

LED lighting for model ships

General information

LED is an abbreviation for Light Emitting Diode.

LEDs differ in several ways from a light bulb (incandescent light bulb). The brightness of an LED is determined by the current flowing through the LED, whereas the brightness of a light bulb is determined by the voltage flowing through the light bulb.

LEDs consume a lot less electrical energy and give out a lot less heat than light bulbs.

LEDs are polarized, they must be connected correctly with respect to plus and minus and cannot be connected to AC current. Light bulbs are not polarized and can be connected to both AC and DC current.

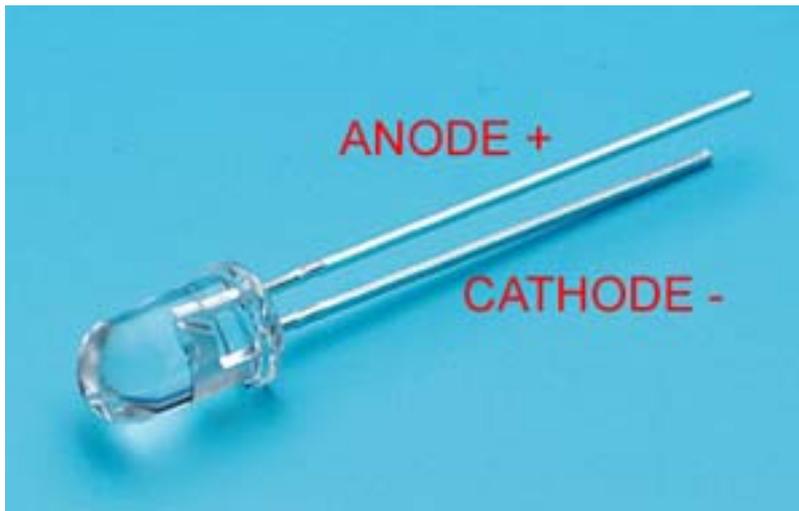
One disadvantage with LEDs is that they do not emit light all the way around the body (360 degrees), a light bulb does. LEDs have typical emission angles of 30 to 40 degrees.

Some words of warning:

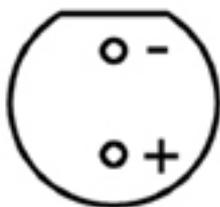
The higher the current flowing through an LED the brighter it will light, but the higher currents shortens the life span of the LED, too much current and the LED will burn out at once, so do not exceed the LED's rated current.

Connecting LED's

Connections on LEDs are named ANODE (+) and CATHODE (-). The ANODE (+) is the longest leg and the CATHODE (-) is the shortest leg.



Often, but not always the connections can be identified by looking at the bottom of the LED. The leg nearest the flattened part of the body is the CATHODE (-).

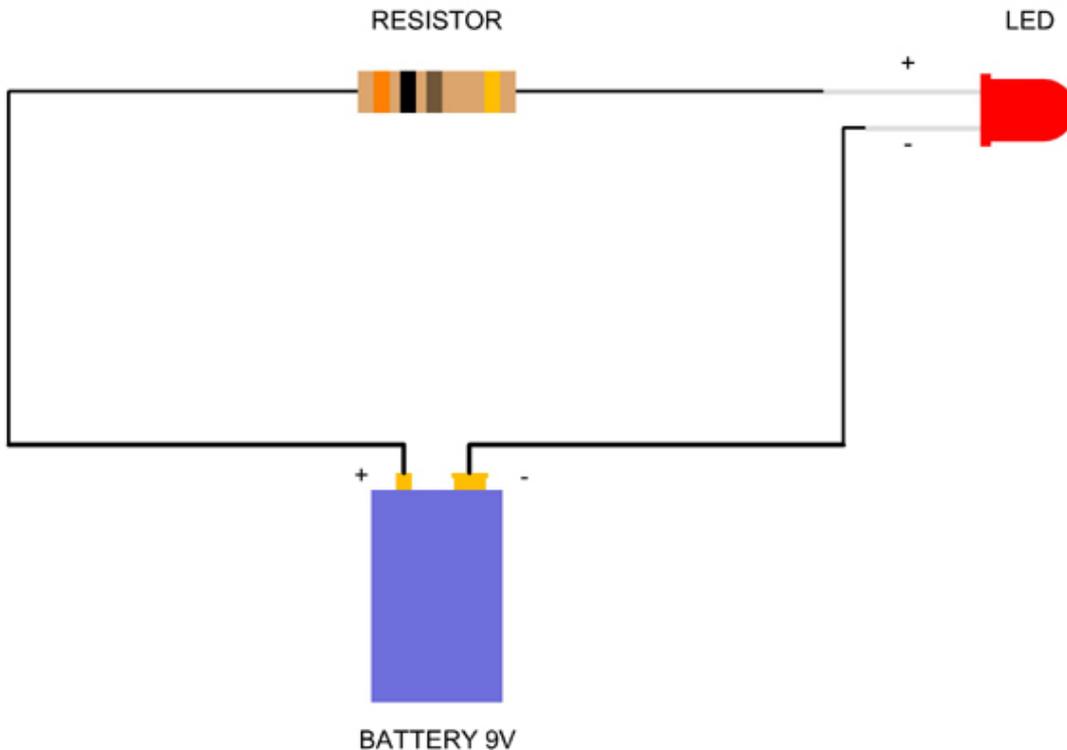


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An LED lights when the voltage across the LED is higher than its forward voltage rating, often 2.2V.

