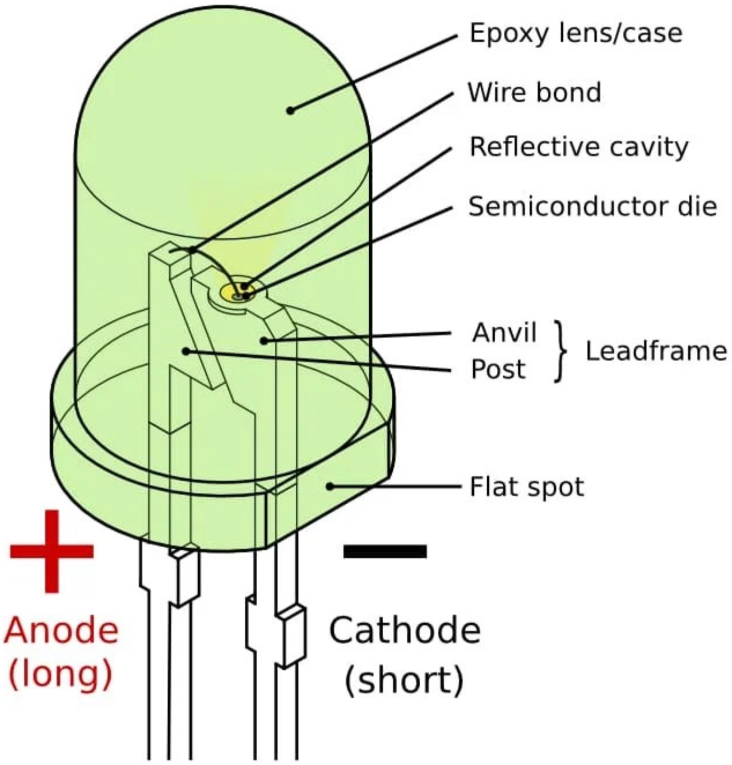
LED (Light-emitting

diode) explained



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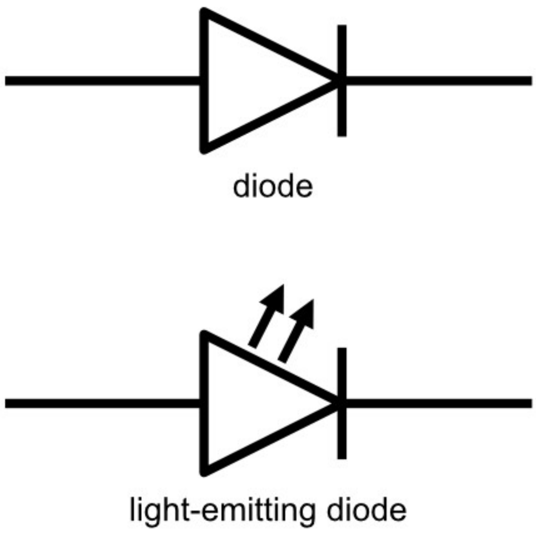
LED (Light-emitting diode) explained

Pretty much everywhere you look, you will see an LED in use. It doesn't matter if you're looking at your smartphone, TV, car, or coffee machine, there are some likely in them. **LEDs are widely used and supported**, and come in many colors, shapes, and sizes. The first Arduino project usually being taught is making an LED blink because of its simplicity and LEDs' widespread use. Let's dive into the world of LEDs together and learn a thing or two about them!

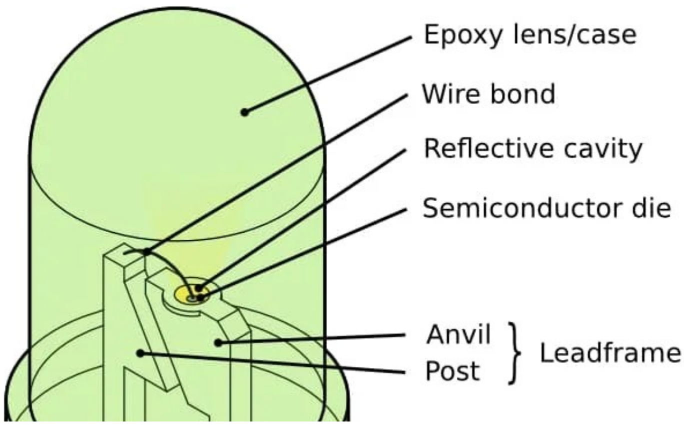
What is an LED?

