This introduction to breadboards is used to provide a printed guide for the build class. Some items were reformatted from the html to allow it to be printed, and videos and other items that don't aid a printed version were removed. Only the first part of this guide is printed here.

Since this guide is generic some of the details may differ from the breadboard provided in this kit/

Please see https://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-breadboard for the original and complete document. This material is copyrighted by ScienceBuddies and provided under their allowance for 200 copies.

Other guides can be found at:
https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard
https://learn.adafruit.com/breadboards-for-beginners/introduction

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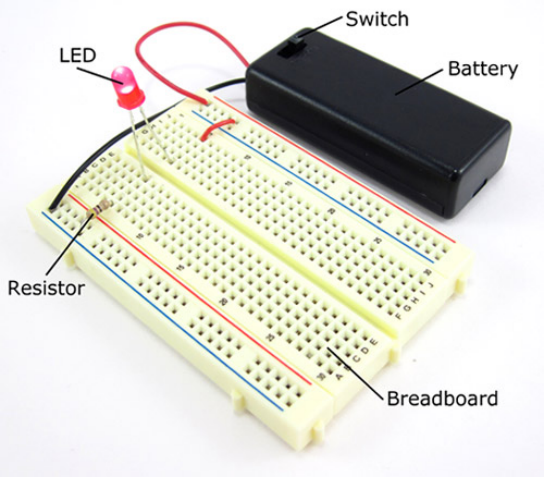
Many electronics projects use something called a **breadboard**. What is a breadboard, and how do you use it?

Introduction

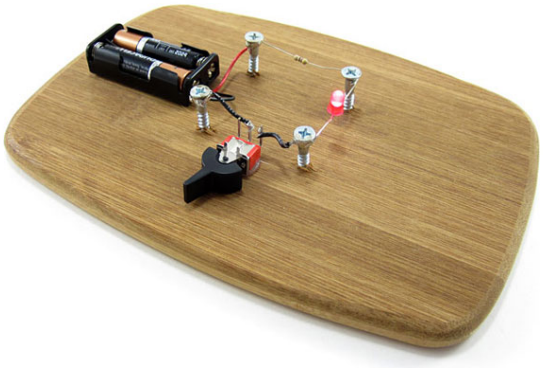
What is a breadboard?

A breadboard is a rectangular plastic board with a bunch of tiny holes in it. These holes let you easily insert electronic components to **prototype** (meaning to build and test an early version of) an electronic circuit, like this one with a battery, switch, resistor, and an LED (light-emitting diode). To learn more about individual electronic components, see our Electronics Primer.

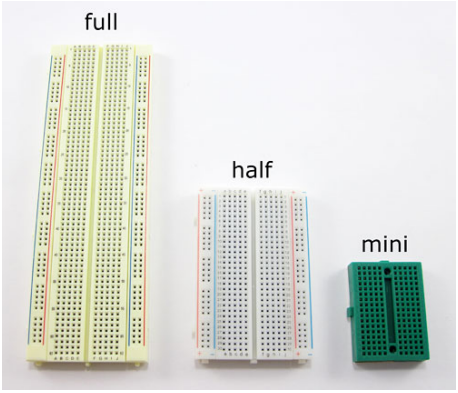


The connections are not permanent, so it is easy to *remove* a component if you make a mistake, or just start over and do a new project. This makes breadboards great for beginners who are new to electronics. You can use breadboards to make all sorts of fun electronics projects, from different types of robots or an electronic drum set, to an electronic rain detector to help conserve water in a garden, just to name a few.

Where does the name "breadboard" come from?



You might be wondering what any of this has to do with bread. 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. Luckily, since you probably do not want to ruin all your cutting boards for the sake of an electronics project, today there are better options.

