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How to Choose and Wire LEDs For ShockWave 3 Sound Module

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INTRODUCTION

This article has been written to help modelers who are not conversant with basic electrical theory, choose LEDs for RC Model applications with the ShockWave 3 sound module and to choose the appropriate series resistors for use with LEDs, when these are necessary.

CHOOSING LEDS

There are basically two classes of LEDS – small low-current indicator LEDs and high-power lighting LEDs.

Small Indicator LEDs are typically 3mm or 5mm diameter and often come in a round clear or coloured plastic body with two radial leads out of one end such as shown here:

These kinds of LEDs typically consume about 10-30mA (milliAmps) and have a voltage across them, when on, of between 2.0-3.3Volts.

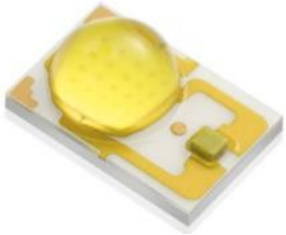
These LEDS are not exceedingly bright since they are designed for status indicating applications and not for outside applications some distance away. Therefore, they are not ideally suited to model airplanes usage where the model is always flown outdoors, at some distance away. However, they are adequate for small indoor flyers and may be effective at night in the dark.

Viewing angle is sometimes an issue with these kinds of LEDs. Because they have a molded lens at the end of the package to increase the brightness, that also means that their brightness falls off quite dramatically to either side as you move your eyes away from its central axis.

High power lighting LEDS come in a huge variety of package sizes and shapes, many of which are surface mounted on a substrate with no wires attached. While these are more difficult for the average RC hobbyist to handle, they offer extreme brightness and consume anywhere from a few 100mA's to a few

Amps. Whilst many of the high-power LED chips are quite large, there are some that are small enough to be used in model applications such as at the end of gun barrels to represent gun muzzle flashes.

An example of these are Luxeon Rebel LEDs such as those shown here:



These are very small – only 3mm x 4.5mm but can produce as much as 200 lumens of light with a current of 700mA. That amount of light is very bright and they can be easily seen in bright daylight from a hundred feet or so. Even at 350ma, their light output is amazingly bright.

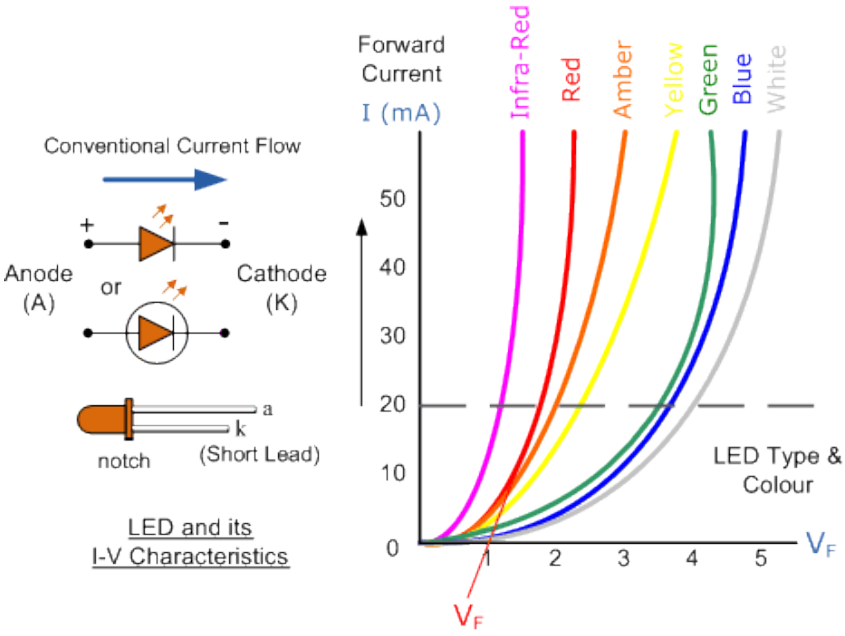
One disadvantage is that they are leadless. Therefore, the modeler has to solder fine insulated wires, e.g. 28AWG, onto the solder pads which are in turn, very small. This requires a very fine tipped soldering iron, fine gauge flux cored solder, e.g. 27AWG (0.015" diameter), a very steady hand and very good eyesight. An illuminated magnifier lamp helps with this task.

