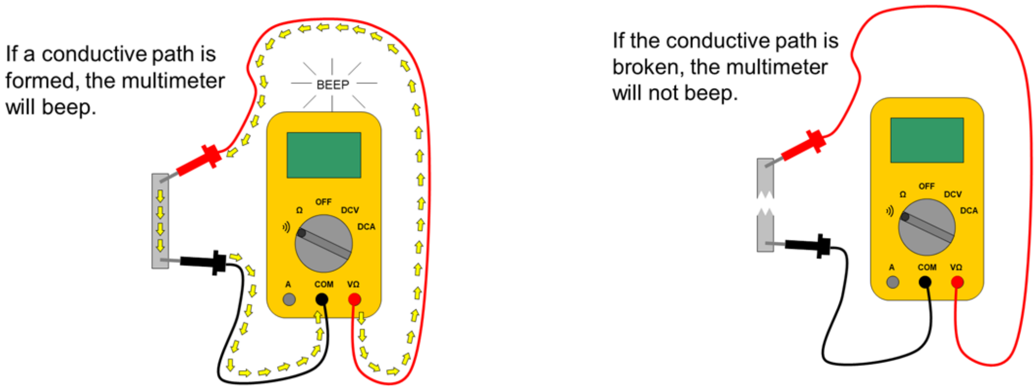
How to check the continuity of a circuit (~ 2.5 min)

One of the most used features, it tells us if there is a complete conductive path between the 2 measured points. We can use it to see if two elements are connected in the correct way or if a cable is good.

Steps:

1. Plug the black probe into the COM port on your multimeter
2. Plug the red probe into the VΩmA port
3. Turn the dial the symbol of a diode / soundwaves
4. First, connect the 2 probes and check the multimeter display. Then, disconnect the 2 probes and check the multimeter display.
    a. If the probes are connected—either by a continuous circuit, or by touching each other directly—the test current flows through. The screen displays a value of zero (or near zero)
    b. If the test current isn't detected, it means there's no continuity. The screen will display 1 or OL (open loop)
5. Check the continuity of a wire
6. Later, check the continuity of a circuit

The multimeter tests continuity by sending a little current through one probe, and checking whether the other probe receives it. In simple circuits, continuity is non-directional, meaning it doesn't matter which probe goes where. But there are exceptions - for instance, if there's a diode in your circuit.



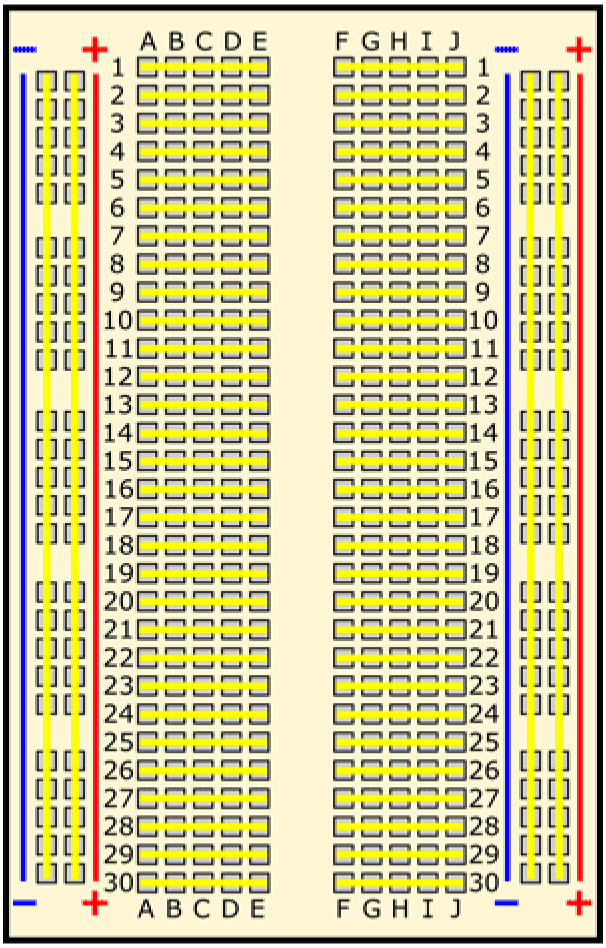
Source: https://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-multimeter