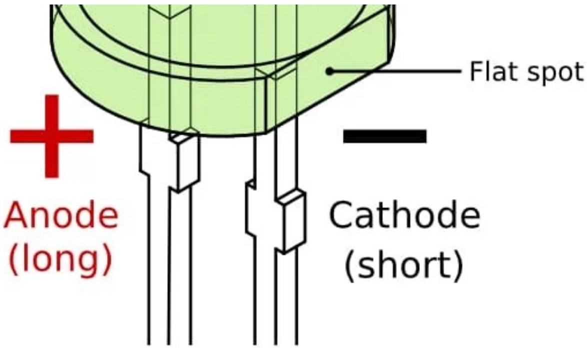
The first question that might pop into your mind is, what is exactly an LED? A regular diode is a semiconductor device that works as a one-way switch for electrical current. It allows current in only one direction and will stop it from flowing in the other. An LED works the same way. The only difference is that it **emits light when the current passes through**, as the name suggests. This similarity is reflected even in the schematic , as seen below.



The only difference between a diode and an LED in the schematic is the arrows added over the symbol. They represent the light being emitted from the diode.

If you take a closer look at an LED, you will see it's made of several parts. The case or housing of the LED is usually made from epoxy or plastic material. This makes it more durable to fall or similar damage. The inside of the LED consists of two main parts – post and anvil. The post is the positive side of the LED, the anode side, and the anvil is the negative side, the cathode. A die is inside a little divot on the anvil, and the bond wire leaps from anvil to post, connecting the two.



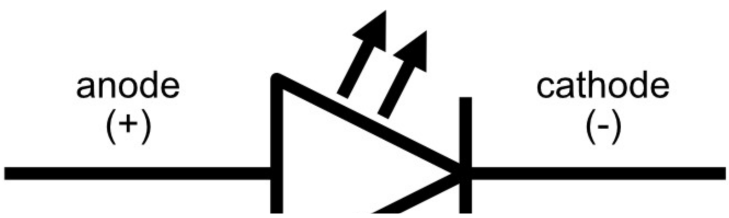


For the light to be emitted, **the diode has to be made from special material**. The semiconductor die, the thing that makes LED emit light, is made from gallium arsenide (GaAs), gallium phosphide (GaP), gallium arsenide phosphide (GaAsP), silicon carbide (SiC), gallium indium nitride (GaInN), aluminum gallium indium phosphide (AlGaInP), and similar chemical compounds. The color of the LED will depend on the compound used.

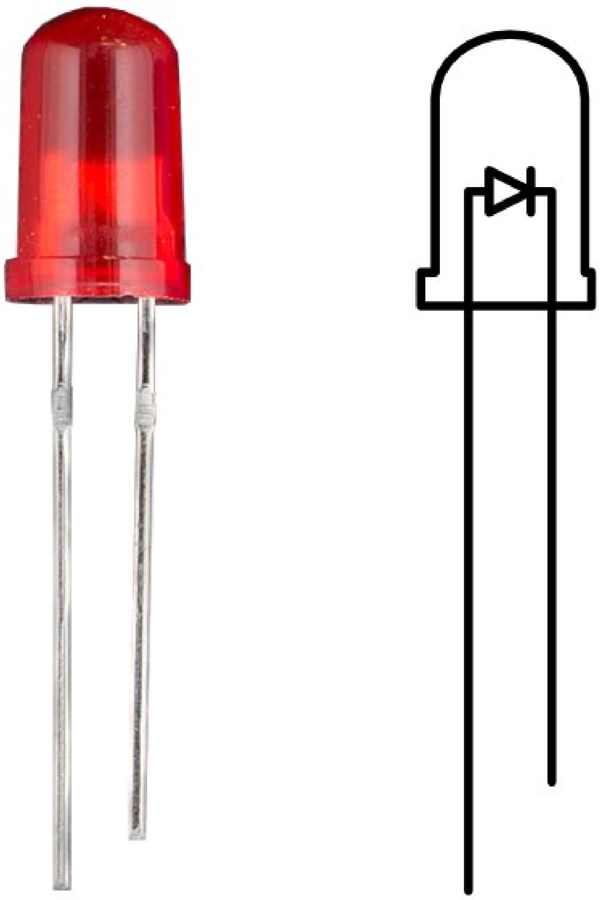
To understand how to work with LEDs, we have to know some things about them.