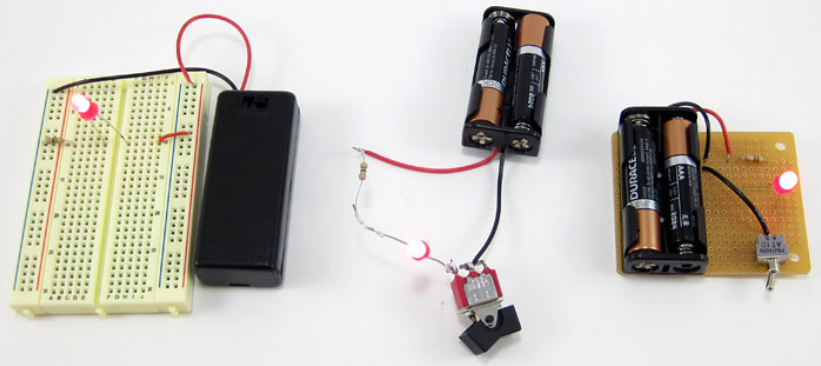


Are there different kinds of breadboards?

Modern breadboards are made from plastic, and come in all shapes, sizes, and even different colors. While larger and smaller sizes are available, the most common sizes you will probably see are "full-size," "half-size," and "mini" breadboards. Most breadboards also come with tabs and notches on the sides that allow you to snap multiple boards together. However, a single half-sized breadboard is sufficient for many beginner-level projects.

What is a "solderless" breadboard?

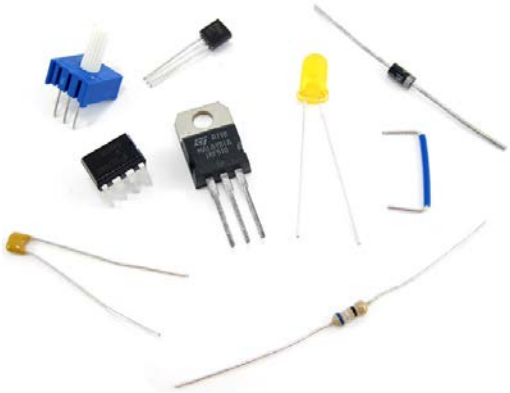
Technically, these breadboards are called **solderless** breadboards because they do not require soldering to make connections. **Soldering** is a method where electronic components are joined together by melting a special type of metal called **solder**. Electronic components can be soldered directly together, but more commonly they are soldered onto **printed circuit boards** (PCBs). PCBs are what you will see if you take the cover off many electronic devices, like a computer or cell phone. Frequently, engineers will use solderless breadboards to prototype and test a circuit before building the final, permanent design on a PCB. This image shows the same circuit (battery, switch, resistor, and LED) built three different ways: on a solderless breadboard (left), with the components soldered directly together (middle), and on a printed circuit board (right):



Soldering is a great technique to learn if you are interested in electronics, but the connections are much more permanent and it requires purchasing some tools to get started. The rest of this tutorial will focus on solderless breadboards, but you can read our soldering tutorial to learn more about soldering.

Which electronic parts are compatible with breadboards?

So, how do electronic components fit into a breadboard? Many electronic components have long metal legs called **leads** (pronounced "leeds"). Sometimes, shorter metal legs are referred to as **pins** instead. Almost all components with leads will work with a breadboard (to learn more about these components and which types work with a breadboard, see the Advanced section).



Breadboards are designed so you can push these leads into the holes. They will be held in place snugly enough that they will not fall out (even if you turn the breadboard upside-down), but lightly enough that you can easily pull on them to remove them.

Do I need any tools to use a breadboard?

You do not need any special tools to use a solderless breadboard. However, many electronic components are very tiny, and you may find them difficult to handle. A pair of miniature needle nose pliers or tweezers may make it easier to pick up small components.

What is inside a breadboard?

The leads can fit into the breadboard because the *inside* of a breadboard is made up of rows of tiny metal clips. This is what the clips look like when they are removed from a breadboard.

