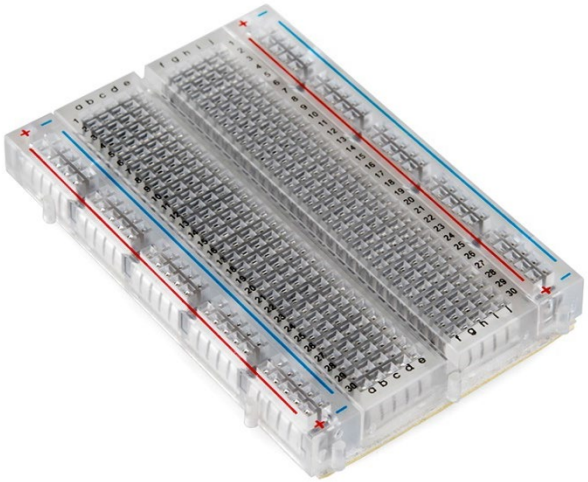
Adapted from:
https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard/all
https://www.rohm.com/electronics-basics/leds/what-are-leds
https://www.dummies.com/article/technology/electronics/general-electronics/what-are-resistors-used-for-141435

Module 3: Working with LEDs

For this module you will need:

- ESP32
- Breadboard
- Male-to-Male jumper wires
- Resistor
- LED

Breadboards are one of the most fundamental pieces when learning how to build circuits. In this tutorial, you will learn a little bit about what breadboards are, why they are called breadboards, and how to use one. Once you are done you should have a basic understanding of how breadboards work and be able to build a basic circuit on a breadboard.



What's in a Name?

When you picture a breadboard in your head, you may envision a big piece of wood and a large loaf of freshly baked bread. You wouldn't be too far off either.

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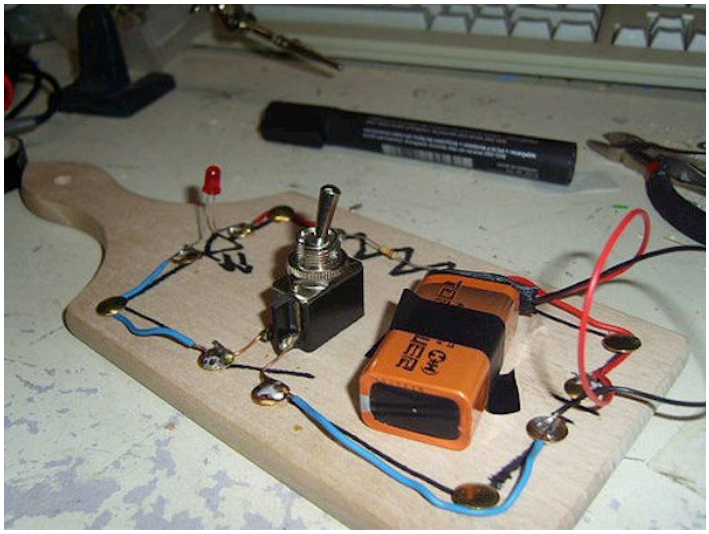
Bread on a breadboard

So why do we call this electronic “circuit builder” a breadboard? Many years ago, when electronics were big and bulky, people would grab their mom’s breadboard, a few nails or thumbtacks, and start connecting wires onto the board to give themselves a platform on which to build their circuits.



Circuit on an "original" breadboard (image courtesy of mischka and their awesome literal breadboard tutorial)

Since then, electronic components have gotten a lot smaller, and we’ve come up with better ways to connect circuits, making moms all over the world happy to have their breadboards back. However, we are stuck with the confusing name. Technically, these are still breadboards, but this discussion is going to be on modern, "solderless" breadboards.

Terminal Strips

Here we have a breadboard where the adhesive backing has been removed. You can see lots of horizontal rows of metal strips on the bottom of the breadboard.