Another important consideration for using these small LEDs, is their heat dissipation. Since they can take 700mA and about 3Volts, they will get very hot and burn out unless they are mounted on a heatsink. Although they could be epoxied using thermally conductive epoxy to a heatsink such as a small aluminium rod, this is generally inconvenient for most RC modelers. However, for use in flashing gun barrels where the LED is on for short intermittent bursts of no more than a few seconds they can be used without a heatsink.

BASIC LED OPERATION

LEDs, like any other diode, conduct current one way only and have a very sharp current/forward voltage curve. By **"forward voltage"** we mean the voltage in the direction which causes the diode to conduct and convert the electrical energy into light. What this means is that as the LED starts to conduct and produce light, as the voltage across it is increased by only a small amount, the current will increase by a very large amount.

Figure 1 - Typical LED Current vs Voltage Curves



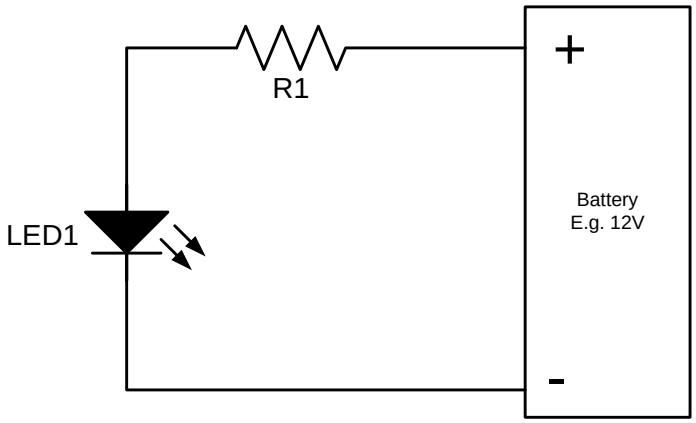
All diodes, LEDs included, have a very steep current vs voltage curve as shown here:

LEDs such as these in a yellow colour, usually have a forward voltage rating of about 2.0-2.2 Volts at a forward current of 20mA.

To use them at a practical battery voltage of a 2S LiPo, for example, they should be wired in series together with a series current limiting resistor as shown next:

WIRING A SINGLE BARE LED

Figure 2 - Basic One LED - One resistor circuit



In Figure 2 above, let's assume we want to limit the current to 20mA nominal. I say "nominal" because when fully charged the "12 Volt" battery will be more like 14.5 Volts and its voltage will drop with time as current is drawn from it.

Since the LEDs forward current versus voltage curve is so steep, we can liken the LED to a semi-constant voltage drop with varying current. So let's assume the diode has a "nominal" 2.2 Volt forward voltage drop. Then resistor R1 above will have 12 – 2-2 = 9.8 Volts across it.

If we want to set the current to 20mA (0.02Amps) we use basic Ohm's law : V= I x R where V is in Volts, I is in Amperes (Amps) and R is in Ohms. Therefore R = V / I and so R = 9.8 / 0.02 = 490 Ohms. Resistors come in standard values, and the nearest values are 470 or 510 Ohms.

We would choose the 510 Ohm value to be “on the safe side”.

Current flowing through any electrical device will generate heat due to the power being dissipated in it and the amount of power or heat energy is measured in watts. There is another simple formula that says P = V x I where P is power in Watts, V is in Volts and I is in Amps. So in the example above the resistor R1 will be generating 9.8 x 0.02 = 0.196 Watts. Therefore, the resistor must be rated for at least this power which means you would select a ¼ Watt resistor.

If the battery voltage was to go up, the voltage drop across the resistor would go up as the voltage drop across the LED would go up only a very small amount, but in order to contain the current within the LEDs limits, the resistor would have to be increased in value. This also means the power and heat generated by the resistor would go up also. Therefore, you may have to go to a ½ Watt or even a 1 Watt resistor, depending on the voltages and currents involved.