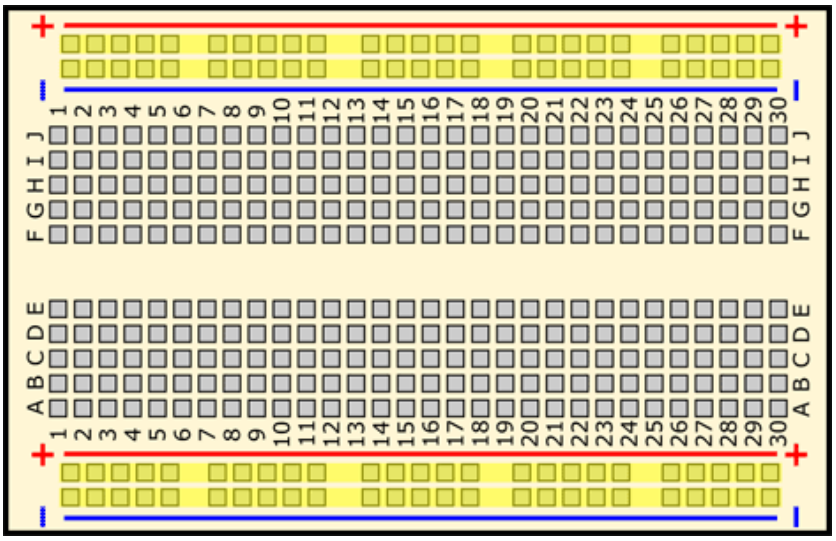
When you press a component's lead into a breadboard hole, one of these clips grabs onto it. Some breadboards are actually made of transparent plastic, so you can see the clips inside.

Most breadboards have a backing layer that prevents the metal clips from falling out. The backing is typically a layer of sticky, double-sided tape covered by a protective layer of paper. If you want to permanently "stick" the breadboard to something (for example, a robot), you just need to peel off the paper layer to expose the sticky tape underneath. In this picture, the breadboard on the right has had its backing removed completely (so you can see all the metal clips). The breadboard on the left still has its sticky backing, with one corner of the paper layer peeled up.

Don't take the backing off of your own, the pictures are illustrative only!

What do the colored lines and plus and minus signs mean?

What about the long strips on the side of the breadboard, highlighted in yellow here?



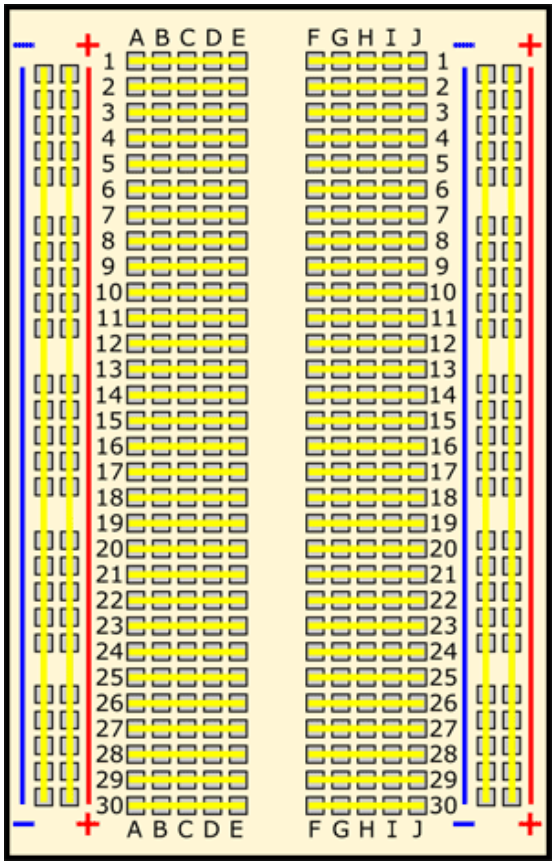
These strips are typically marked by red and blue (or red and black) lines, with plus (+) and minus (-) signs, respectively. They are called the **buses**, also referred to as **rails**, and are typically used to supply electrical power to your circuit when you connect them to a battery pack or other external power supply. You may hear the buses referred to by different names; for example, *power bus*, *positive bus*, and *voltage bus* all refer to the one next to the red line with the plus (+) sign. Similarly, *negative bus* and *ground bus*

both refer to one next to the blue (or black) line with the minus (-) sign. Sound confusing? Use this table to help you remember—there are different ways to refer to the buses, but they all mean the same thing. Do not worry if you see them referred to by different names in different places (for example, in different Science Buddies projects or other places on the internet). Sometimes you might hear "power buses" (or rails) used to refer to *both* of the buses (or rails) together, not just the positive one.