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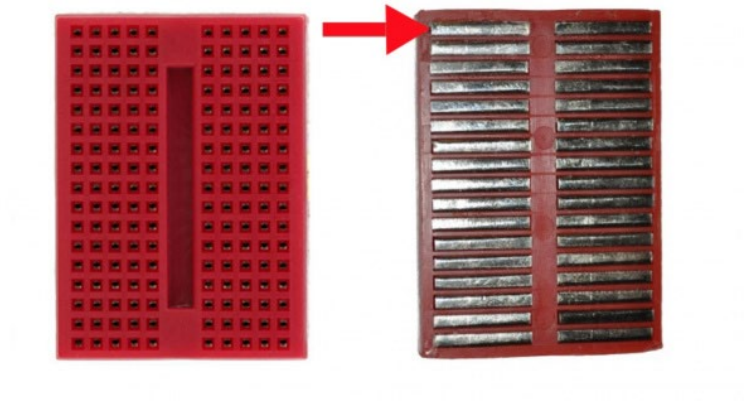

A SparkFun Mini Breadboard from the top (left) and the same breadboard flipped over with the adhesive back removed (right).

The tops of the metal rows have little clips that hide under the plastic holes. Each metal strip and socket is spaced with a standard pitch of 0.1" (2.54mm). These clips allow you to stick a wire or the leg of a component into the exposed holes on a breadboard, which then hold it in place.

A single strip of conductive metal removed from the above breadboard.

Once inserted that component will be electrically connected to anything else placed in that row. This is because the metal rows are conductive and allow current to flow from any point in that strip.

Notice that there are only five clips on this strip. This is typical on almost all breadboards. Thus, you can only have up to five components connected in one particular section of the breadboard. The row has ten holes, so why can you only connect five components? You'll also notice that each horizontal row is separated by a ravine, or crevasse, in the middle of the breadboard. This ravine isolates both sides of a given row from one another, and they are not electrically connected. We'll discuss the purpose of this in just a bit, but, for now, just know that each side of a given row is disconnected from the other, leaving you with five spots for components on either side.

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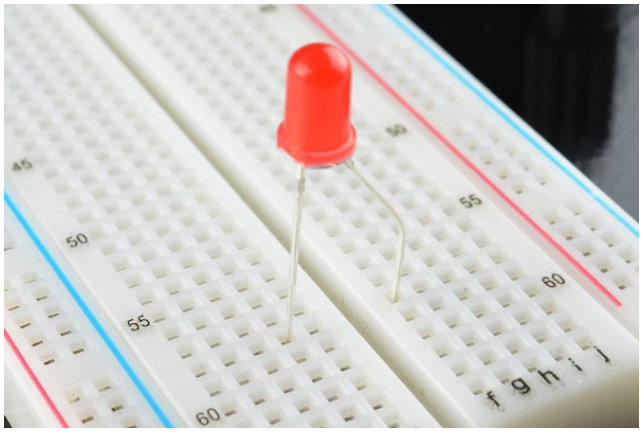
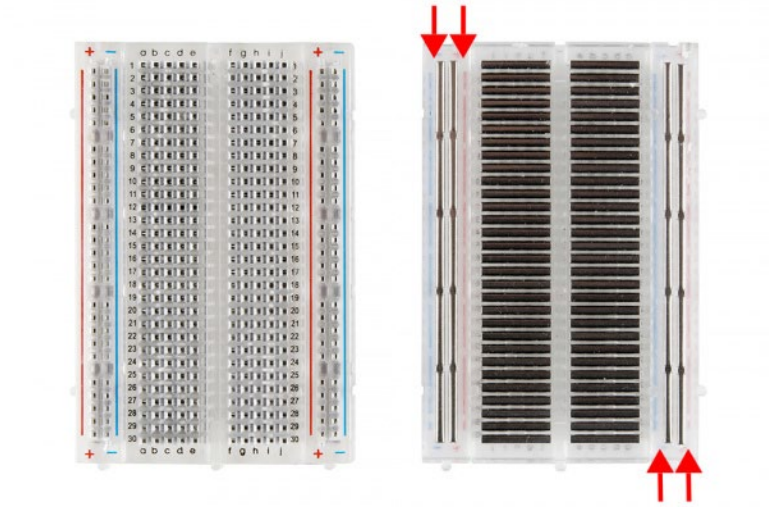


An LED inserted into a breadboard. Notice how each leg of the LED is placed on either side of the ravine. This prevents the connections to the LED from being shorted.