2. Basic electronic components

2.1 Breadboard

How does a breadboard work? How to use

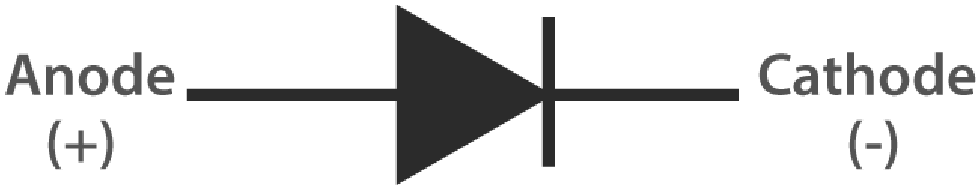
- Short tutorial (~ 1min)
- Properly detailed tutorial (~ 12 min)
- Blog post version of the detailed tutorial



The term breadboard comes from the early days of electronics, when people would literally drive nails or screws into wooden boards on which they cut bread in order to connect their circuits.

2.1 Diode

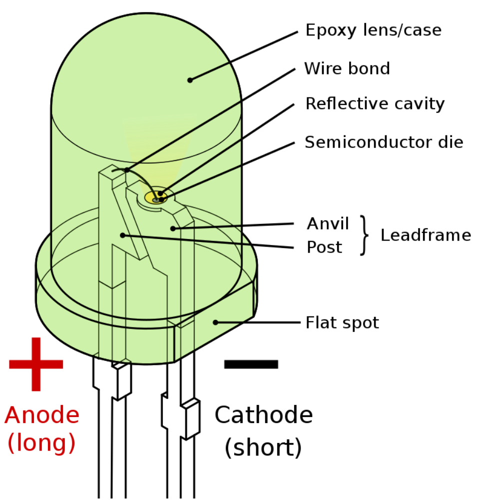
A **diode** is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction.
Diodes have polarity, determined by an **anode** (positive lead) and **cathode** (negative lead). Most diodes allow current to flow only when positive voltage is applied to the anode.

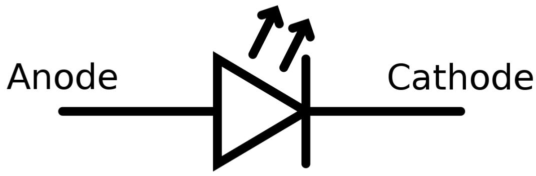


Exercise: Test the continuity of a diode in both directions using a multimeter.

2.2 Light-emitting diode (LED)

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it.