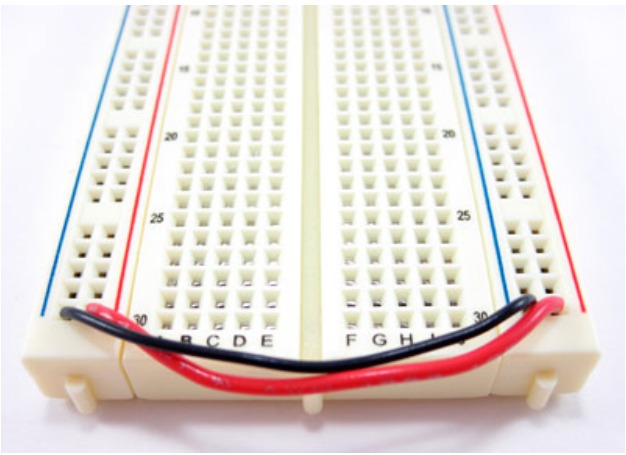
Positive	Negative
Power	Ground
Plus sign (+)	Minus sign (-)
Red	Blue or black

Note that there is no physical difference between the positive and negative buses, and using them is not a requirement. The labels just make it easier to organize your circuit, similar to color-coding your wires.

How are the holes connected?



Remember that the inside of the breadboard is made up of sets of five metal clips. This means that each set of five holes forming a half-row (columns A–E or columns F–J) is electrically connected. For example, that means hole A1 is electrically connected to holes B1, C1, D1, and E1. It is *not* connected to hole A2, because that hole is in a different row, with a separate set of metal clips. It is also *not* connected to holes F1, G1, H1, I1, or J1, because they are on the other "half" of the breadboard—the clips are not connected across the gap in the middle (to learn about the gap in the middle of the breadboard, see the Advanced section). Unlike all the main breadboard rows, which are connected in sets of five holes, the buses typically run the entire length of the breadboard (but there are some exceptions). This image shows which holes are electrically connected in a typical half-sized breadboard, highlighted in yellow lines.



Buses on opposite sides of the breadboard are *not* connected to each other. Typically, to make power and ground available on both sides of the breadboard, you would connect the buses with jumper wires, like this. Make sure to connect positive to positive and negative to negative (see the section on buses if you need a reminder about which color is which).

Are all breadboards labeled the same way?

