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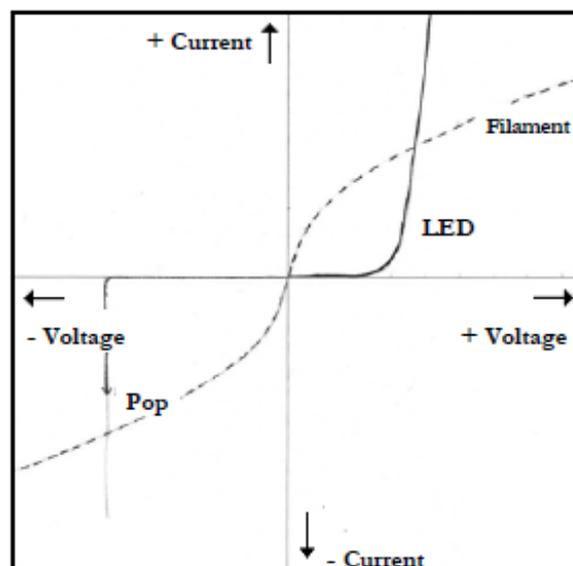
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## LEDs for Locomotive Lighting

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We all know how to use a conventional filament bulb; connect a 6 volt bulb to a 6 volt battery and you're in business; and it doesn't matter which way round it is connected. What you may not realise is that, as the resistance of the filament increases with temperature, there is an inrush of current when first switched on which is why bulbs nearly always fail at that time. The final current taken is then proportional to the square root of the voltage, which makes a filament bulb quite tolerant of over-voltage. Indeed, in the days when electronics was difficult, filament bulbs were used to regulate current in servomotors.

Light emitting Diodes (LEDs) however have completely different characteristics. A diode conducts current in one direction and is high resistance in the other; but, of course, it is not as simple as that. If an increasing voltage is applied to a diode, in the forward direction the current will increase rapidly only once a characteristic voltage is reached. In the reverse direction, very little current will flow until a breakdown voltage is reached and the diode goes pop. This breakdown voltage is very high for a rectifier diode but very low (5v) for an LED. A typical Current/voltage characteristic is shown in the diagram. Due to production tolerance, the forward voltage varies from diode to diode. So, if the LED is supplied with a voltage, then due to the voltage/current characteristic, it is most likely that either the LED will not be bright enough or it will pop. i.e. we must control the current to the LED. We do this, either with a semiconductor circuit or, more usually, with a resistor. LED indicators are sometimes sold with a built in resistor but if you want a wide choice of device and supply voltage then an external resistor is preferable and cheaper.



Filament bulb and LED characteristics

The common uses for LEDs in a locomotive are headlights (white), tail lights (red) and cab illumination (any). The main differences between the white and the red LEDs are voltage drop and price. There are also various sizes from 2mm to 10mm diameter and a range of beam divergences and brightness. I suggest the following types from the Maplin's catalogue:

N28BY, 3mm diameter white, typical voltage drop ( $V_f$ ) 3.2v, price £1-08.

N21BY, 5mm dia white, typical voltage drop 3.2v, price £1-08.

N29BY, 3mm diameter red,  $V_f$  2.3v, price 70p.

N22BY, 5mm diameter red,  $V_f$  2.3v, price 70p.

Virtually all LEDs have a maximum reverse voltage of 5v so it is easy to blow them up that way, isn't it Richard? The negative lead connects to the shorter lead, which, in the case of a round LED, also has a flat adjacent. Once in a circuit, it may not be easy to tell.

As we have to control the current with a resistor, we have to calculate the value using good old Ohm's law:

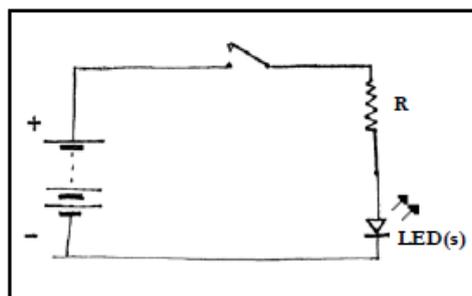
current = voltage/resistance and so resistance = voltage /current.

The voltage is the supply minus the forward drop in the LED(s). A safe current to use is 10ma which is half the absolute maximum continuous rating at 70 deg C.

The voltage across the resistor is the supply voltage minus the  $V_f$  of the LED. From the figures above, it is clear that the supply voltage for one white LED cannot be less than 3.2v.

Alternatively, if the supply is high enough, then LEDs can be put in series with one resistor used to control the current to all. For example, using a 6v supply for 1 white LED

gives  $6v - 3.2v = 2.8v$  across the resistor. For 10 ma, this gives a  $280\Omega$  resistor and  $270\Omega$  is the nearest preferred value. Another example, three white LEDs in series with a 12v supply would require a  $240\Omega$  resistor. Alternatively, if they were wired separately to the supply, each would need an  $880\Omega$  resistor.



LED Circuit

The calculations are similar for the red LEDs but if a flashing light is preferred, these can be purchased with the flashing chip inside and are connected directly to a supply of 6 to 14 volts but watch out, they will not tolerate any reverse voltage at all.