The current flowing through the LED must be limited so that the current is not higher than the LED's rated current, often 20 mA. Current limiting is carried out using a resistor of the correct value, the resistor is connected in series with the LED.

Always check the forward voltage rating (V_f) and max current (I_f) for the LED you are using, it varies even between LEDs of the same size but of a different color.



The math required for calculating the value of the resistor is very simple:

Resistor value (ohms) =

$$\frac{\text{battery voltage (V)} - \text{LED's forward voltage rating (Vf)}}{\text{LED's current rating (If)}}$$

In the above diagram we have a battery voltage of 9V, the forward voltage rating is 2V and the current rating is 20 mA (0.02A).

9 minus 2.2 = 6.8

6.8 divided by 0.02 = 340

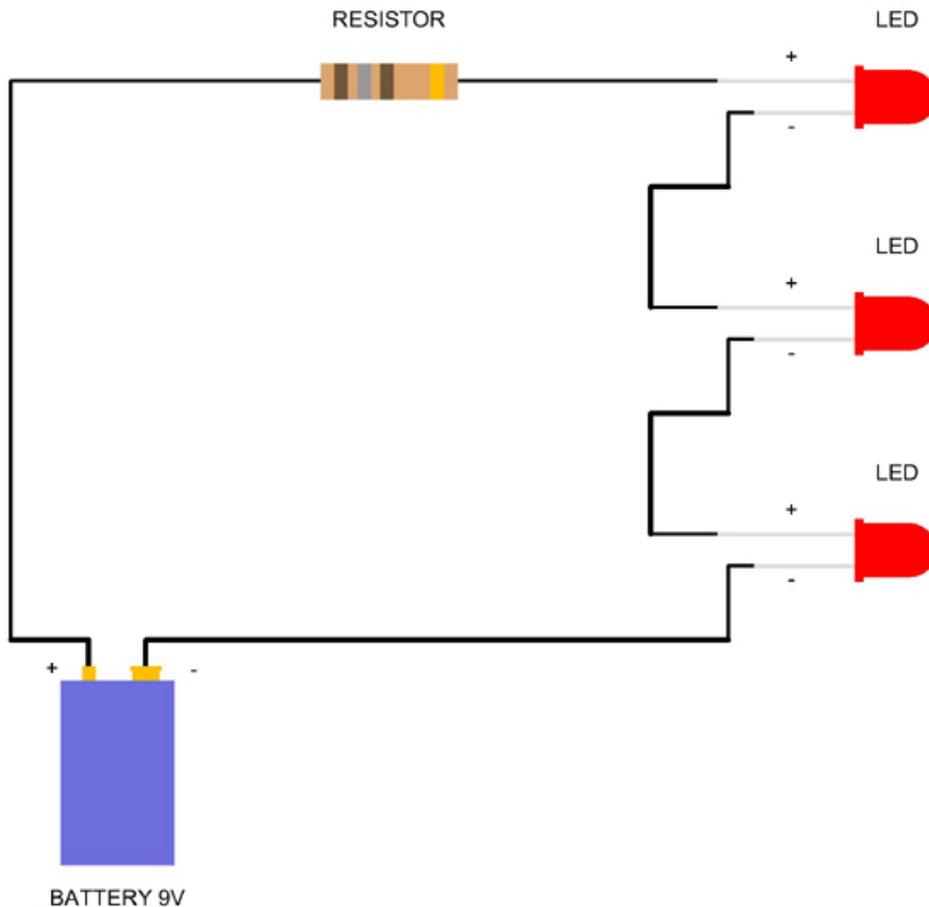
The above diagram requires a resistor with a value of 340 ohms. Resistors are only available in standard values therefore we have to round up or down to the nearest standard value, in this case 390 ohms. A standard 0.25W carbon resistor will do the job.

You do not have to use a battery to power the LEDs on your model. Any DC power supply or battery eliminator will do and the voltage can vary from 6V to 24V, you just do the math to calculate the value of the resistor.

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When connecting several LEDs to the same battery there are two ways to do it:

1 - Series connection



The advantage with this method is that you can power these three LEDs for about 20 hours from a 9V (PP3) battery.