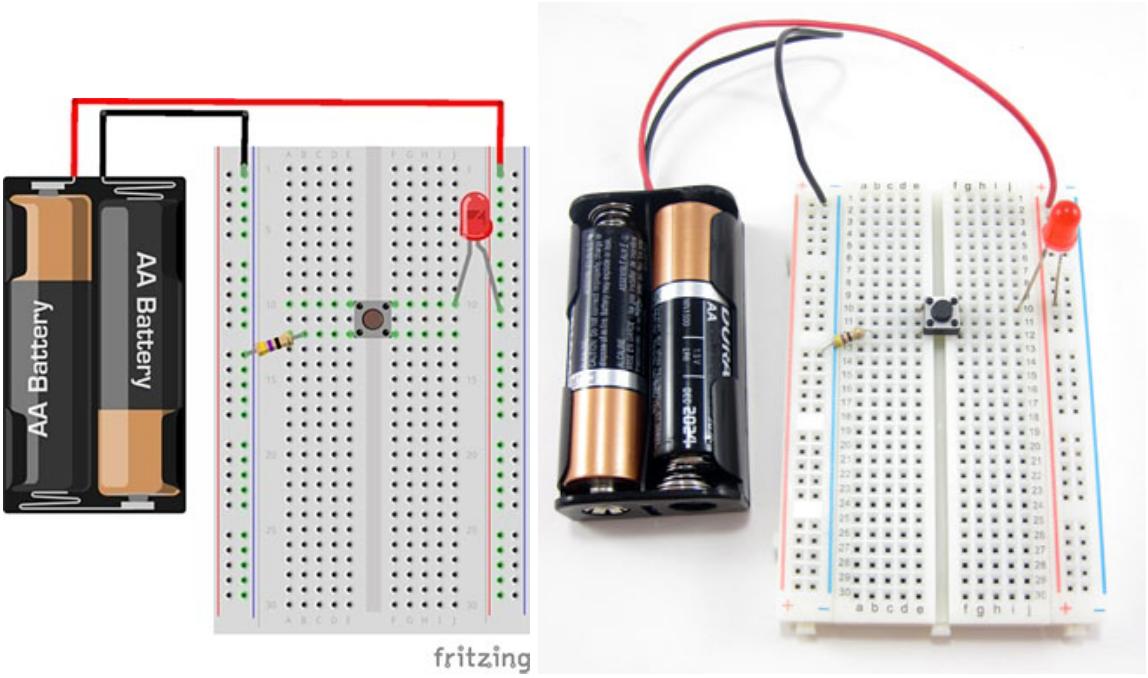
Note that exact configurations might vary from breadboard to breadboard. For example, some breadboards have the labels printed in "landscape" orientation instead of "portrait" orientation. Some breadboards have the buses broken in half along the length of the breadboard (useful if you need to supply your circuit with two different voltage levels). Most "mini" breadboards do not have buses or labels printed on them at all.

There may be small differences in how the buses are labeled from breadboard to breadboard. Some breadboards only have the colored lines and no plus (+) or minus (-) signs. Some breadboards have the positive buses on the left and the negative buses on the right, and on other breadboards, this is reversed. Regardless of how they are labeled and the left/right positions, the function of the buses remains the same.

Using a breadboard

What is a breadboard diagram?

A **breadboard diagram** is a computer-generated drawing of a circuit on a breadboard. Unlike a **circuit diagram** or a **schematic** (which use symbols to represent electronic components; see the Advanced section to learn more), breadboard diagrams make it easy for beginners to follow instructions to build a circuit because they are designed to look like the "real thing." For example, this diagram (made with a free program called Fritzing) shows a basic circuit with a battery pack, an LED, a resistor, and a pushbutton, which looks very similar to the physical circuit:

