Using LEDs

By Steve Oppermann

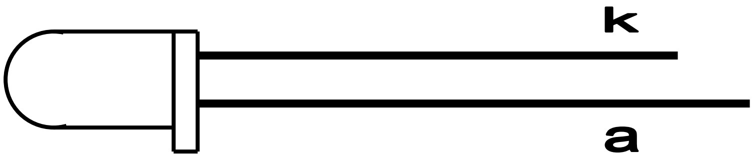
Don't be put off electronics because it all sounds too complex. It isn't necessary to understand the inner workings of the internal combustion engine to drive a car. Likewise with a little help you can use electronics in your modelling and build useful circuits by applying the skills and knowledge you already possess.

Modern miniature electronic components could have been invented with the railway modeller in mind. The two fields go together naturally and the LED is one perfect example.

LED is an acronym for Light Emitting Diode. LEDs come in all sorts of shapes, colours and sizes. They all have one thing in common – when a small voltage is applied to the LED a small current passes through and causes the LED to give off some form of light. I say some form of light because there are Infra-Red LEDs that do emit light, which however is not visible to the human eye.

Broadly speaking an LED is similar electronically to any other diode in that it passes current in one direction only. Other diodes such as rectifiers can withstand high reverse voltages depending on type. A LED by contrast will only cope with small reverse voltages in the order of 5 volts or less. When operated within their specified limits, LEDs draw very little current, produce no heat and last indefinitely. They very seldom fail – usually a failure is the result of incorrect supply or operation. They are also inexpensive – very often cheaper than the grain of wheat/rice or other small incandescent lamps that they replace.

The actual part of the LED which produces the light is similar to other semiconductors and consists of layers of silicon called a junction which have impurities purposely added to produce the desired characteristics. A typical red LED contains silicon dosed with something called Gallium Arsenide. Physically the diode junction is quite small, the remainder of the LED being a plastic case to support and protect the delicate junction and provide electrical insulation. Two or more wire pins for electrical connection protrude from the body. Typically one pin is longer – this is the positive connection or anode (a). In addition most LEDs have a flat on one side of the body – the pin nearest the flat is the negative connection or cathode (k).



Uses
Because they do not produce heat they can be used inside plastic buildings and rolling stock without risk of damage. The very small sizes available make them ideal for head and tail lights, signals, station platform lights and street lighting. Yellows and oranges can be used for gas lamps and coal fires.
Bright white LEDs can be used for high intensity headlights on modern image trains and for lighthouse beams. Combinations of white and blue suitably flashing can simulate welding and third rail arcing.

Types
LEDs are available a variety of colours. Common colours such as red, green, yellow and amber in 3mm and 5mm diameter are available from electronic supply houses for a few pence each with discounts for quantities of 10 or more. Bright white, blue, turquoise and purple and special high power red and green are all more expensive but compared to lamps still not dear considering the advantages they offer.
Round LEDs can be as large as 10mm or as small as 0.8mm. There are also square, rectangular, triangular, flat or round topped, narrow beam or diffused light and many more. If you are not confused yet I will mention bi-and tri-colour LEDs, flashing LEDs and finally flashing LEDs that change colour as they flash.
The colour of the body is not always an indication of the light colour emitted. Red, green, orange and yellow LEDs usually emit that colour but a water clear body can emit high brightness red or green whilst milky white can emit blue, brilliant white or bi-and tri-colour.
LEDs can be salvaged from toys, electronic equipment, and mobile phones.

Voltage
Typically LEDs operate on small voltages – red 1.8 volts, orange 2.0 volts with yellow and green 2.2 volts. Whites and blues usually 3.5 volts with some white and flashing LEDs up to 5 volts. Remember, this is a guide and it pays to check with suppliers or manufacturers.

LEDs will operate on direct current (DC) or alternating current (AC).
Direct current is where the polarity is fixed and current flows in one direction only eg. as with a torch battery.
Alternating current is where the polarity and hence the current flow changes constantly eg. 50 Hz household mains supply. The 50 Hz (Hertz) refers to the rate of alternations, in this case 50 times per second.