Power Rails

Now that we've seen how the connections in a breadboard are made, let's look at a larger, more typical breadboard. Aside from horizontal rows, breadboards usually have what are called power rails that run vertically along the sides.



A medium-size breadboard with the adhesive back removed to expose the power rails.

These power rails are metal strips that are identical to the ones that run horizontally, except they are, typically*, all connected. When building a circuit, you tend to need power in lots of different places. The power rails give you lots of easy access to power wherever you need it in your circuit. Usually they will be labeled with a '+' and a '-' and have a **red** and **blue** or **black** stripe, to indicate the positive and negative side.

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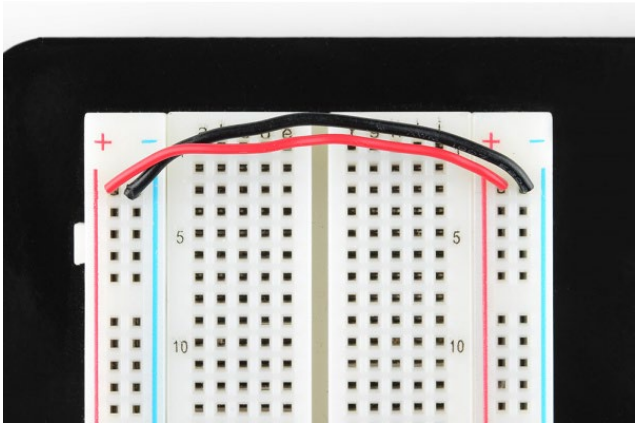
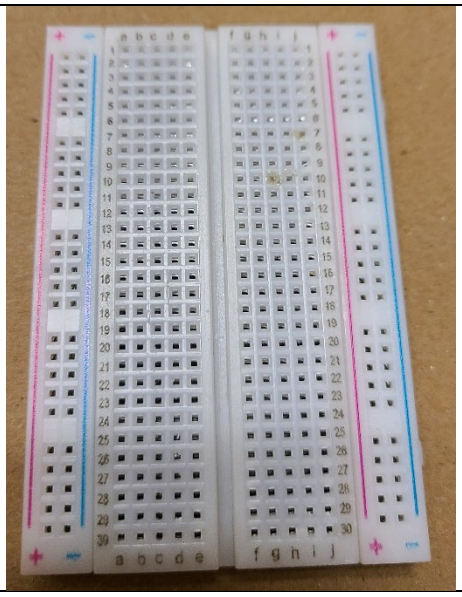
It is important to be aware that the power rails on either side are not connected, so if you want the same power source on both sides, you will need to connect the two sides with some jumper wires. Keep in mind that the markings are there just as a reference. There is no rule that says you have to plug power into the '+' rail and ground into the '-'rail, though it's good practice to keep everything in order.



Two jumper wires used to connect the power rails on both sides. Always attach the '+' to '+' and the '-' to '-'.

Observe the breadboard. There are numbers indicating the row, and letters indicating the column. Along the sides are the power and ground "rails".	