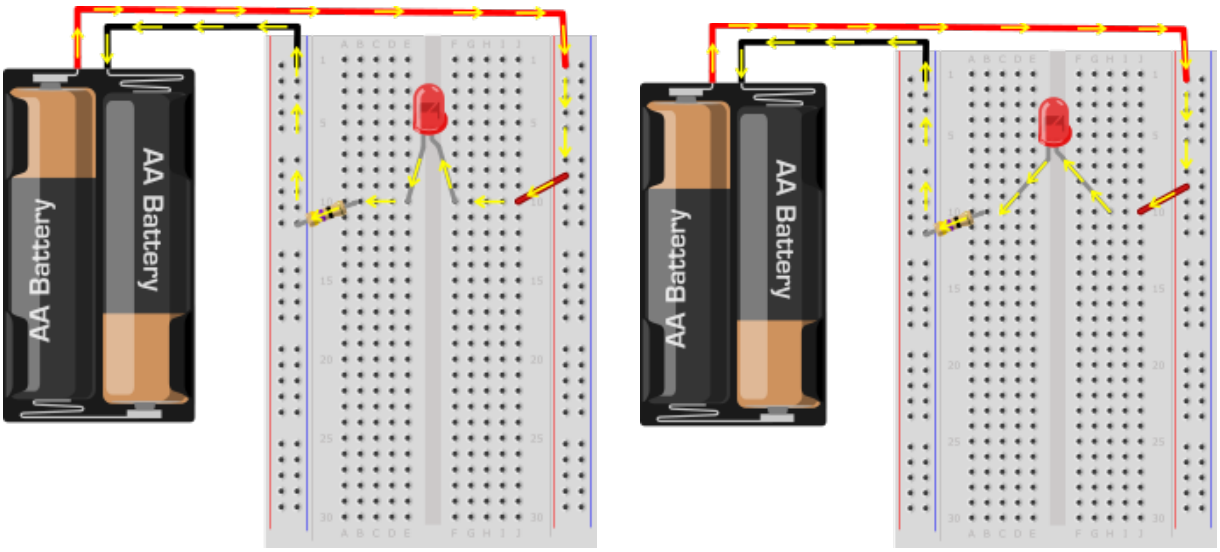


Sometimes, breadboard diagrams might be accompanied by (or replaced with) written directions that tell you where to put each component on the breadboard.

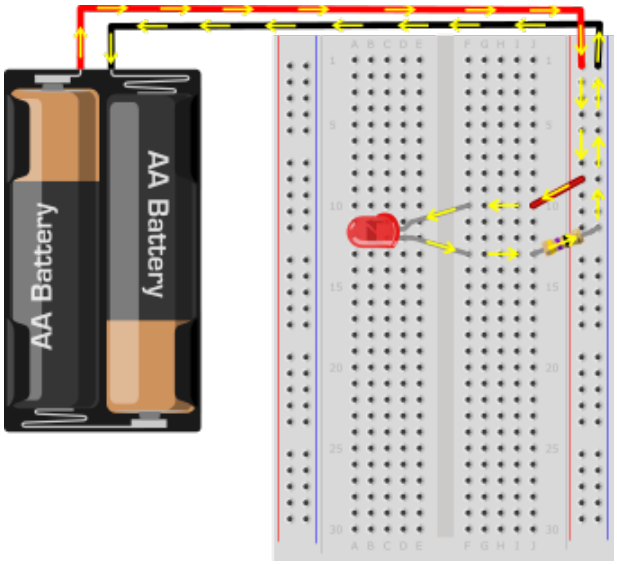
Does my circuit have to match the breadboard diagram exactly?

The short answer is "no." However, when you are first starting out using breadboards, it is probably best to follow the breadboard diagrams exactly.

To understand this, it helps to understand how a breadboard's holes are electrically connected. There are different ways to change the *physical* layout of a circuit on a breadboard without actually changing the *electrical* connections. For example, these two circuits are electrically identical; even though the leads of the LED have moved, there is still a complete path (called a **closed circuit**) for electricity to flow through the LED (highlighted with yellow arrows). So, even if the directions say "put the LED's long lead in hole F10," the circuit will still work if you put it in hole F12 instead (but *not* if you put it in hole F9 or F11, because different rows are not connected).

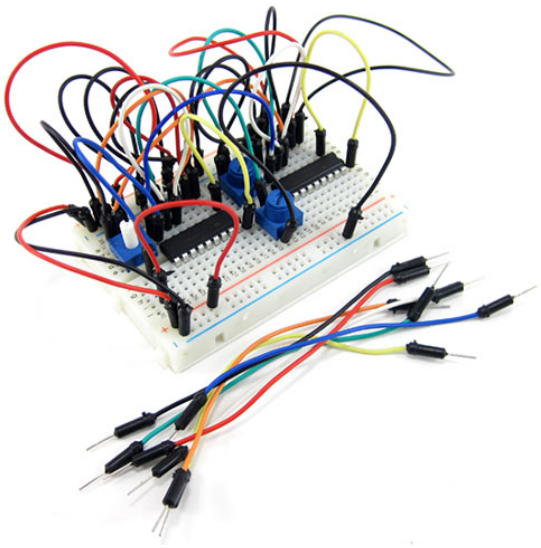


However, you can also completely rearrange the components on the breadboard. As long as the circuit is *electrically* equivalent, it will still work. Even though this circuit "looks different" than the previous two because the components have been rearranged, electricity still follows an equivalent path through the LED and the resistor.