Polarity

In electronics, **polarity indicates the symmetry of a component**, meaning it will matter how you connect it if it's polarized. Non-polarized components can be connected either way and they will work properly (e.g. resistors). As mentioned, a diode will allow the current to flow in only one direction. Thus, an **LED is polarized** and will only emit light if it's connected correctly. For it to work properly, the **current must go from anode to cathode**. The anode must be connected to the positive end and the cathode to the negative. If it's the other way around, the LED will remain off. It won't break, it just won't work, and it might stop the whole circuit. On a schematic diagram, the anode should be the line coming to the broad side of the triangle.



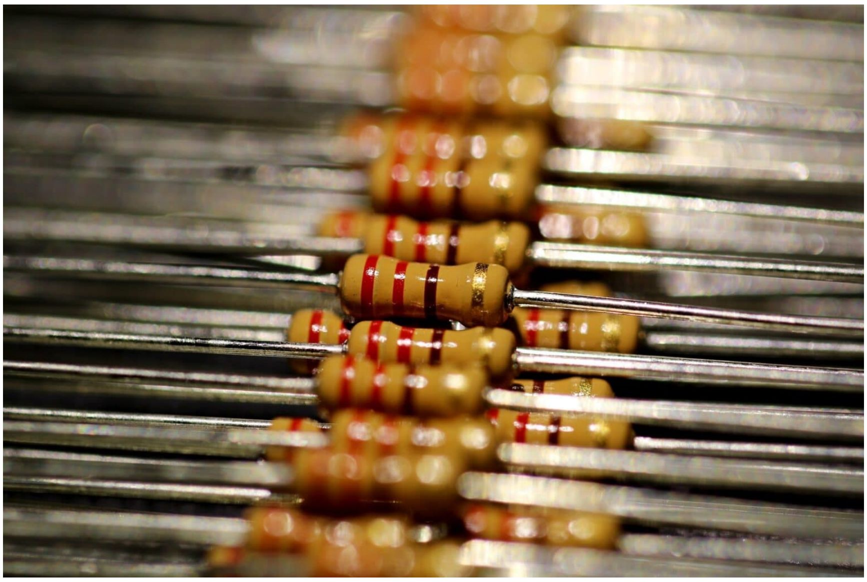
Every diode should have some physical mark to differentiate the anode from the cathode. On most regular LEDs you will work with, the anode "leg" or pin is longer than the cathode. Since you can't see the pins' lengths once you plug them in a breadboard or solder them, the cathode side of the case will be slightly cut off. It might be hard to notice at first, but once you find it, you'll have no trouble seeing it in the future.



Current and resistors

The light emitted will depend on the current the LED draws. The more light it emits, the more power it uses, thus the more batteries it drains. **Diodes in general do not limit current** and will destroy themselves if they consume too much of it. Resistors are used to prevent this from happening. They will restrict the electrons' flow in the circuit and save the LED from drawing too much power. But with so many resistors out there, which one should you use to prevent your LED from burning itself?

We made a tutorial on resistors so if you're not sure how to calculate its resistance, find out here . For most LEDs, you'll be fine with using a 330-ohm resistor. That's the one with two orange and one brown color band. **The stronger resistor you use, the less bright LED will be**.



If you don't want to calculate the resistance, you can always try plugging in different resistors to see what happens. Resistors let go of extra power as heat so if it's getting warm, you'll likely want a smaller one. If it's too small, however, you might burn out your LED. When you plug in your resistor and LED on the circuit, check if the LED quickly blinked on and off. If that's the case, you burned your LED and should use the stronger resistor. If the LED is on, but it's not as bright as you hoped for, try using a different resistor. Experiment this way until you get wanted LED brightness. Keep in mind that this is not the recommended way of doing things, and we strongly encourage you to learn how to read resistor values.