SOME LEDS COME WITH BUILT-IN RESISTORS

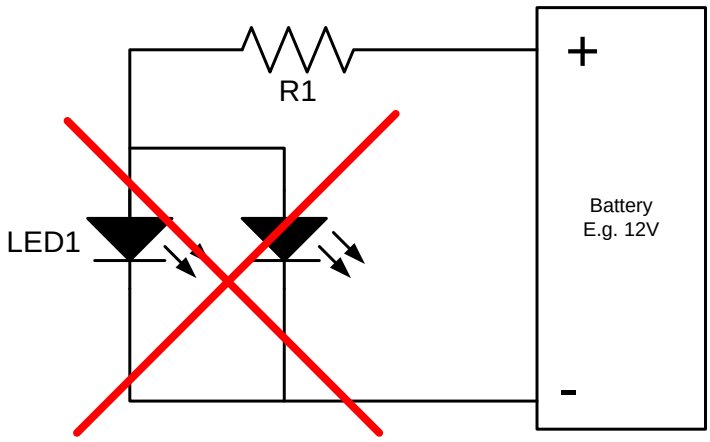
Many LEDS design for RC Hobbyists come with series resistors already built in. Therefore, they can typically be used over much wider voltage range.

Some such as these:

are rated from 4Volts – 12 Volts. The current will vary widely over that range and therefore so will the brightness.

WIRING MULTIPLE LEDS WITHOUT BUILT-IN RESISTORS

Figure 3 Two LEDs in Parallel - BAD PRACTICE



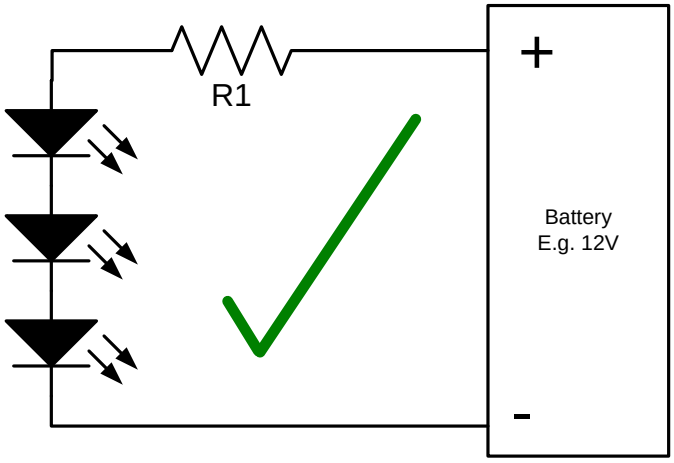
One possible way to wire multiple LEDs is to wire them in parallel as shown in Figure 3.

THIS IS BAD PRACTICE because the LEDs are never identical and small variations between them may cause one LED to take more current than the other and so, at minimum, they may be of different brightness, or at worst, one may exceed its maximum current rating.

Also, this doubles the total amount of current that the series resistor has to pass, so now its power rating has to be doubled e.g. a ½ Watt resistor instead of ¼ Watt. Not only is this wasteful of battery power, but ½ Watt resistors are more expensive than ¼ Watt ones.

For multiple LEDs it is much better to put as many LEDs **OF THE SAME TYPE AND COLOUR** as possible in series as shown in Figure 4.

