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LED Circuitry Tutorial

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Circuitry 101: How to Hook Up LEDs

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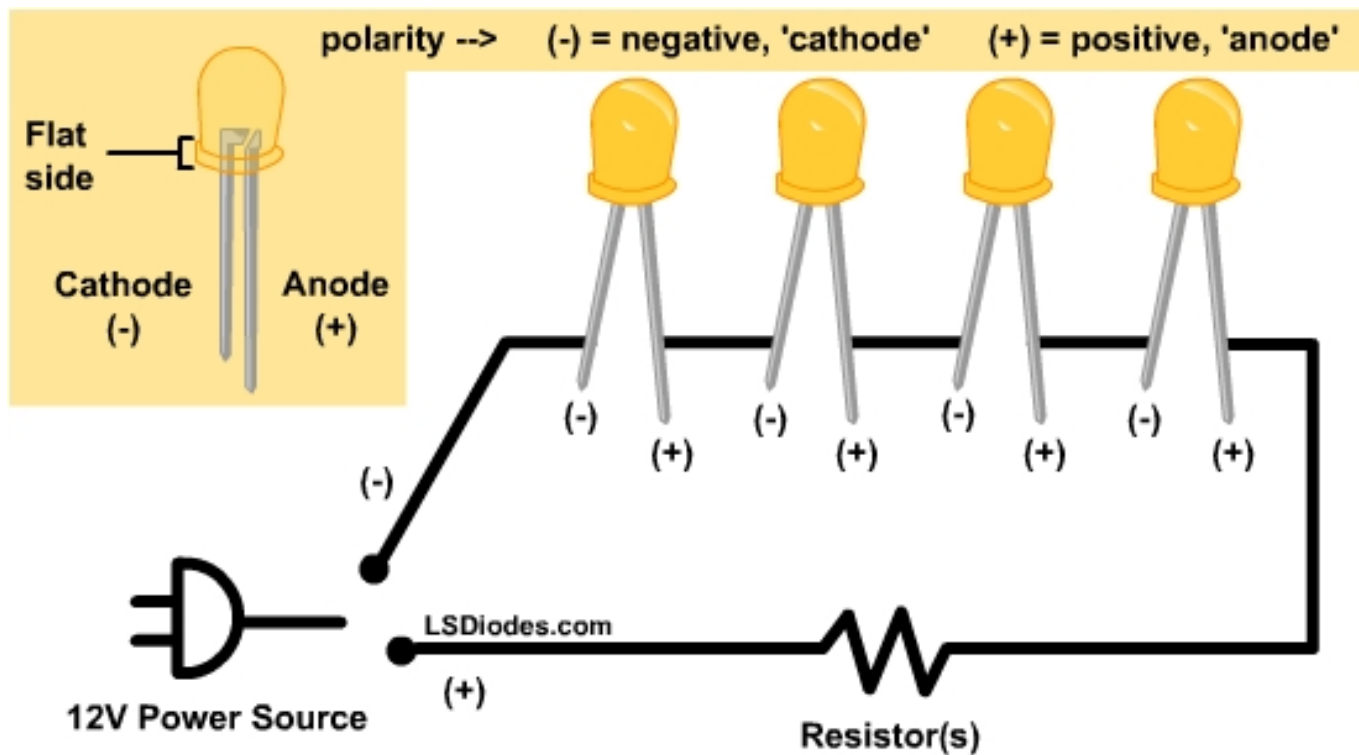
Below we've created a **very** basic guide to help people unfamiliar with circuits get their LEDs up and running without blowing them out and wasting all their money. IT IS VERY BASIC!! Current is hardly ever mentioned, not because it's not important, but because we've found it makes things confusing when trying to teach people about this sort of thing. If we've done a bad job explaining things or if you have a question this doesn't answer, use the contact form at the bottom of this page to let us know what's up.

There's two basic types of circuits: **Series** and **Parallel**.

Series or "How do I power lots of LEDs off a higher voltage source?"

When LEDs are placed in a series, the voltage is dispersed between the LEDs, meaning less voltage goes to each LED. This can be very useful. For example, if a 12 volt adapter were powering one LED, there'd be 12V going through that LED which is way too much for any LED to handle and would result in a rather unpleasant burning smell.