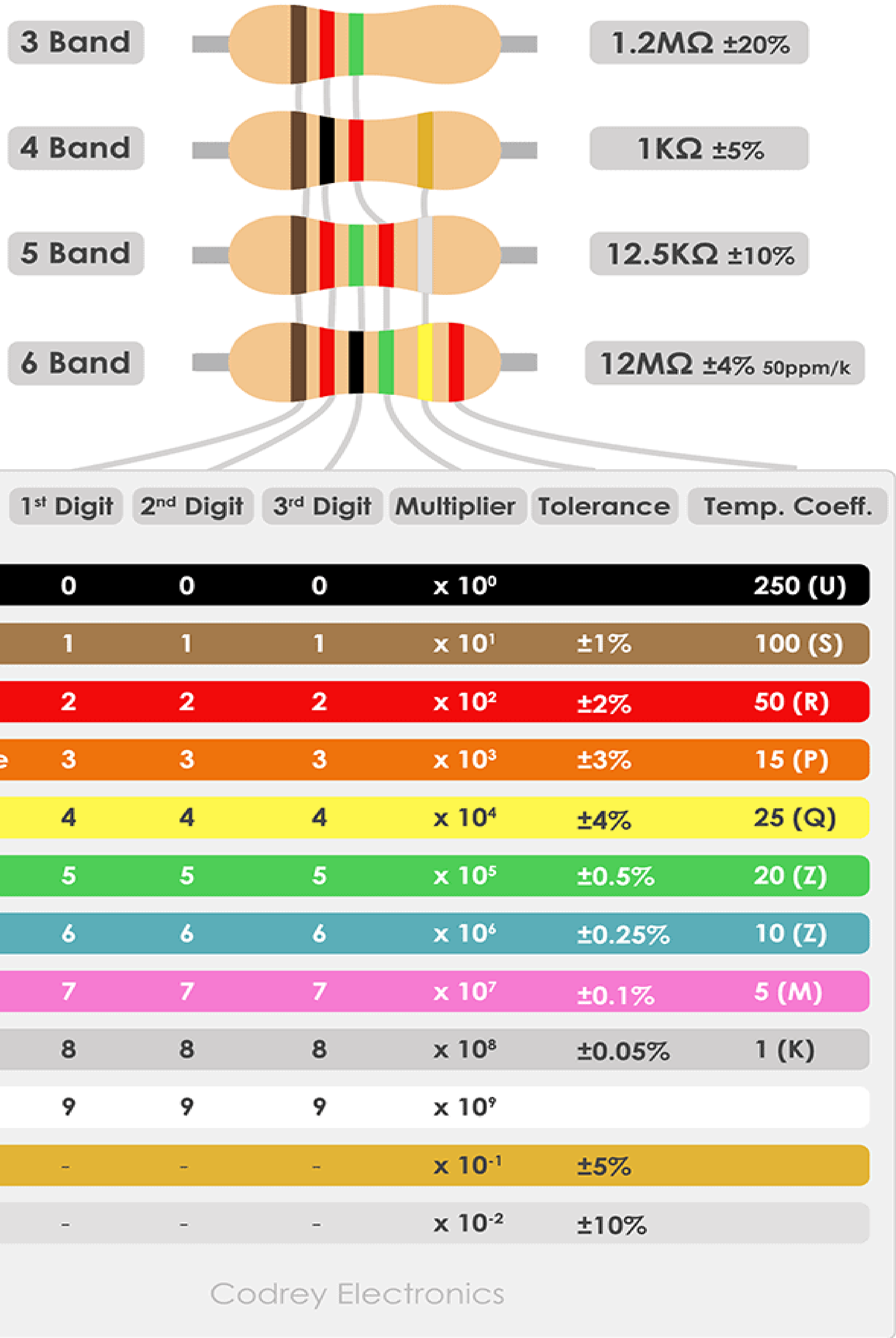




The LED, just like a normal diode, allows for current to flow in one direction only. It also produces light when the current passes through it, though.

Exercise: test the continuity of an LED in both directions using a multimeter.

2.3 Resistors



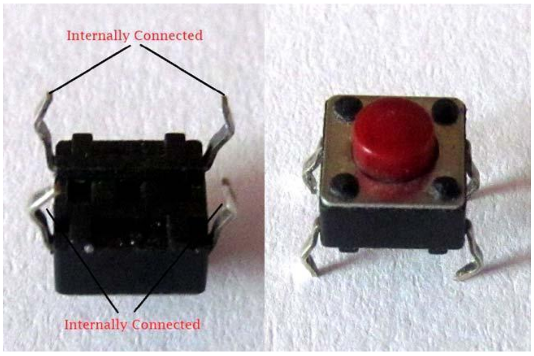
	1st Digit	2nd Digit	3rd Digit	Multiplier	Tolerance	Temp. Coeff.
Black	0	0	0	x 10^{0}		250 (U)
Brown	1	1	1	x 10^{1}	±1%	100 (S)
Red	2	2	2	x 10^{2}	±2%	50 (R)
Orange	3	3	3	x 10^{3}	±3%	15 (P)
Yellow	4	4	4	x 10^{4}	±4%	25 (Q)
Green	5	5	5	x 10^{5}	±0.5%	20 (Z)
Blue	6	6	6	x 10^{6}	±0.25%	10 (Z)
Violet	7	7	7	x 10^{7}	±0.1%	5 (M)
Grey	8	8	8	x 10^{8}	±0.05%	1 (K)
White	9	9	9	x 10^{9}		
Gold	-	-	-	x 10^{-1}	±5%	
Silver	-	-	-	x 10^{-2}	±10%	

