LED's Part 1

In a recent publication of our Club Magazine there was an excellent article on Navigation Lighting by Ken Gould. I have now been asked to write a follow on article regarding the practical considerations of installing various types of lighting for a model boat.

There are two types of lighting mainly in use today these are 'Grain of Wheat' bulbs and LED's (Light Emitting Diodes - 3mm types).

Grain of wheat bulbs typically requires a supply of 50mA at 12v or 60mA at 6v and 4.5v, thus if five lights are required for a vessel the total current consumed would be:-

50ma x 5 = 250mA (0.25Amp at 12volt = 3watts).

60ma x 5 = 300mA (0.3Amp at 6volts = 2watts)

Light Emitting Diodes (LEDs) require far less current, anything between 3 to 30mA so that if five lights where required the total current consumed would be:-

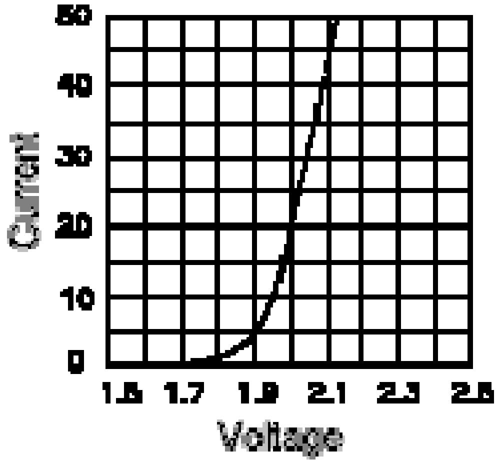
15mA x 5 = 75mA (0.075Amp at 12volts = 0.9watts) or (0.075mA at 6volts = 0.45watts)

It can be seen that the use of LEDs is a favourable option as they do not consume the amount of current that a Grain-of wheat bulb and therefore will not drain the battery as quickly, in addition Grain of Wheat are made of glass and are susceptible to breakage.

LIGHT EMITTING DIODES As a rule of thumb, different colour LEDs require different forward voltages to operate - RED LEDs take the least, and as the colour moves up the colour spectrum toward BLUE, the voltage requirement increases. Typically, a red LED requires about 2 volts, while blue LEDs require around 4 volts. This is because of the different types of material used to create the colour of the LEDs. The table below shows the typical voltage drop across different colour LEDs and their material make-up.

Colour	Voltage Drop	Materials
RED	1.8 to 2.1V	Aluminium gallium arsenide (AlGaAs), Gallium arsenide phosphide (GaAsP), Gallium phosphide (GaP)
ORANGE	2.2V	Aluminium gallium indium phosphide (AlGaInP), Gallium arsenide phosphide (GaAsP)
YELLOW	2.4V	Aluminium gallium indium phosphide (AlGaInP), Gallium arsenide phosphide (GaAsP), Gallium phosphide (GaP)
GREEN	2.6V	Aluminium gallium phosphide (AlGaP), Aluminium gallium indium phosphide (AlGaInP), Gallium nitride (GaN)
BLUE	3.0 to 4.0V	Gallium nitride (GaN), Indium gallium nitride (InGaN), Silicon carbide (SiC), Sapphire (Al2O3), Zinc selenide (ZnSe)
WHITE	3.0 to 4.0V	Gallium nitride (GaN [if AlGaN Quantum Barrier present]), Gallium nitride (GaN) based – Indium gallium nitride (InGaN) active layer

Typically, LEDs require between 10 to 30 mA of current, regardless of their voltage requirements. The graph below shows how much current a typical red LED will draw at various voltages.



Notice that the LED draws no current under 1.7 volts; the LED is "off". Between 1.7 volts and about 1.95 volts, the "dynamic resistance", the ratio of voltage to current, decreases to 4 ohms. Above 1.95 volts, the LED is fully "on", and dynamic resistance remains constant. Dynamic resistance differs from resistance in that the curve isn't linear. Just remember that this non-linear relationship between voltage and current means that Ohms Law does not apply for LEDs under this condition.

Notice how steep the slope is - almost vertical. LEDs have a much more vertical slope than do normal diodes. This means that a tiny increase in voltage can produce a large increase current. In the above-mentioned LED, 2 volts is required to drive the LED properly, but as little as 2.04 volts could destroy it. To keep the current down to a reasonable level, a series resistor must be included in the circuit.

The formula for calculating the value of the series resistor is:

$$\mathbf{R_{series} = (V - V_f) / I_f}$$

Where $\mathbf{R_{series}}$ is the resistor value in ohms, **V** is the supply voltage, $\mathbf{V_f}$ is the voltage drop across the LED, and $\mathbf{I_f}$ is the LED current.

For example, the above LED would run very nicely off 12 volts with a 500 ohm series resistor. Since 500 ohms is an odd value, you could do almost as well with a 470 ohm resistor, which would result in the LED drawing 21 mA.