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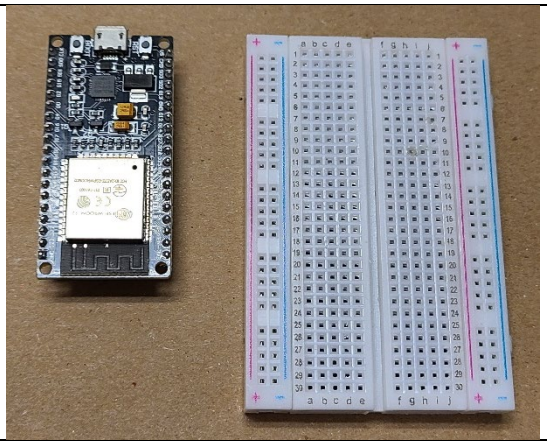
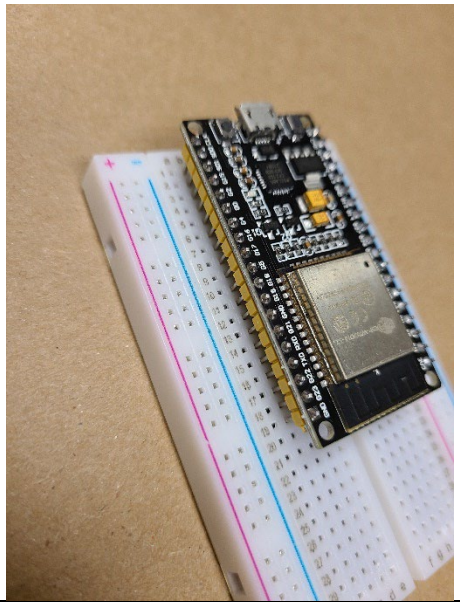
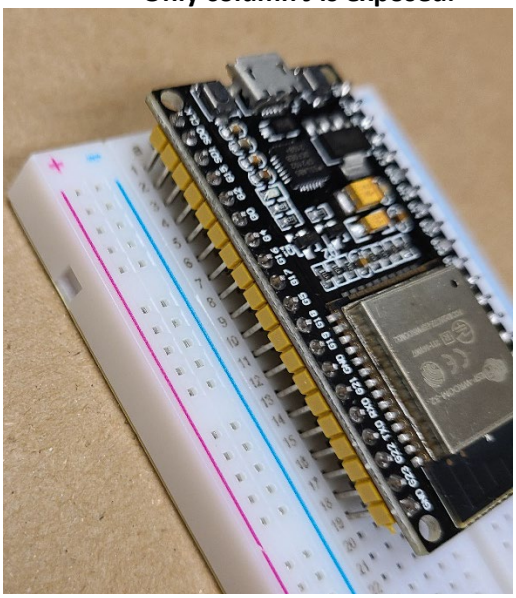
<table>
<tr><td>Place your ESP32 next to the breadboard.
Be sure to align the micro-USB connector to the top of row 1. Place the ESP32 onto the breadboard.</td><td>  </td></tr>
<tr><td>If you are able to expose columns A and J while mounting, that is good.</td><td>If you are not able to expose both column A and J then only expose column J, by inserting the side of the ESP32 into column A.</td></tr>
<tr><td>  </td><td>Only column J is exposed.
  </td></tr>
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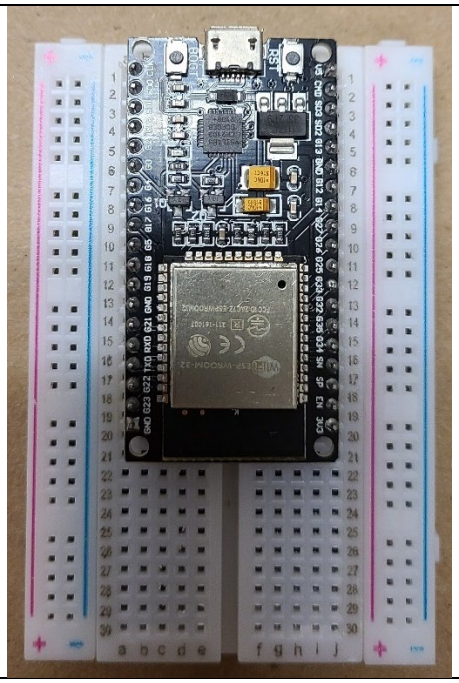
Press the ESP32 down firmly, be careful not to cut yourself on the pins along the edges, also be sure to not break the board.	

Do not connect your ESP32 to the computer.