What are jumper wires and what kind should I use?

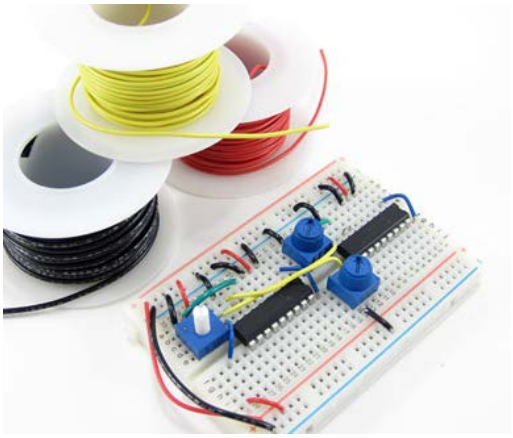
Jumper wires are wires that are used to make connections on a breadboard. They have stiff ends that are easy to push into the breadboard holes. There are several different options available when purchasing jumper wires.



Flexible jumper wires are made of a flexible wire with a rigid pin attached to both ends. These wires usually come in packs of varying colors. This makes it easy to color-code your circuit (see the section on color-coding). While these wires are easy to use for beginner circuits, they can get very messy for more complicated circuits; because they are so long, you will wind up with a tangled nest of wires that are hard to trace (sometimes called a "rat's nest" or "spaghetti").

Jumper wire kits are packs of pre-cut lengths of wire that have their ends bent down 90 degrees, so they are ready to put into a breadboard. The kits are available in larger and smaller sizes. These kits are very convenient because they come with wires of many different pre-cut lengths. The disadvantage is that there is typically only one length of each color. This can make it difficult to color-code your circuit (for example, you might want a long black wire, but your kit might only have short black wires). Your circuit will still work just fine, but color-coding can help you stay more organized (again, see the section on color-coding for more information). Notice how this circuit looks much less messy than the previous one, since the wires are shorter.

Finally, you can also buy spools of solid-core hookup wire and a pair of wire strippers and cut your own jumper wires. This is the best long-term option if you plan on doing lots of electronics projects, because you can cut wires to the exact length you need, and pick which colors you want. It is also much more cost-effective per length of wire. Buying a kit of six different colors is a good place to start. It is important to buy **solid core** wire (which is made from a single, solid piece of metal) and not **stranded** wire (which is made from multiple, smaller strands of wire, like a rope). Stranded wire is much more flexible, so it is very hard to push into a breadboard's holes. You also need to purchase the right **wire gauge**, which is a way of measuring wire diameter. 22 AWG (American Wire Gauge) is the most common gauge used for breadboards. To learn more about wire gauge and how to strip wire, see the Science Buddies Wire Stripping Tutorial. Notice how in this circuit, red and black are used for all the connections to the buses (see the section on color-coding to learn more).