An LED will operate successfully on low voltage AC. It will actually flash in time with the supply alternations but the rate of flashing is too fast for our eyes to register in much the same way as we do not notice lamps in our houses flashing.

To operate successfully on the 12 to 16 volts commonly found in the model railway world the simplest solution is to install a resistor in series with the LED to limit the current flow.

Resistors

Suitable resistors consist of a ceramic rod a few mm in diameter and perhaps 10mm long with tinned wire ‘pigtails’ at each end. They are available in a range of resistance values and power rating. The resistance is measured in Ohms and the power rating in Watts (named for pioneers in these fields). Generally speaking the larger the resistor the higher the power rating in Watts. In most model applications ¼ and ½ Watt resistors will be adequate.

Most resistors are so small that it is impractical to print their values on them using numeric characters. Instead they are marked using a code of coloured bands (refer to the resistor colour chart).

The common values are arranged to provide a logically ascending series of values each spaced so that taking into account the maximum and minimum allowed by a percentage tolerance they do not overlap. The tolerance is also indicated by a coloured band.

A resistor with 4 colour bands would be as follows:

band one – first figure of value
band two - second figure of value
band three – number of zeros (or multiplier)
band four – tolerance (eg. 1%, 2%, 5%, 10%)

So, a resistor with yellow (4), violet (7), brown (1) and gold (5%) would have a resistance value of 470 Ohms, 5% tolerance.

Don’t panic if your resistors have 5 colour bands. The chart also covers them.

Resistors only cost a few pence each with discounts for quantity of 10 or more of the same resistance value. When buying resistors check the colour code yourself – people in shops often make mistakes – they often know less about electronics than you do and furthermore it is all too common for resistors to be inadvertently placed in the wrong bin by staff or customers. Resistor values are often written in universally understood shorthand. For example a 1,000 Ohm resistor may be written 1K Ohm where K stands for kilo. Similarly 1,000,000 Ohms appears as 1M Ohm with M stands for mega. Another standard notation is to include the letter R to represent the decimal point.
Eg. 470 Ohms is written 470R whilst 4.7 Ohms is 4R7.

Which Resistor ?
The correct value resistor for an application can be arrived at by several means: trial and error, folklore, by calculation, by consulting a table.

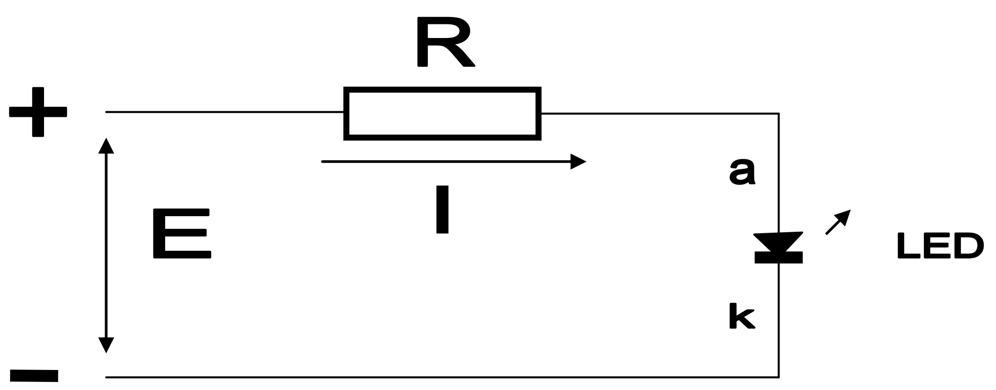
Trial and error – start with a high value and reduce until the LED just lights.

Folklore – practical experience over many years using common red, green and orange LEDs on 12 to 16 volts has shown that a 1000 Ohm (usually written 1 K Ohm) resistor is satisfactory.