Assemble this schematic:

GND pin to blue rail

3v3 pin to **red rail on the RST side of the board**

10kΩ resistor connecting GND to hole: 30F

LED anode in the 3v3 rail, LED cathode to hole: 30G/30H/30I/30J

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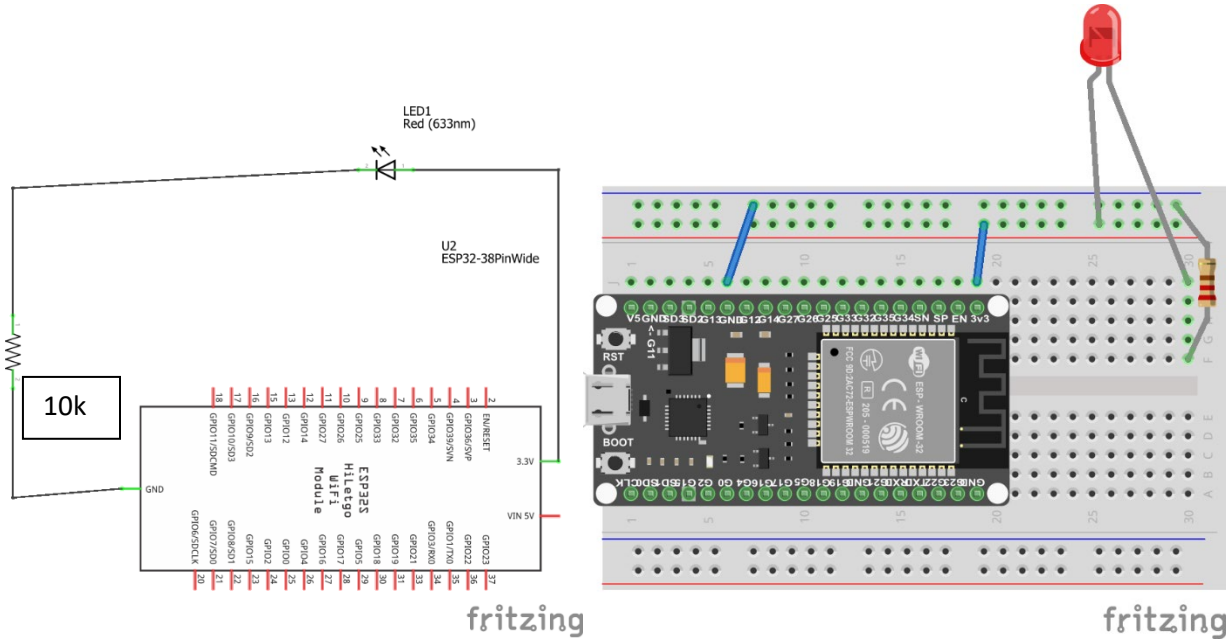

Ask your mentor to verify you assembled your schematic correctly.

Plug in your ESP32 to the computer.

The LED should illuminate.

From: https://www.rohm.com/electronics-basics/leds/what-are-leds

What are LEDs?

LEDs are a type of semiconductor called "Light Emitting Diode". White LEDs, which have achieved practical realization through the use of high-brightness blue LEDs developed in 1993 based on Gallium Nitride, are attracting increased attention as a 4th type of light source.

How do LEDs Emit Light?

LEDs (Light Emitting Diodes) are semiconductor light sources that combine a P-type semiconductor (larger hole concentration) with an N-type semiconductor (larger electron concentration). Applying a sufficient forward voltage will cause the electrons and holes to recombine at the P-N junction, releasing energy in the form of light.

Compared with conventional light sources that first convert electrical energy into heat, and then into light, LEDs (Light Emitting Diodes) convert electrical energy directly into light, delivering efficient light generation with little-wasted electricity.

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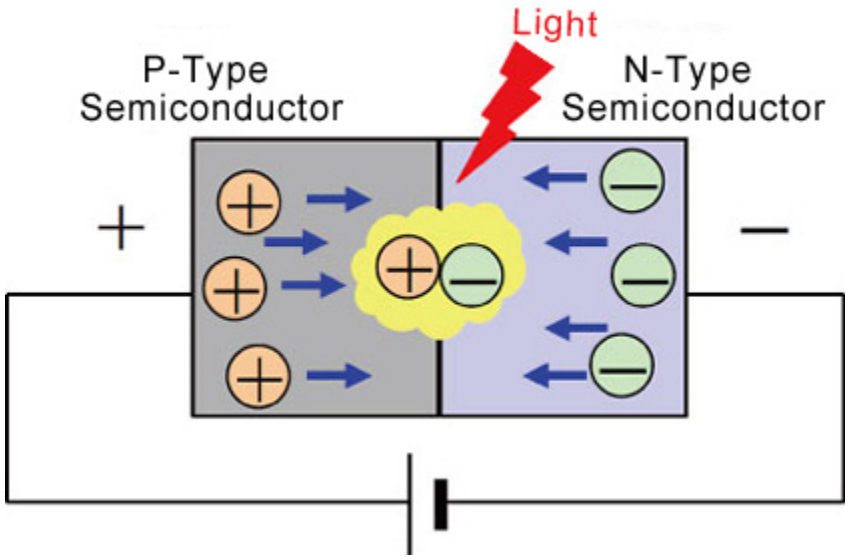