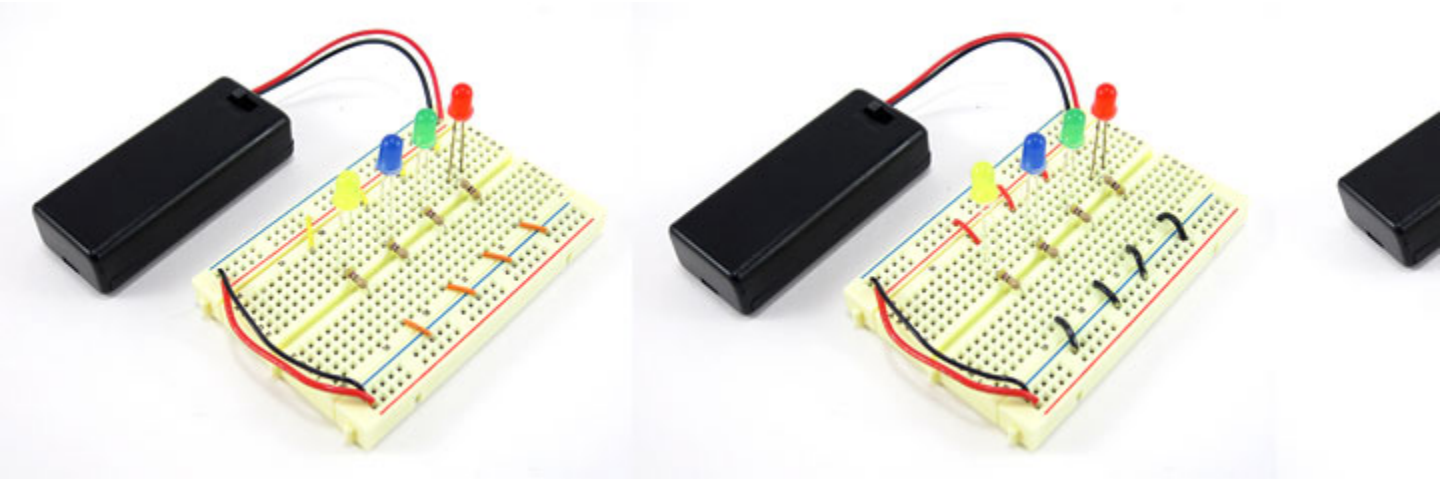


Should I color-code my circuit?

Whether or not you color-code your circuit depends largely on what type of jumper wire you purchase (see the question about jumper wires). Color-coding is a matter of convenience in that it can help you stay more organized, but using different color wires will not change how your circuit works. **Important**: This statement only applies to **jumper wires**. Some circuit components, like battery packs and certain sensors, come with colored wires already attached to them. Keeping track of these colors *does* matter (for example, do not get the red and black leads on a battery pack mixed up). All jumper wires, however, are just metal on the inside with colored plastic insulation on the outside. The color of the plastic does not affect how electricity flows through the wire.

In electronics, it is generally standard to use red wire for positive (+) connections and black wire for negative (-) connections. What other colors you use is largely a matter of choice and will depend on the specific circuit you are building. For example, there are a few different ways you could wire this circuit with red, green, blue, and yellow LEDs, but they will all work exactly the same:

- If you purchased a pre-cut jumper wire kit, use whatever wire colors are available at the appropriate lengths (left image).
- Use red and black wires for the positive and negative sides of each LED, respectively (center image).
- Only use red and black wires for the bus connections, and use red, green, blue, and yellow wire for the respective LEDs (right image).



Remember the important part: *the color of the wires does not affect how the circuit works!* The three circuits in this image will all work exactly the same (the LEDs will light up when the battery pack is turned

on) even though they have different color wires. If a breadboard diagram shows a blue wire and you use an orange wire instead, nothing will be wrong with your circuit.

How do I build a circuit?

To build a circuit:

- Follow the breadboard diagram for the circuit, connecting one component at a time.
- Always connect the batteries or power supply to your circuit *last*. This will give you a chance to double-check all your connections before you turn your circuit on for the first time.
- Keep an eye out for common mistakes that many beginners make when using a breadboard.

How do I test my circuit?

How you test your circuit will depend on the specific circuit you are building. In general, you should follow this procedure:

- Double-check your circuit and the breadboard diagram to make sure all your components are in the right place.
- Check what your circuit is supposed to do according to the project directions. Is it supposed to flash lights, make noise, somehow respond to a sensor (like a motion or light sensor), or make a robot move? Many Science Buddies projects will contain a written description and/or video of how your circuit should work.
- Turn the power to your circuit on (for example, by sliding a battery pack switch from OFF to ON). If you see or smell smoke, turn off or disconnect the power supply *immediately*. This means you have a short circuit.
- Follow the project directions to use your circuit (for example, shining a flashlight at a light-tracking robot, or waving your hand in front of a motion sensor).
- If your circuit does not work, you need to troubleshoot (or **debug**, meaning to look for problems or "bugs" in your circuit). See the common mistakes section for things you should check.