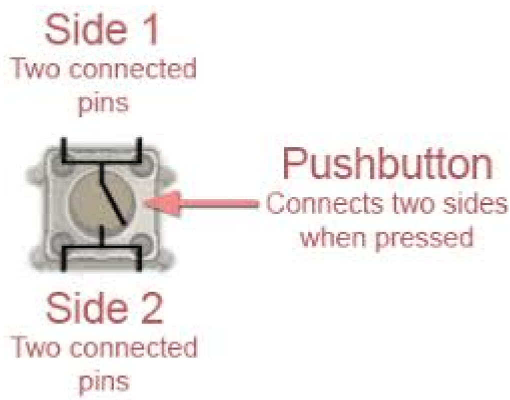
Source: https://www.arrow.com/en/research-and-events/articles/resistor-color-code

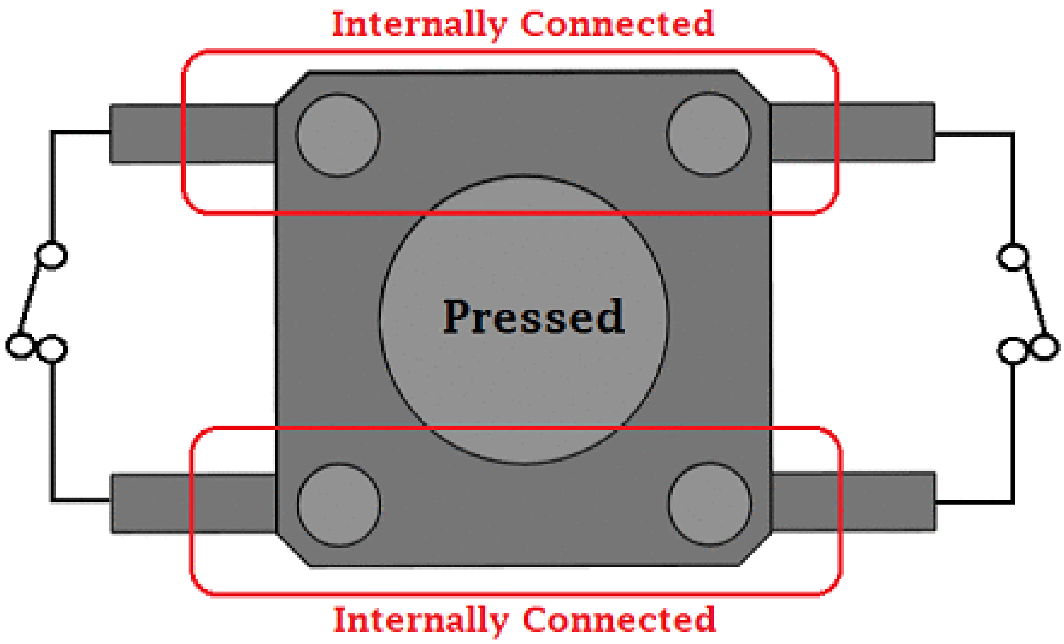
Exercise: Take a resistance in front of you and calculate its value. Then, continue to measure it.

2.4 Button / Switch

Pushbuttons or switches connect two points in a circuit when you press them. When the pushbutton is open (unpressed) there is no connection between the two legs of the pushbutton.