When you're looking at LED's datasheet , you'll see three things listed that you'll find useful. They are the forward current, peak forward current, and suggestion using current. Most LEDs will have the forward current rated at 20 mA. This means for optimal performance, you could run them on 20 mA. This doesn't mean you have to necessarily run them at that value, just that it's recommended for most cases. Peak forward current is usually set at 30 mA. You can run them on higher than that, but you're risking breaking them. Suggestion using current is usually set to 16-18 mA. We would recommend using LEDs at around 10 mA to extend their shelf life, as the brightness difference between 10 and 20 mA is relatively insignificant.

Forward voltage

A term you'll likely see often when working with LEDs is the forward voltage. It is a number that will help you with the voltage your circuit needs to supply to LEDs. This number becomes especially important if you have more than one LED connected to one power source. If you provide 5 V to your circuit, your components put together shouldn't exceed that number.

Here's a list of the most common forward voltages for LEDs depending on the color:

- Red – 1.6 V
- Orange – 2 V
- Yellow – 2.1 V
- Green – 1.9 V
- Blue – 2.4 V
- Ultraviolet – 3 V
- Clear white- 3.5V

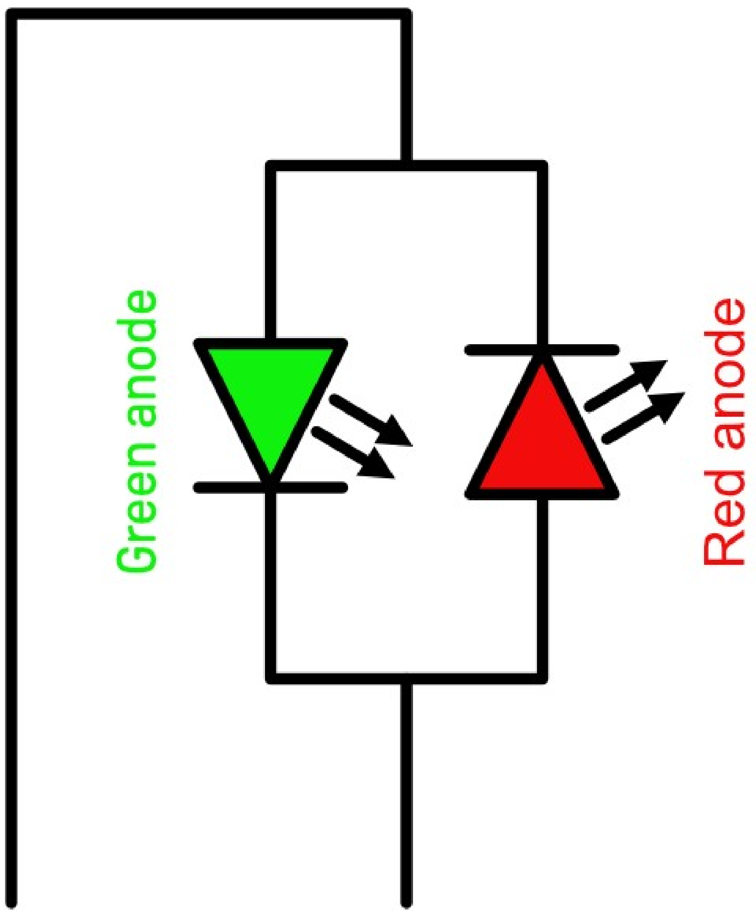
Types of LEDs

We've talked about regular, one-color, simple LEDs thus far. But LEDs have come much further than that and there are a bunch of types today. Here are some of the ones we find particularly interesting to work with.