Calculation – the series resistance can be determined by using the following formula:

$$\mathbf{R = (E - Vf) \times \frac{1000}{I}}$$

Where R is the required resistance in Ohms
E is the DC supply voltage
Vf is the forward voltage drop of the LED typically 2 volts
I is the forward current of the LED in milliamps (mA)



(Example only) - by Ohm’s Law for a supply of 12 volts and allowing 2 volts drop across the LED for a forward current of 20 mA through the LED the required resistance would be 500 Ohms (12 – 2 = 10, divided by 0.02 = 500) The nearest common resistor is 470 Ohms or 560 Ohms.

Table - I have provided a table of common supply voltages and the required resistor.

	Supply Voltage	Series Resistor
Vf = 2 volts I = 20mA	6 volts	220 Ohms
Vf = 2 volts I = 20mA	9 volts	330 Ohms
Vf = 2 volts I = 20mA	12 volts	560 Ohms
Vf = 2 volts I = 20mA	16 volts	680 Ohms
Vf = 2 volts I = 20mA	24 volts	1200 Ohms

Soldering
The most reliable method of connecting LEDs to supply wiring and resistors is soft soldering using a small tipped low Wattage electric iron and fine gauge resin cored solder suitable for electronic work. Around 20 to 25 Watts is ideal. In any soldering the key is cleanliness, cleanliness, cleanliness, cleanliness.

Wrap the wire around the pin of the LED. Apply solder and iron simultaneously for the shortest time possible to make the joint but definitely only seconds. You can protect the LED from heat damage by clamping a heat sink – small forceps, alligator clip, small foldback clip – to the pin between the LED and the solder joint.

Because the pins on an LED are close together it's a good idea to slip a length of insulating sleeving over the pins and solder joints.

Surgery
Provided that you are reasonably careful it is possible to alter LEDs. The plastic body can be shaped and altered using the usual tools – files, saws, drills and cutting disks. The main thing is to avoid going too deep so that you damage the silicon junction inside, which most times you will be able to see quite clearly. Also it helps after cutting or filing etc. to polish the surface to restore the light – giving properties. As an example, a yellow LED could be filed and shaped to resemble a gas lamp and mounted on a pole.

By drilling a very small hole in a LED and super gluing in a fibre optic filament it is possible to provide a very small and flexible light source remote from the larger LED. The wire pins to can be bent to become part of a structure – eg. a signal. Just be careful not to bend too sharply or too close to the LED.

Hints when using LEDs
Make sure you know what the supply voltage is - measure with a meter if possible. Labels and nameplates on mains plug packs and model train control units are notoriously inaccurate.

Use the correct series resistor for your supply voltage. Check the table and the colour code chart. Read the colour code or better still, if you have a multimeter use it to check the resistance.

Connect the LED to the correct polarity. Typically LEDs have one longer pin – this is the positive connection or anode (a). In addition most LEDs have a flat on one side of the body – the pin nearest the flat is the negative connection or cathode (k). There are exceptions – not every LED has a flat, some LEDs have pins of equal length. If you are not sure, try briefly connecting a low voltage, say 2.5 volts directly to the LED. If it does not light, reverse the connection. Take note of the correct connection and mark the positive pin or anode with a marker pen. LEDs are fairly robust. They can stand 2-3 times the rated voltage and 10 times the rated current for a brief second or two whilst you are experimenting but this is not recommended practice.

A word of advice.
When purchasing LEDs, resistors or any electronic components for that matter you will generally find electronic supply houses provide the best option in terms of range, price and service. They are usually geared up to offer a quick efficient mail order service for small mixed quantities. Model railway shops usually have to charge much higher prices for equivalent items because they obtain THEIR supplies in smaller quantities.

PLEASE NOTE
This is intended as a broad overview of LEDs and their application in modelling. It is not is not a guarantee that a specific device or part number will perform in a particular fashion. For accurate up to date information and specifications consult the manufacturers data sheets (usually available on a website) or your supplier.

Suppliers
Jaycar
Altronics
RS Components
Futurlec
Ebay

Help Line
I would be happy to try and answer any specific queries via e-mail

stopper2@bigpond.com