Using LEDs

by David Archibald

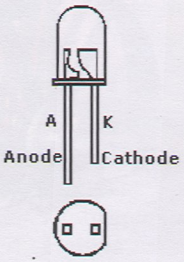
This article is an attempt to explain how to use **L**ight **E**mitting **D**iodes (or LEDs), and is aimed at those with little electrical training. However, some simple calculations are unavoidable to obtain proper operation.

LEDs are the modern solid state equivalent of the light bulb. They each generate light, but this is where the similarities end. LEDs are inherently more efficient, more reliable and more rugged than light bulbs.

When first introduced, LEDs were only available in red, but now come in red, orange, yellow, green, blue and white, or even multi-colour. They can be used for marker lights, tail lights, signal lights, cab lights, clearance lights and general lighting. Due to their internal construction, they usually emit light towards the front in an approx 60 — 70 degree angle, so for applications where general lighting is required, buy the type with a diffused (milky) body, or use a diffuser. The body of a LED does not have to be coloured for it to emit its colour, it may be a totally clear package.

Questions commonly asked are "*What voltage do LEDs need?*", or "*What is the voltage rating of a LED?*" This is a relatively non-answerable question. Although a voltage is present across them when operating, they are NOT a voltage dependant component. LEDs do require a current through them to operate, and require a current limiting device, usually a resistor. It is the value of the current through the LED which determines their brightness. Every LED has a maximum permissible current, and if this is exceeded, will damage or destroy it.

This is the usual circuit symbol for a LED.
The "A" means Anode (positive or +ve) and the "K" means Cathode (negative or -ve). The arrows represent the light output.



Identifying the connections.
There are 2 legs, the longer lead is the Anode and the shorter one the Cathode. There is also a small flat on the body next to the cathode.

Although LEDs are not voltage dependant devices, they do require a minimum voltage to operate. This varies from approx 1.6V to 4V depending on the type. The table below shows some typical values for common LEDs.

Type	Colour	I_F max	V_F typ	V_R max	Luminous intensity
Standard	Red	30mA	1.7V	5V	10mcd @ 10mA
Standard	Bright Red	30mA	1.9V	5V	80mcd @ 10mA
High Intensity	Red	30mA	1.85V	5V	500mcd @ 20mA
Standard	Yellow	30mA	2.1V	5V	30mcd @ 10mA
Standard	Green	25mA	2.2V	5V	30mcd @ 10mA
High Intensity	Blue	30mA	3.6V	5V	650mcd @ 20mA
High Intensity	White	30mA	3,6V	5V	600mcd @ 20mA

I_F max maximum forward current. 1mA = 1 milliamp = 0.001A (forward means LED connected the right way round)

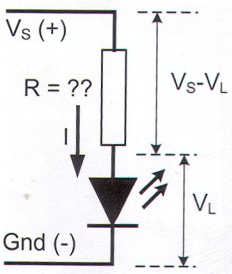
V_F typ Typical forward voltage (VL in resistor calculation)

V_R max Maximum reverse voltage (reverse means LED connected back to front)

Luminous intensity Brightness at the given current, mcd = millicandela

How to use a LED

I_F and **V_F typ** are the 2 LED parameters needed for calculations.



The simplest and usual way of connection. Just a resistor in series with the LED to limit the current, and connected across the power supply.

V_S - supply voltage (+ve)

Gnd - ground or 0 Volts (-ve)

V_L - the LED's typical forward voltage (V_F typ from the table above)

I - is the LED operating current and the arrow represents the direction of flow

R - current limiting resistor

(V_S - V_L) is part of the calculation we need to determine the value of R.

Now we must do some simple calculations to determine the value of **R**.

Step 1 Set some basic values first: - (using a Bright Red LED operating from 6V for this example)

- Select the LED to use, and therefore we know the value of V_L (V_F) (1.9V)
- Choose the operating current (I_F) (This must be less than the I_F max value, say 10mA = 0.010A = I)
- Choose the supply voltage (V_S) (6V)

Step 2 Calculate the other values:-

- Calculate (V_S - V_L) = (6 - 1.9) = 4.1V
- Calculate the value of R from the formula:-

R = (V_S - V_L) / I

= 4.1/0.010 = 410 ohms (Use nearest standard resistor value of 390 or 470 ohms)

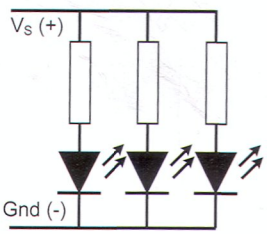
Calculations complete! The LED will now be correctly driven within its ratings.

NOTES:

- **NEVER** connect a LED directly across the power supply without a current limiting device (resistor). There is nothing to limit the current though it and will result in destruction of the LED!
- Values of I_F and R are not super critical. Provided the LED is still within its ratings, all that happens is that the LED is a bit too bright or too dim.
- If the LED is too bright, choose a lower value for I_F, say ½ the previous value, and calculate the resistor again.
- It is recommended that the voltage across the resistor be greater than say 1.5V.
- Standard resistor values are decade multiples (1x, 10x, 100x ...), or sub-multiples (0.1x, 0.01x), of 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and are readily available and cheap (<$0.05 ea). Normally 0.25W or 0.5W power rating is satisfactory.

Powering multiple LEDs from the same supply

Method 1



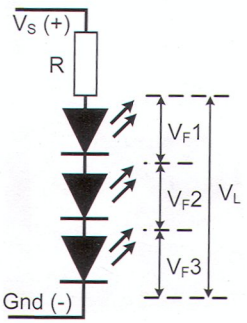
Parallel connection with each LED running from the power supply.

Calculate R for each LED separately as above (but usually the same).

Advantage of this method is that if some of the LEDs need to be brighter or dimmer than others, the values of the resistors can be selected individually. Can also operate from a lower voltage supply.

Disadvantage is a higher current drain from the supply. Note that even 5 x LEDs in parallel this way draw typically only 50 mA (0.050A) total compared to a typical small flashlight bulb of 300mA each.

Method 2



Series connection of multiple LEDs from a single supply.

Advantage is that it draws the same current as a single LED and only 1 resistor is needed. I_F is the same for all LEDs in the series string.

Disadvantage is that the value of V_L is the sum of the V_Fs of all LEDs in the series string. May prevent operation from lower supply voltages.

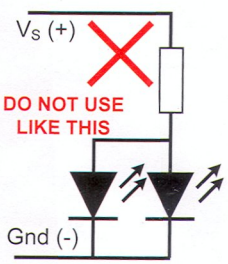
In the calculation for the series resistor,

$$V_L = V_F1 + V_F2 + V_F3$$

where V_F is the typical forward voltage of each LED in the string.

Any number of LEDs may be in the string, even different types and colours, the only proviso is that the supply voltage is high enough to feed them.

Do Not Connect Like this – Wrong



This type of connection is wrong. Although LEDs of the same type have the same nominal V_F, in practice they are slightly different, and definitely different for different types and brands. One LED (the one with the lowest V_F) will take most of the current while the other one will get very little, with consequent big differences in light output and possible damage to the LEDs.

Use one of the configurations above.