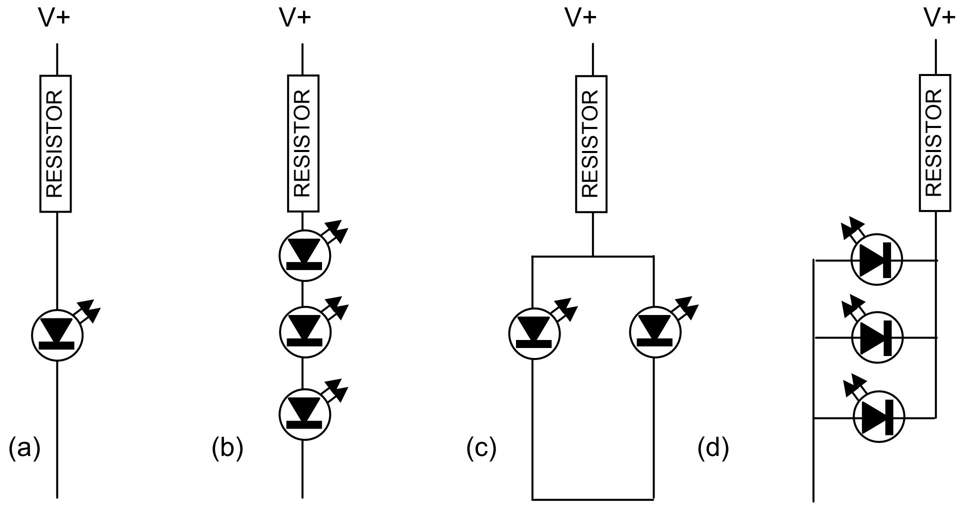
You can use a single resistor to control the current to a series of LEDs, in which case $\mathbf{V_f}$ is the total voltage drop across all the LEDs. You can sometimes get away with using a single resistor to control the current to a group of LEDs in parallel, but it's not generally a good idea - if there is any variation in the LEDs, they won't each draw the same current, resulting in differences in brightness.

Is a Series Resistor Really Necessary?

In a word, no. However, neither is a seat belt. Both are "cheap insurance" against disaster.

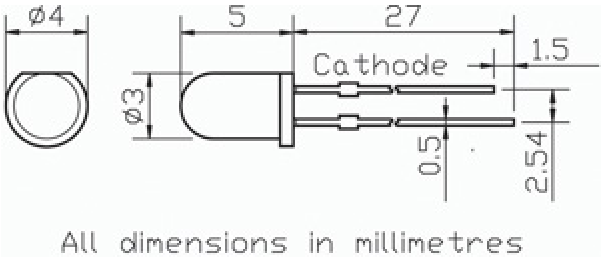
A series resistor is not necessary if the voltage can be regulated to match the LEDs **V_f** but in practice this would not be possible when running the LEDs from the general battery within a model. The fully charged battery voltage would be higher than the part discharged voltage!

The diagram below shows different configurations for connecting up LEDs, (a) a single LED. (b) Three LEDs in series. (c) Two LEDs supplied by one resistor and (d) Three LEDs in parallel using just one resistor, when using this last configuration all the LEDs should be of the same colour and manufacture/type this is to minimise the problem of having one LED at a different brightness to the others.



It should also be noted that LEDs are polarised, that means that they will only work when the negative supply is connected to the Cathode.

A drawing of a LED is shown below; the Cathode is identified by the short lead and also by the flat on the side of the LED Lens/Body.



In the following example we will calculate the series resistor for a LED. It is required to operate at 15mA to produce the desired amount of light and is to run from a 7.2v dc supply, the series resistor required would be:-

R_{series} = (V - V_f) / I_f = (7.2v – 2.2v)/0.015amps = 333 ohms, nearest preferred value is 330Ω

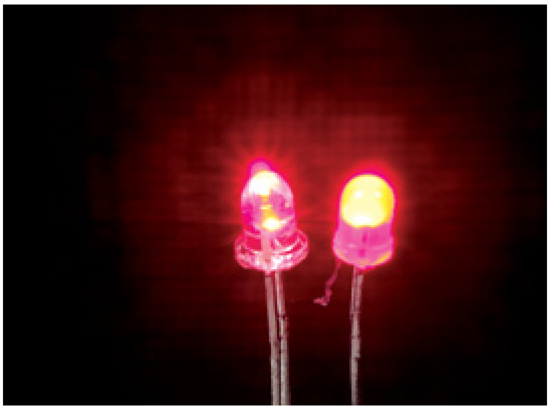
The brightness of LEDs is measured in millicandela (mcd), or thousandths of a candela. Indicator LEDs are typically in the region of 50 mcd; "ultra-bright" LEDs can reach 15,000 mcd, or higher.

By way of comparison, a typical 100 watt incandescent bulb puts out around 1700 lumen - if that light is radiated equally in all directions, it will have a brightness of around 135,000 mcd. Focused into a 20° beam, it will have a brightness of around 18,000,000 mcd.

The table below lists a few different types of LED devices that are available from MAPLIN, not that I am recommending that you purchase the devices from them but they do give the LEDs specification showing their light output (mcd) for given voltage and current conditions together with some pictures of the LEDs in the table.

LED Type	Maplin Part No.	Forward Volts	Typical Current	Typical Light o/p ccd	Price ea
3mm STD White	GV65V	4	20ma	1.5	2.49
3mm STD White	N30AT	4	20ma	3.2	1.49
3mm Super Bright Red	UF72P	2.5	20ma	700	0.39
3mm Green	WL33L	2.5	10ma	5	0.19
3mm Red	WL34M	2.5	10ma	8	0.19

GV65 and N30AT



UF72P

In practice a LED does not need to be very bright for navigation lighting and only set to take about 10mA. Cabin lighting is another matter and can be much brighter with a LED set to take up to 20mA.

I hope this short article has been of some interest to you and will give you some insight into the workings and characteristics of LED devices.

In PART 2 I will suggest some practical ways for wiring the LEDs into a model boat for navigation and cabin lighting.

Tony Dalton

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