The disadvantage of this method is that the number of LEDs is limited by the battery voltage, the total sum of the forward voltage rating of all the LEDs cannot exceed the battery voltage. In this case we cannot connect more than 4 LEDs. Another disadvantage with this method is the "Christmas tree lights effect", if one LED dies then all the LEDs go out.

This method only needs one resistor, the math for calculating the value of the resistor is:

Resistor value (ohms) =

$$\frac{\text{battery voltage} - (V_f \text{ LED 1} + V_f \text{ LED 2} + V_f \text{ LED 3})}{\text{LED's current rating (I}_f)}$$

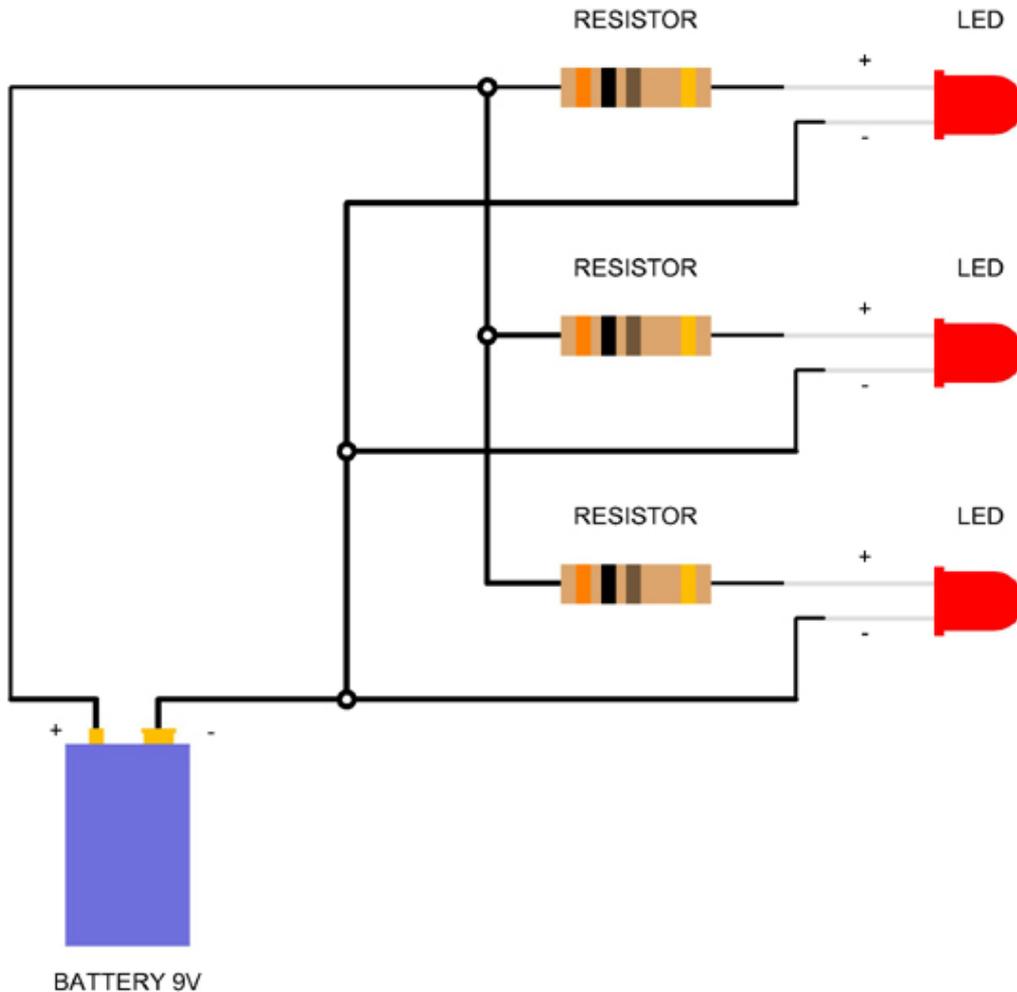
In the above diagram we have a battery voltage of 9V, the forward voltage rating of each LED is 2.2V and the current rating of each LED is 20 mA (0.02A).

$$9 \text{ minus } 2.2+2.2+2.2 = 3.6$$
$$3.6 \text{ divided by } 0.02 = 180$$

The above diagram requires a resistor with a value of 180 ohms, the nearest standard value, in this case is 180 ohms.

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2 – Parallel connection



The advantage with this method is that you can connect as many LEDs as you like, but the more LEDs you add to the battery the shorter is the life of the battery. With this method you can power these 3 LEDs for only 10 hours from a 9V (PP3) battery.

The value of the resistors with this method will be the same as for the resistor in the first example with one LED, i.e. each resistor will be 390ohms. That is to say; you calculate the value of the resistor for each individual LED.