Figure 4 - Multiple LEDs in Series - GOOD PRACTICE



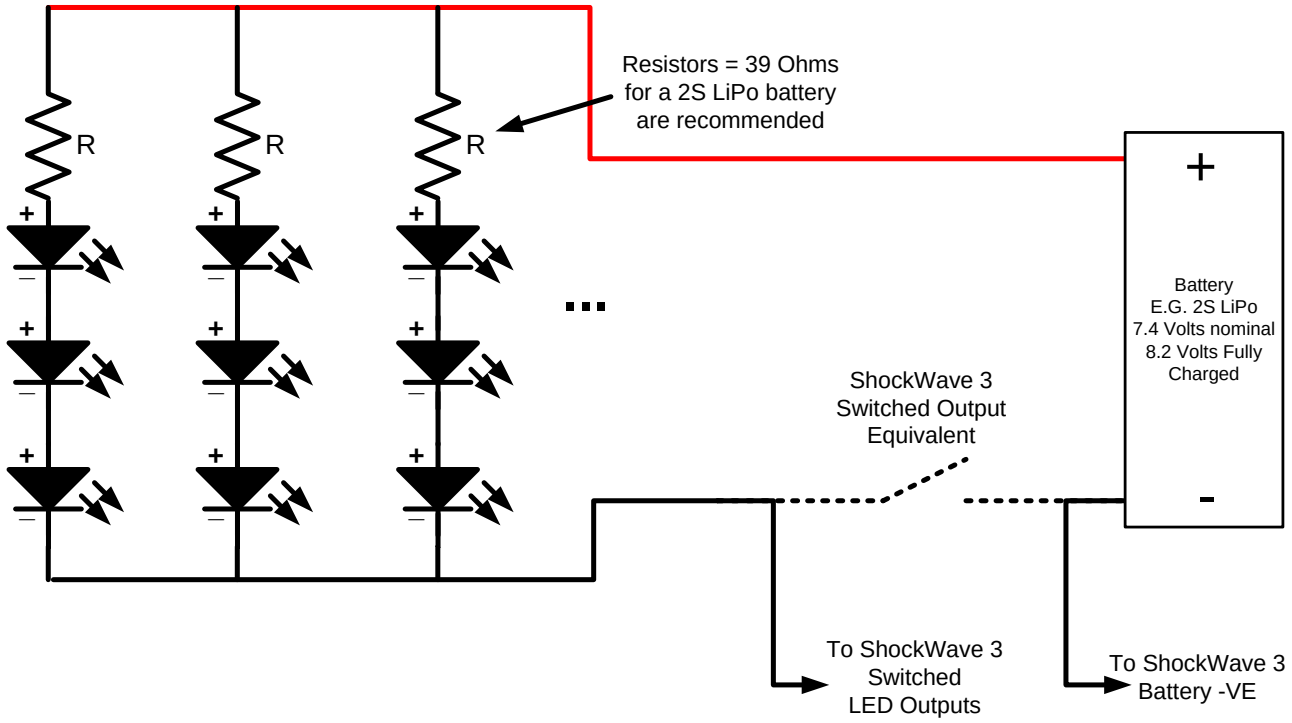
In Figure 4 we have 3 LEDs in series therefore, using the same LEDs as before, the total voltage drop across them would be 6.6 Volts and the resistor would have to drop only 5.4 Volts and thus would be 5.4 / 0.02 = 270 Ohms. But the best effect of this is that the power dissipated in the resistor is now only 5.4 x 0.02 = 0.108 Watts. Therefore a 1/8 Watt resistor would suffice.

When using high intensity power LEDS such as those used for lighting, extra care must be taken to choose the resistor carefully, especially with regard to its power rating.

SERIES/PARALLEL CONNECTIONS OF MULTIPLE LEDS WITHOUT BUILT-IN RESISTORS

Sometimes we need many LEDs connected to the same source, for example for multiple gun muzzle flashes or for EDF afterburner lights.

Figure 5 - Series/Parallel Connections of LED Arrays



The series resistors are necessary to prevent the LEDs from drawing too much current and burning themselves out. For example, as shown above, each diode will have about 2.2Volts across it, so three in series will have about 6.6Volts. But the 2S LiPo can have as high a voltage as 8.2Volts when fully charged. If that full battery voltage was applied directly to the three LEDs in series, they would each see 8.2 / 3Volts = 2.73Volts which means the LED would try to draw about 30mA which may shorten their life since they are designed to consume 20mA.

Usually, the maximum power rating of 5mm LEDs is in the region of 60milliWatts (mW). At a forward voltage of 2.2V and a current of 20mA they are dissipating 2.2 x 20 = 44mW. At a forward voltage of 2.73Volts and a current of 30mA they are dissipating 2.73 x 30 = 82mW which exceeds their maximum power rating, hence the likelihood of a shortened lifetime without the series resistors.

All diodes, LEDs included, also have a maximum reverse voltage (i.e. the direction in which they do not conduct normally). Connecting any diode to a reverse voltage higher than its maximum reverse voltage will usually cause catastrophic breakdown and destruction of the device.

LED reverse voltage ratings are usually quite low e.g. 5 Volts so **DO NOT** connect them backwards. Usually, the longer lead is the positive connection.

CONNECTIONS FOR MULTIPLE LEDS WITH BUILT-IN RESISTORS

If the LEDs come with series resistors already built in, then you do not need to add additional series resistors and, furthermore, they should not be wired in series, otherwise all the built-in resistors will be in a series chain and the required voltage to operate them will be very high.

Figure 6 - Connections for Multiple LEDs with Built-In Resistors