However, if you take that same 12V power source and put 4 LEDs in series, there would be 3V going to each LED and (assuming the LEDs are made to run off 3V) each would be powered and just dandy. Check out this illustration:



$$\frac{\text{Volts}}{\text{LEDs}} = \frac{12}{4} = 3\text{V} \text{ going through each LED}$$

It's important to notice how the LEDs are positioned: (-) (+), (-) (+), etc. making sure that the end (-) connects to the (-) wire and the end (+) connects to the (+) wire, if any LEDs are backwards nothing bad will happen, they just won't turn on.

If three LEDs were in series with a 12V source, each would receive 4V, if six were in series, each would receive 2V, etc.

"But what if I have four LEDs powered from a 12V source and I want each to receive less than 3V/ea?" This is where the little 'Resistor(s)' squiggly comes in. By adding a resistor it's possible to tone down the amount of voltage each receives. To find out what value resistor you should use, use an led calculator such as [this one](#). Go to the middle form where it says 'LEDs in series' and simply type in your power sources' voltage, the LEDs' voltage you'd like and the LEDs current capability (use 20mA.) It then tells you what ohmage resistor to stick in the circuit.

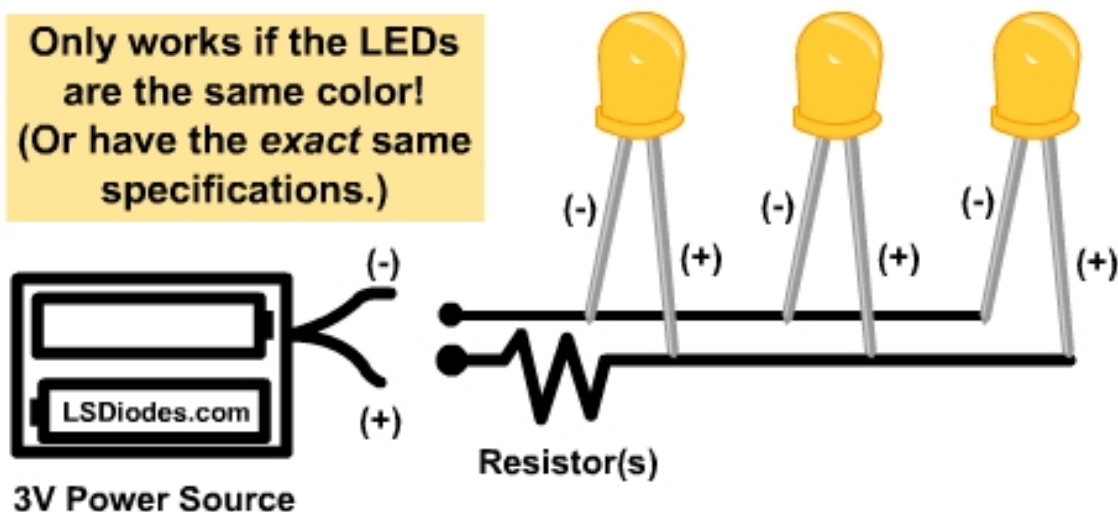
Parallel or "How do I power lots of LEDs off a lower voltage source?"

Let's say you wanted to power three of your brand new LEDs off a 3V battery pack (two 1.5V AA's in series, make sense?) you found lying around. If you were to series the three LEDs there'd be 1V going to each ($3 \text{ Volts} / 3 \text{ LEDs} = 1 \text{V}$ for each LED). That's not enough to power your LEDs! You want them to have the full 3V going to each. Here's how:

One wire connects all the (-) legs and heads to the (-) lead of the source.

Other wire connects all the (+) legs and heads to the (+) lead of the source.