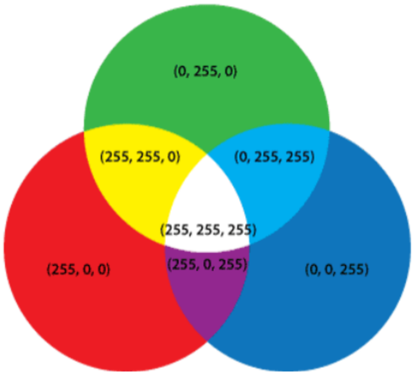






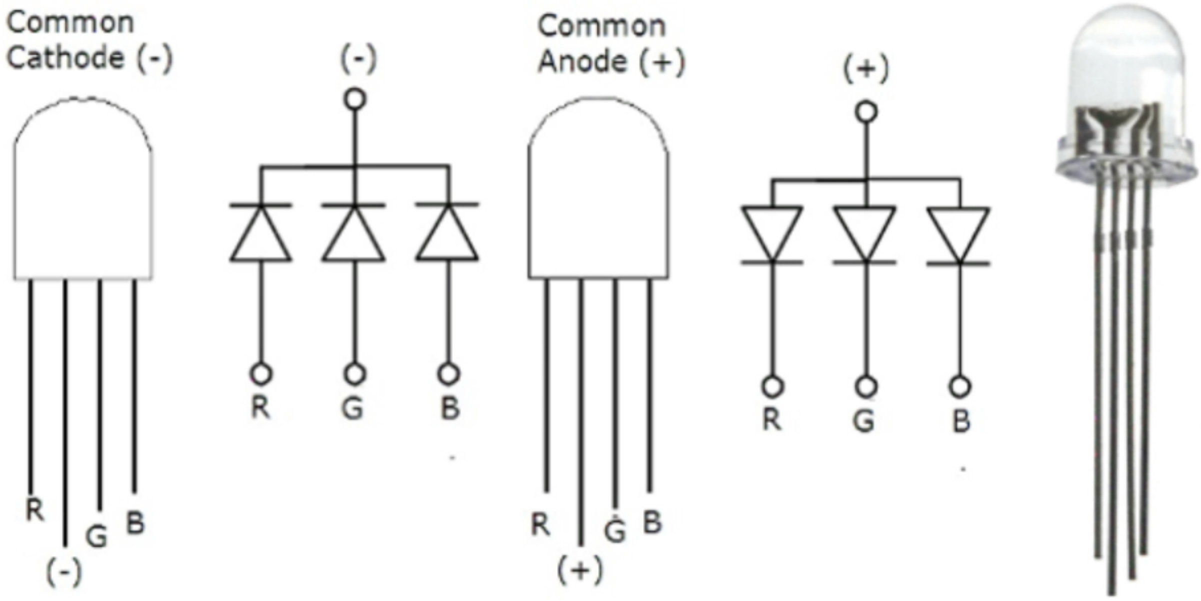
2.5 RGB LED

These LEDs have three tiny LEDs of 3 primary colors (**red, green and blue**) where a terminal is common for all. Some have common positive terminal (anode) and some have common negative terminal (cathode). When different voltages are applied to different LEDs, they make a mixture and produce several thousands of colors.



There are actually two types of RGB LEDs; the common cathode one and common anode one.
With a **common anode** you connect the anode to the +5v and each individual LED to a resistor each. Connect that resistor to an output pin.
Then a write LOW to that pin will turn the LED on and a HIGH will turn it off. This is called **current sinking**.

With a **common cathode** you connect the cathode to ground and connect each LED's anode through a resistor to the output pin.
Then a HIGH turns it on. This is called **current sourcing**.