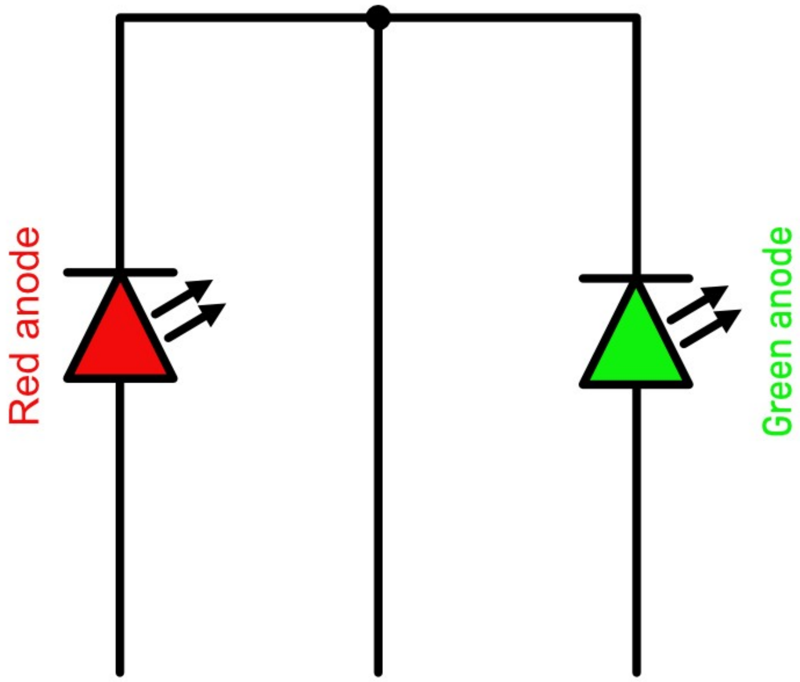
Bi-color and tri-color LED

Bi-color and tri-color LEDs will **light up in a color depending on the current flow direction**. Regular bi-color LED has two wires. The LEDs are connected back to back, anode to cathode. The color of the light will depend on the anode which is provided with positive voltage. Let's say the LEDs in our example have colors green and red.

If the red anode is provided voltage, the red LED will light up. Conversely, if the green anode is provided voltage, the green LED will light up. In this system, only one LED can light up at a time.

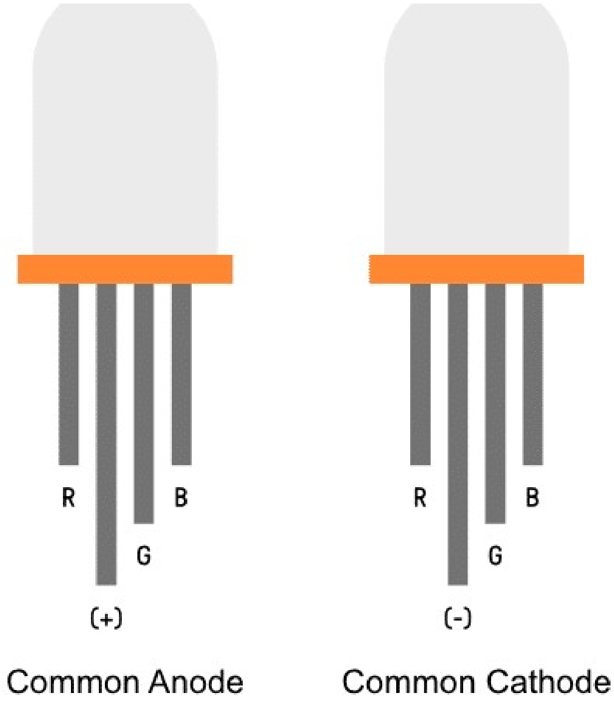


Tri-color LEDs are a bit different. They have three wires, one for each anode and the middle one for the cathode. Like with the bi-color LED, depending on the anode provided with a positive voltage, that color will light up. Here's a catch. Because the two anodes are wired separately, you can apply a positive voltage to both wires. If you do, the LED will light up in a third color, which is a mixture of both.