**Only works if the LEDs are the same color!
(Or have the exact same specifications.)**

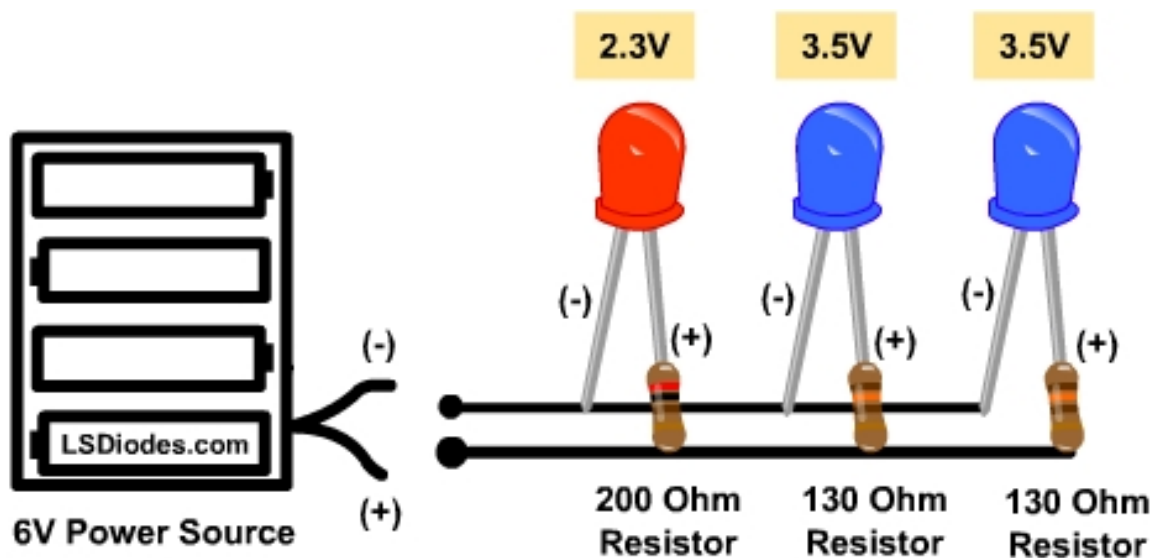


Each LED receives 3V

How this works is that while every LED receives the same amount of voltage, the current of the source is dispersed between the LEDs. What this means for you is that you have 20 LEDs paralleled off a battery, it's going to drain the battery a lot quicker than if you only had 2 LEDs in parallel. If you're paralleling off a wall adapter, for instance though, the source can constantly renew itself so you can essentially parallel as many as you'd like without fear of draining the wall ;P.

To use resistors in a parallel circuit, say if you'd like each LED above to receive 2.5V instead of 3V, use an [LED calculator](#) (make sure you're in the parallel section) to find the right ohmage and then stick it somewhere in the circuit!

"Why do the LEDs have to be the same color?" If you mix colors, say if you paralleled a red (~2.3V) and two blue (~3.5V), the blue LEDs would not light. Why's this? Because the electricity is going to take the easiest path it can to complete the circuit and in this scenario the red LED requires less energy, leaving the two blue unpowered and lonely. To fix this you would need to stick a resistor onto the leg of each LED to 'equalize' all of the LEDs. Note illustration:



Each LED receives its necessary voltage and the circuit treats each LED equally.

To find the resistor you'd need for each LED, use the 'Single LED' portion of an [LED calculator](#) , type in the supply voltage, LED's voltage and 20mA for each LED and there you go. Now each LED will turn on and each will receive it's desired amount of power. Thanks to Mike Moorrees for pointing this out, "The resistors act like 'shocks' in a car, they give the power source some 'squish' and let each LED find its happy place (forward voltage)."

Courtesy of LSDiodes.com (Skylar and Chris) Aug, '03

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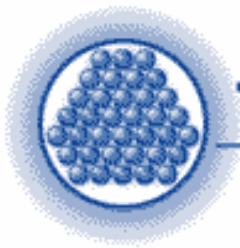
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Technical Information

L.E.D Basics

Most LEDs have their characteristics specified at a current of 20 mA. If you want really good reliability and you are not certain you don't have worse-than-average heat conductivity in your mounting, heat buildup in wherever you mount them, voltage/current variations, etc. then design for 15 milliamps.