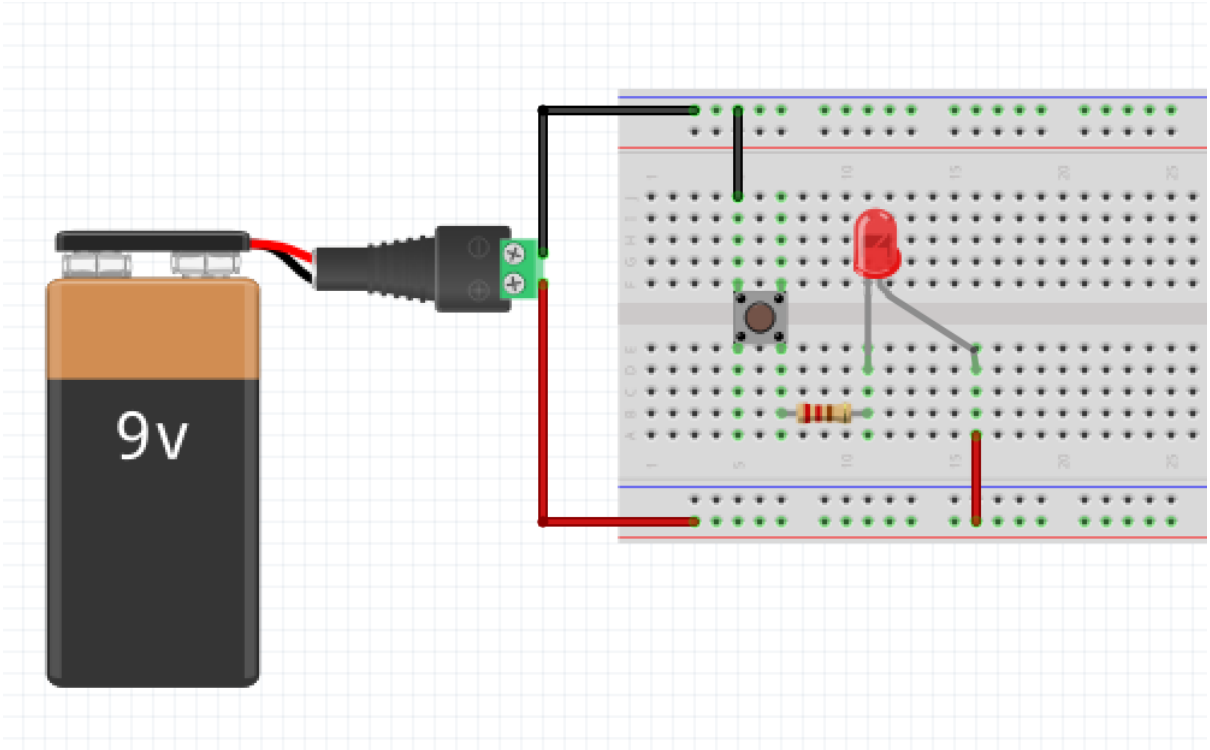


To check if you have a common cathode or common anode you can use a multimeter. Set it to diode and first use **- on the long pin** and **+ on a small one**. If it lights up, it's a common **cathode**. If not, use **+ on the long pin and - on a small one**; if it lights up now, then it's a common **anode**.

Exercise: light up two colors at the same time using continuity check. What happens? Why?

- There isn't enough current, and the one we have flows through the path of minimal resistance

3. Building breadboard circuits



4. Breadboard circuit challenges

4.1 Create a circuit with an RGB LED and a button for each color. Connect them to power.

a. Address the resistance of this circuit. What is the required value and where do you place it?
   i. Generally, we won't use Ohm's law for calculating led resistors. It is common practice to use 220 or 330 ohm resistors. The idea is to use a resistor for each color channel. If you don't, when you light up 1, 2 or 3 colors, the led will have different intensities

b. Can you light up more colors at the same time?
   i. Yes, either by pressing more buttons or by connecting more channels to one button

c. What happens if you want to use only 1 button for 2 colors?
   i. When you press the button intending to light up two colors simultaneously, you're essentially connecting two LED channels in parallel. This is important for two reasons:
      1. Current: The total current in the circuit increases since each LED draws its own current. If each LED requires 20mA, then the total current when both LEDs are activated is approximately 40mA.
      2. Resistance: The resistance in the circuit needs to be adjusted to account for this increased current if you want both LEDs to maintain their brightness.