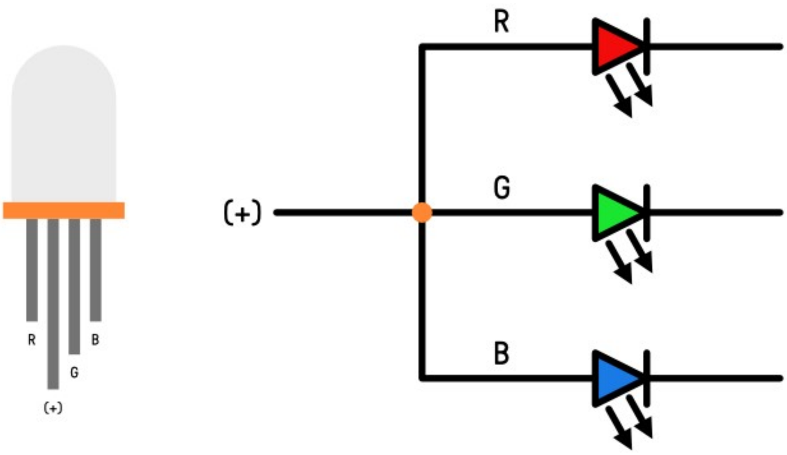


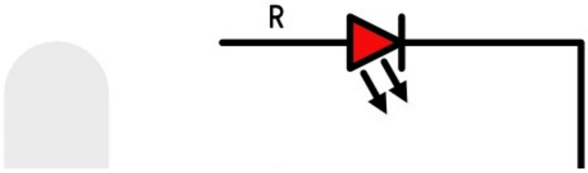
RGB LED

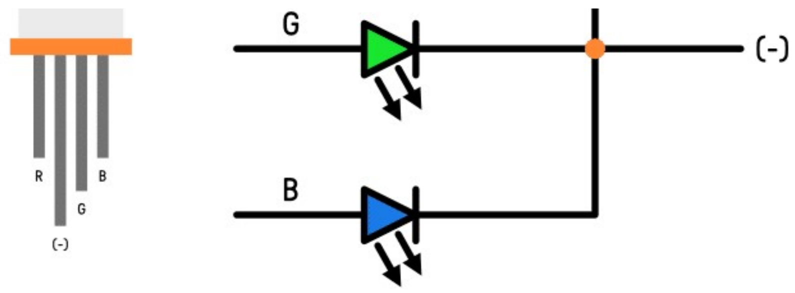
RGB is short for red, blue, and green. **RGB LED is essentially LEDs in those colors put together**. Combining those colors, RGB LED can produce almost any color, but it struggles with shades of pink and brown. With legs for each of the three colors, an RGB LED will have **a fourth leg, for anode or cathode**. When looking at an RGB LED, you should face it so the second leg from the left is the longest. They should then be in the following order: red, anode or cathode, green, and blue.



The red, green, and blue wires are all connected to the external anode or cathode wire (the second leg). Depending on whether you have anode or cathode RGB LED, you'll supply power differently. If you have an anode one, you'll connect the anode wire on the power supply to the positive terminal. A low signal will need to be applied to red, green, and blue wires. However, if you have a cathode one, you'll connect the cathode wire on the power supply to the negative terminal. A high signal will need to be applied to the red, green, and blue wires.







Infrared LED

An **infrared LED**, or IR LED, looks like a normal LED at first and can be hard to distinguish. The main difference is that it **emits light in the infrared range**. This is outside of the normal visible spectrum so you won't see this type of LED emit light. They allow for the cheap production of infrared light and enable wireless communication between devices and sensors. That is why they are common in machine-to-machine environments, as well as Internet of Things applications.