What is a resistor?

Resistors are among the most popular electronic components around because they're simple yet versatile. One of the most common uses of a resistor is to limit the amount of current in part of a circuit. However, resistors can also be used to control the amount of voltage provided to part of a circuit and to help create timing circuits.

Limiting current

The circuit in the following figure shows a 6-volt battery supplying current to a light-emitting diode (LED) through a resistor (shown as a zigzag). LEDs (like many other electronic parts) eat up current like a kid eats candy: They try to gobble up as much as you give them. But LEDs run into a problem — they burn themselves out if they draw too much current. The resistor in the circuit serves the useful function of limiting the amount of current sent to the LED (the way a good parent restricts the intake of candy).

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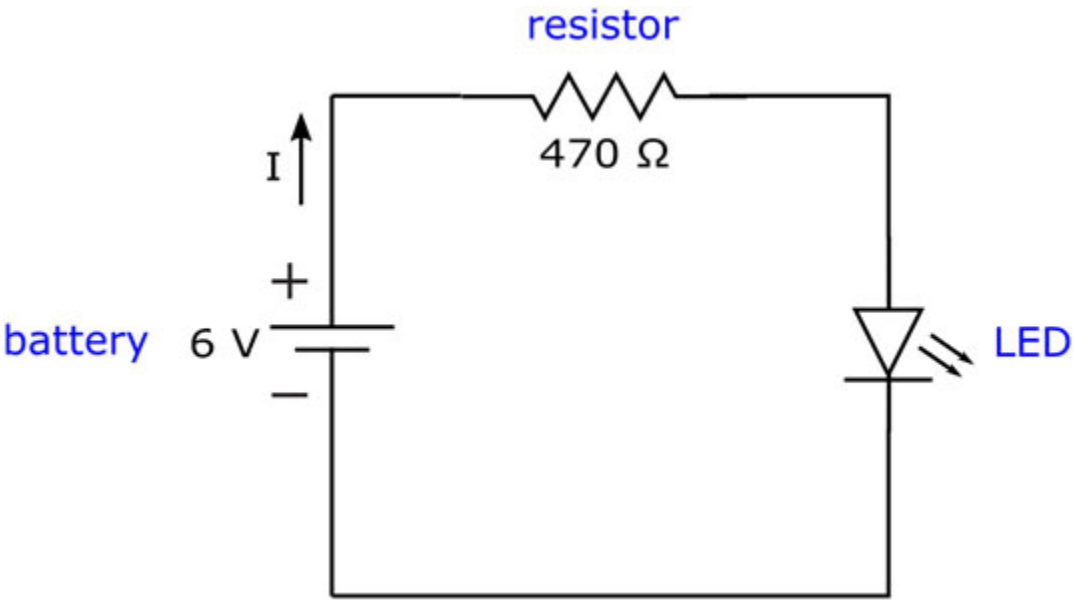

The resistor limits the amount of current, *I*, flowing into sensitive components, such as the light-emitting diode (LED) in this circuit.

Too much current can destroy many sensitive electronic components — such as transistors and integrated circuits. By putting a resistor at the input to a sensitive part, you limit the current that reaches the part. (But if you use too high a resistance, you'll limit the current so much you won't see the light, although it's there!) This simple technique can save you a lot of time and money that you would otherwise lose fixing accidental blow-ups of your circuits.