Now for how to make 15 milliamps flow through the LED:

First you need to know the LED voltage drop. It is safe enough to assume 1.7 volts for non-high-brightness red, 1.9 volts for high-brightness, high-efficiency and low-current red, and 2 volts for orange and yellow, and 2.1 volts for green. Assume 3.4 volts for bright white, bright non-yellowish green, and most blue types. Assume 4.6 volts for 430 nm bright blue types such as Everbright and Radio Shack. Design for 12 milliamps for the 3.4 volt types and 10 milliamps for the 430 nm blue.

You can design for higher current if you are adventurous or you know you will have a good lack of heat buildup. In such a case, design for 25 ma for the types with voltage near 2 volts, 18 ma for the 3.4 volt types, and 15 ma for the 430 nm blue.

Meet or exceed the maximum rated current of the LED only under favorable conditions of lack of heat buildup. Some LED current ratings assume some really favorable test conditions - such as being surrounded by air no warmer than 25 degrees Celsius and some decent thermal conduction from where the leads are mounted. Running the LED at specified laboratory conditions used for maximum current rating will make it lose half its light output after rated life expectancy (20,000 to 100,000 hours) - optimistically! You can use somewhat higher currents if you heat-sink the leads and/or can tolerate much shorter life expectancy.

Next, know your supply voltage. It should be well above the LED voltage for reliable, stable LED operation. Use at least 3 volts for the lower voltage types, 4.5 volts for the 3.4 volt types, and 6 volts for the 430 nm blue.

The voltage in most cars is 14 volts while the alternator is successfully charging the battery. A well-charged 12 volt lead-acid battery is 12.6 volts with a light load discharging it. Many "wall wart" DC power supplies provide much higher voltage than specified if the load is light, so you need to

measure them under a light load that draws maybe 10-20 milliamps.

Next step is to subtract the LED voltage from the supply voltage. This gives you the voltage that must be dropped by the dropping resistor. Example: 3.4 volt LED with a 6 volt supply voltage. Subtracting these gives 2.6 volts to be dropped by the dropping resistor.

The next step is to divide the dropped voltage by the LED current to get the value of the dropping resistor. If you divide volts by amps, you get the resistor value in ohms. If you divide volts by milliamps, you get the resistor value in kilo-ohms or k.

Example: 6 volt supply, 3.4 volt LED, 12 milliamps. Divide 2.6 by .012. This gives 217 ohms. The nearest standard resistor value is 220 ohms.

If you want to operate the 3.4 volt LED from a 6 volt power supply at the LED's "typical" current of 20 ma, then 2.6 divided by .02 yields a resistor value of 130 ohms. The next higher popular standard value is 150 ohms.

If you want to run a typical 3.4 volt LED from a 6 volt supply at its maximum rated current of 30 ma, then divide 2.6 by .03. This indicates 87 ohms. The next higher popular standard resistor value is 100 ohms. Please beware that I consider the 30 ma rating for 3.4-3.5 volt LEDs to be optimistic.

One more thing to do is to check the resistor wattage. Multiply the dropped voltage by the LED current to get the wattage being dissipated in the resistor. Example: 2.6 volts times .03 amp (30 milliamps) is .078 watt. For good reliability, I recommend not exceeding 60 percent of the wattage rating of the resistor. A 1/4 watt resistor can easily handle .078 watt. In case you need a more powerful resistor, there are 1/2 watt resistors widely available in the popular values.

You can put LEDs in series with only one resistor for the whole series string. Add up the voltages of all the LEDs in the series string. This should not exceed 80 percent of the supply voltage if you want good stability and predictable current consumption. The dropped voltage will then be the supply voltage minus the total voltage of the LEDs in the series string.

Do not put LEDs in parallel with each other. Although this usually works, it is not reliable. LEDs become more conductive as they warm up, which may lead to unstable current distribution through paralleled LEDs. LEDs in parallel need their own individual dropping resistors. Series strings can be paralleled if each string has its own dropping resistor.

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Disclaimer: The information provide herein are basics to educate one on the operating properties and user characteristics of LEDs. We do not imply that the information is accurate or applicable to every aspect of LED usage. Each application will have to be performed on its own merits and with full understanding that damages and injury are the sole responsibility of the "builder". We do not dispense engineering advice. You need to determine the specific products you will need for your specific application.

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