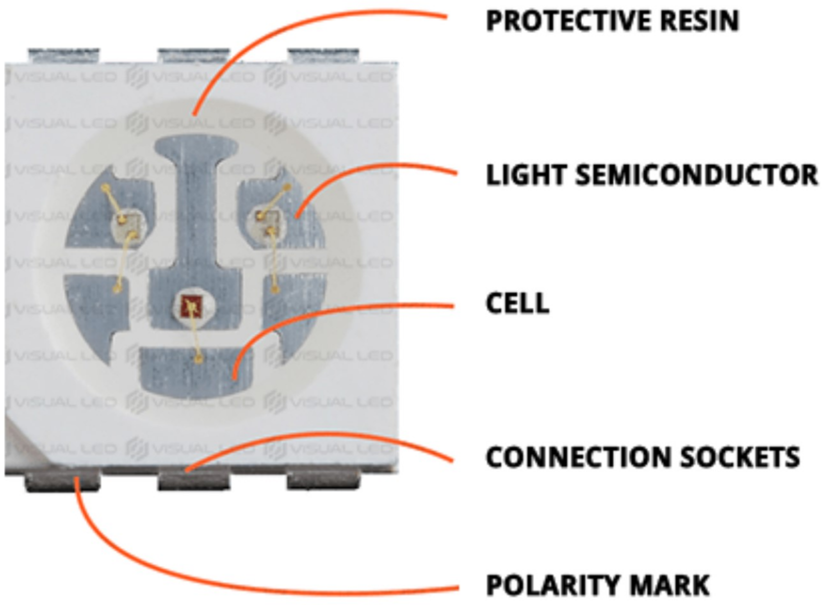
You've likely seen this type of LED in real use. A TV remote control is a prime example of an infrared LED. Some older cell phones that still used physical buttons had IR LEDs to transfer data to other devices.

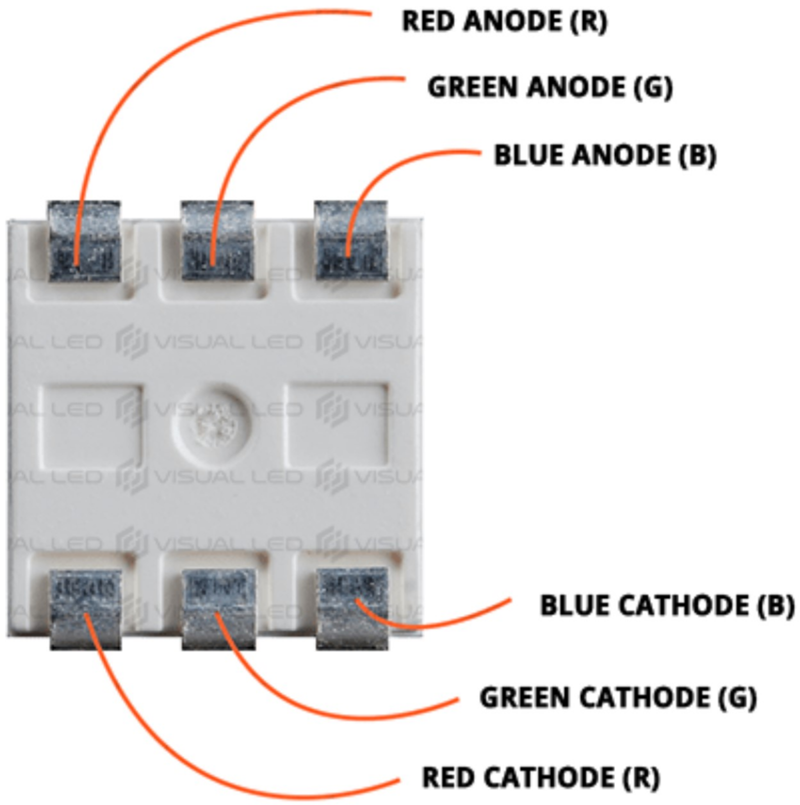
SMD LED

When you look at an Arduino board, you will notice a few SMDs (surface-mount-devices). Like other components, **LEDs can also be surface mounted**. The RX and TX LEDs on Arduino are, as you might have guessed, examples of SMD LEDs. These types of LEDs **don't require any wiring** and are soldered directly onto a circuit board.

There are a couple of SMD LED variants, such as with diffuse or water-clear lens, and three chips. The three chips can have the same or three different colors. If it has different colors, they are red, green, and blue. Thus, the LED can produce virtually any color wanted.

The SMD LEDs are rectangularly shaped and have three cells that contain semiconductor crystals. These crystals produce light when current goes through them. Resin is used for the protection of the SMD cell. A single-color LED will always have one anode and one cathode. The SMD RGB LED will have three anodes and cathodes, one for each color.