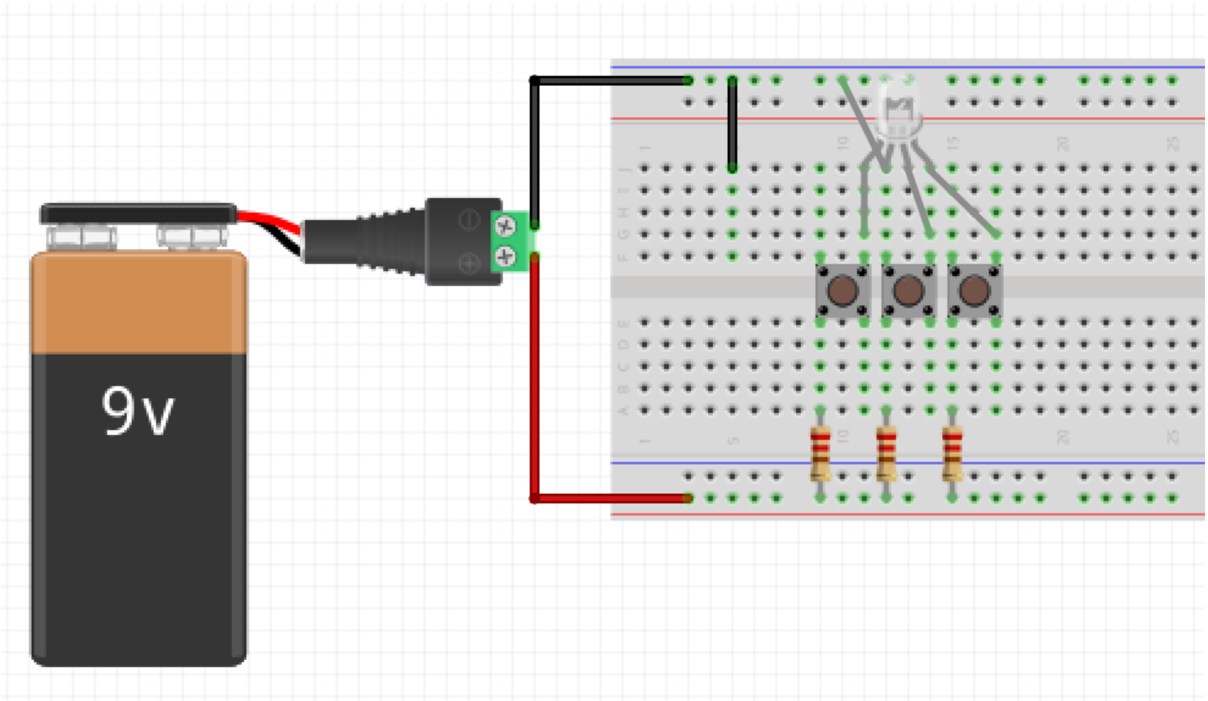
ii. For instance: Let's take a 9V battery (assuming it's fully charged) powering an LED with a 3.2V voltage drop and a current requirement of 20mA. Using Ohm's Law:
   1. R = V / I
   2. R = (9V - 3.2V) / 0.02A
   3. R = (5.8V) / 0.02A = 290 Ohm

iii. Now, if you're using the same 9V battery to power two LEDs (Red and Green channels, both with a 3.2V voltage drop and 20mA current) connected in parallel to the same button, the calculation changes: R = (9V - 3.2V) / 0.04A = 145 Ohm

iv. (Note: While we've used the same voltage drop for demonstration, in reality, different LED colors often have different voltage drops.)

v. **Best Practice:** It's typically recommended to use individual resistors for each parallel-connected component. This ensures consistent brightness and compensates for potential differences in voltage drops between different LED colors.
   1. Using two resistors for two LEDs, each with a 3.2V voltage drop and 20mA current: R = (5.8V) / 0.02A = 290 Ohm
   2. If the LEDs have different voltage drops, say 2V for one and 3.2V for the other, but both require 20mA:
      a. R1= (9V − 2V) / 0.02A = 350 Ohm
      b. R2 = (9V - 3.2V) / 0.02A = 290 Ohm

d. Can you light up more colors at the same time, but with different intensities?
   i. Yes, by using different values for each resistor. And this is the main point: the resistor value should be adapted to the needs of the user, not taken too rigidly from the dataset.



5. Wrap-up, Review and Q&A