Dimming LEDs

You would think that it is just a case of reducing the voltage to dim an LED. If you simply reduce the voltage to a resistor-LED combination you will dim the LED, but an LED with a forward voltage of 2.2V will not begin to light up until there's about 1.5V across it and the difference in brightness between 1.5V and 2.2V is very little. You could also suppose that it is the current flowing through the LED that is controlling the brightness then it will be less bright if you reduce the current. This is also true, but with half the current flowing through it the LED will not be anywhere near half as bright. In fact the difference will be so little that you will hardly notice it. An LED behaves in this way because the relationship of current to brightness in an LED is not linear.

A far superior method of dimming LEDs is to use Pulse Width Modulation (PWM). With PWM an LED or strings of LEDs can all be driven with the recommended forward current, with the dimming achieved by turning the LEDs on and off at high frequency - so fast that the human eye cannot see the blinking effect. The longer the *on* periods are relative to the *off* periods, the brighter the LEDs will appear to the observer. In a future update of this article I will present a simple electronic circuit to achieve this and also a circuit to make an LED flicker like a candle.

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Color Temperature

White light is not pure white as we know. A fluorescent lamp is much whiter than a common light bulb which tends to be a little yellowish and candle light is almost orange.

The color of white light is measured in KELVIN (K) and ranges from the lower red end of the scale up to the higher blue end of the scale. Note that The KELVIN (K) is a measure of the color of white light NOT the brightness.

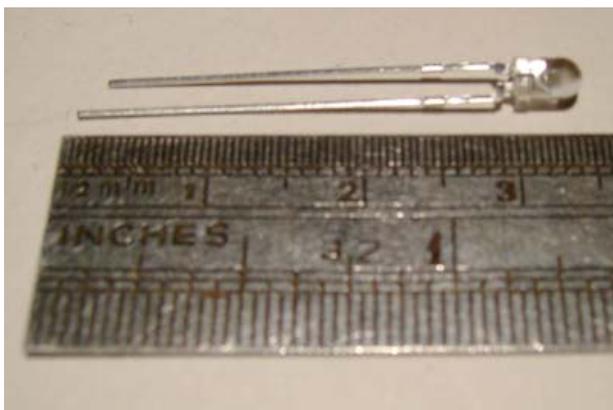


1700 K:	Match flame
1850 K:	Candle
2600 - 3000 K:	Incandescent light bulb
3200 K:	Sunrise/sunset
3400 K:	Studio lamps, photofloods
3500 K:	White fluorescent tube
4100 K:	Moonlight
5000 K:	White LED
5000 - 5400 K:	Sunny day at noon
5500 - 5600 K:	Electronic photo flash
6500 - 7500 K:	Overcast sky
9000 - 12000 K:	Blue sky

Experimenting with white and colored LEDs

We cannot use white LEDs on period ship models because the color temperature is far too harsh. We need a color temperature that represents candle light or oil lamps. There are colored LED's with colored glass and there are colored LED's with clear glass, I got the best light from a yellow LED with clear glass.

The picture below is actually the yellow LED I used for this comparison.



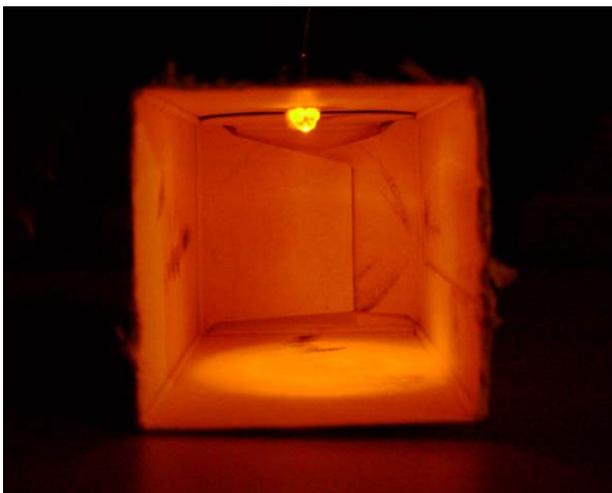
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In the next picture you see the white and yellow LED's from the side, the yellow LED does not give out much light from the side. This is the disadvantage with LED's compared to light bulbs, light bulbs give out the same amount of light from all sides, the light from a LED comes mostly out of the domed top



Here is a picture of the same two LED's, this time taken from above looking down on the domed top. You can clearly see that they are brighter.



Finally a picture of the reflected light from the yellow LED, I put the LED in a small cardboard box to simulate how it might look inside a ships hull.

It was nigh on impossible to take good photos that show the true color, but I can say that the color in the photos is a little bit on the red side. To conclude I would say that we are very near the colour of candle light or oil lamps.