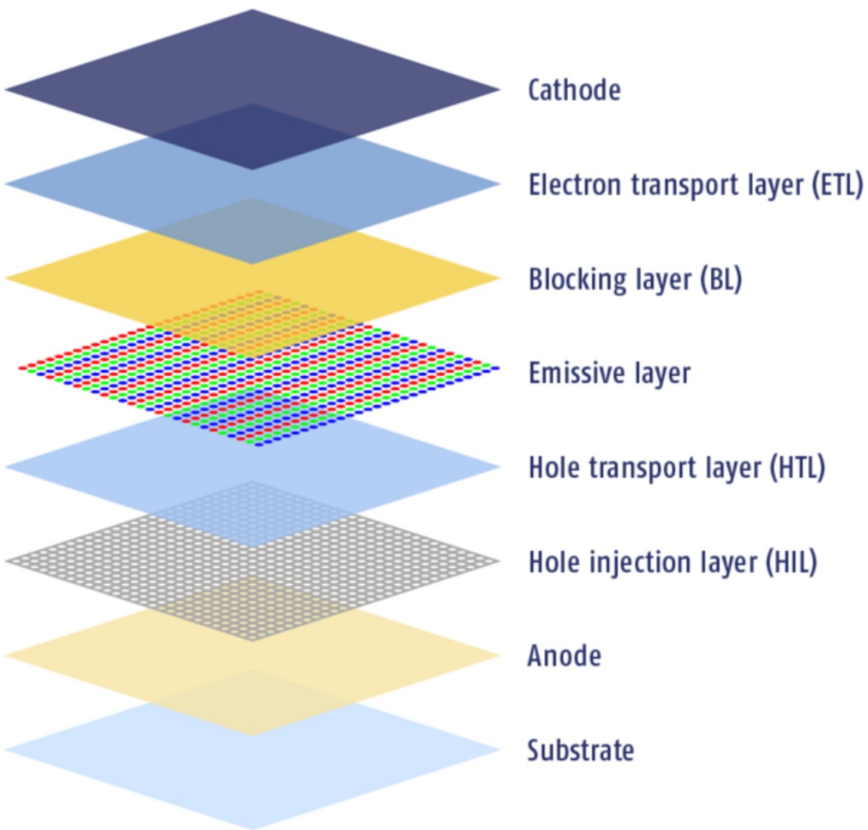




OLED

OLED stands for **organic light-emitting diode**. Unlike other LEDs we've talked about so far, OLED is a **conductive sheet of organic compounds** that emits light when an electric current passes through. This layer, grouped with some others, is placed between two electrodes. The "organic" compound means that it contains carbon-hydrogen bonds, and doesn't refer to materials harvested from nature.

OLEDs are massively used in screens, from smartphones and TVs to Arduino projects . Because of how it's made, each pixel on the OLED display is controlled individually and emits its light. In LCDs, for example, the light comes from a backlighting unit. That is why OLEDs offer better image quality in screens, display bright colors better, and show "real" black.



Pros and cons of using an LED

As with everything we use, LEDs have some pros and cons. Compared to incandescent light sources, LEDs have a longer lifespan and need less power. That is why they are becoming a norm in light bulbs, among other places. Here’s a list of why you should consider using LED is in your projects, and why you might want to seek an alternative.

Pros:

- Very cheap
- Come in different shapes, sizes, and colors
- RGB LEDs allow you to light them up in virtually any color
- Light up very quickly
- Physically robust
- Can easily be dimmed by lowering the forward current or with PWM
- Radiate very little heat
- Long lifetime
- Can be used in a variety of applications

Cons:

- Single LED’s power is low
- Short illumination range
- Can easily burn so they depend on resistors and other components
- Require current-regulated supply
- Different colored LEDs require different voltages

Real-life applications

LEDs are really simple to use and very cheap to produce. They see use virtually everywhere because of this. You're likely using items with LEDs without even realizing it. Our smartphones and smartwatches are using OLEDs. Cars and other vehicles come with LED lights more often than with incandescent as they used to before. Camera flashes, traffic lights, alarm systems, flat panel displays in public places… The list goes on.

We use LEDs pretty much daily in our work. We even use them when tinkering with our projects at home. Take a look at our tutorial pages to find some projects using them. With so many varieties available and so many applications LEDs have, we're sure you thought of some Arduino projects on your own. For which project are you planning to use an LED? Let us know! 🙂

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