Electronics for Model Railways

Chapter 12

Scenic lighting

By Davy Dick

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In memory of Margaret

Contents

Scenic lighting

So far, we have concentrated on the technology that makes the layout run.
Now, lets have a look at some features that can enhance the look and feel of a layout.
Many layouts look good and run well but still seem to lack some sense of life.
This can be partly caused by the lack of movement – the only things moving being the trains. The chapter on animations opens up possibilities to bring other movement on your layout – people, doors, crossing, semaphores, etc.

This chapter looks at lighting your layout, to provide that lived-in look.

Lighting is often overlooked in otherwise excellent layouts. Yet it mostly easy to add to a layout, whether under construction or already existing.

Benefits

These are just some of the lineside features that could be illuminated to good effect;

- Street lamps
- Traffic lights
- Station lights
- Yard lights
- Crossing lights
- Semaphore signal lamps
- Lamps on buffer stops
- Buildings and factories
- Lighthouse
- Flickering fires / welding flashes
- Neon signs
- Flashing beacons in police cars/ambulances/fire engine/breakdown trucks
- Vehicle headlights
- Night scenes / sunset behind the mountains / skyline

To these could be added cinemas, concerts, roadworks, crash scenes, searchlights, and so on – limited only by your imagination.

There are two main uses for lights.

- To be viewed directly (e.g. traffic lights, car lights, etc.).
- To illuminate an area (e.g. a yard light, building interiors, etc.).

You choose the type needed for your circumstances.
Smaller, low level illumination LEDs are best suited for direct viewing.
Straw hat / flat top LEDs produce a more even distribution of light.
Clearly, having the layout looking more like a Xmas tree would not be helpful, but the judicious use of lighting can greatly enhance a layout.
Many of the lighting features require little electronic knowledge and you can buy ready built units for some of the more complicated lighting features.
If you are willing to build your own circuits, you can make substantial savings and build lighting features that perfectly match your layout's character.

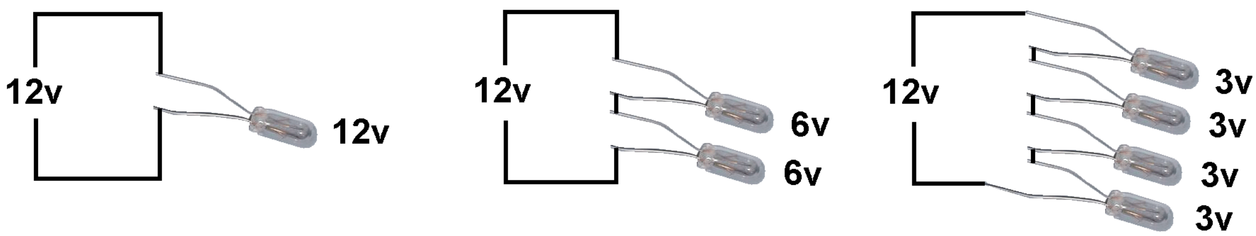
Filament bulbs

Before the coming of LEDs, all layout lighting used tiny incandescent bulbs. These are just much smaller, lower voltage, versions of the house light bulbs in common use.
Sufficient current is passed through the bulb's wire filament to heat it to the point where it gives off light.
The bulbs are available in two sizes, known as 'Grain of wheat' and 'Grain of rice'.
Grain of wheat bulbs are 3mm in diameter, while grain of rice bulbs are 1.8mm in diameter, with some as small as 1.4mm.   They produce a natural light but can be purchased with coloured glass bulbs or lenses.
They are available in 3V, 6V and 12V versions.
They work on AC or DC.

Typical bulb currents are:
Grain of wheat bulbs
    12V at 50mA or 80mA
    6V at 50mA or 60mA
    3V at 120mA
Grain of rice bulbs
    12V at 30ma

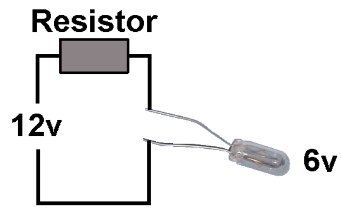
Series and parallel wiring

Since 12V is a common supply on a layout, a 12V bulb can simply be wired across the 12V.



You can fit as many 12V bulb across the supply as you want, subject only to the supply and the wiring being able to cope with the current demands.
If you use 6V bulbs,you can wire two in series across the 12V supply, giving each bulb the 6V it needs. Similarly, you can wire four 3V bulbs in series across the 12V supply.

If you only want to light a single bulb, and it has a lower voltage rating than the supply, you have to put a resistor in series with the bulb to lower the current through the bulb.
Take, for example. Using a 6V 50mA bulb on a 12V supply.
The value of the resistor can be calculated as:

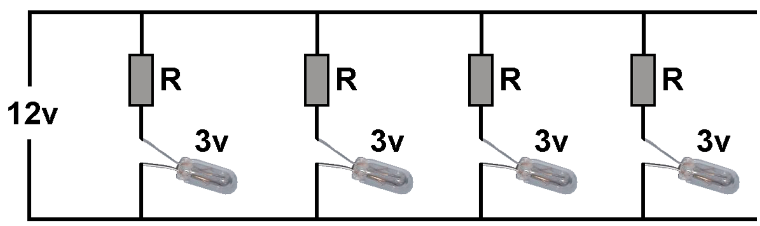


R=V/I

where V is the 6V we want to drop across the resistor (leaving 6V for the bulb) and I is 50mA. So the value of the resistance would be:

R=V/I = 6/0.05 = 120 ohms

That works fine where a single bulb is being lit in a single location. If you want to have multiple bulbs lighting a building or a station platform, then you would not use multiple bulbs in parallel.
If we look at wiring four 3V 120mA bulbs as in the illustration, then 120mA is flowing through each resistor/bulb combination. The total current draw is 480mA (nearly half an Amp) and the power consumption is almost 6W. Wire a dozen inside a mainline station and you have used up 18W – more power than many soldering irons.



Compare that with the earlier example of wiring four bulbs in series across the 12V supply. The current drawn is 120mA (the same current flows through each bulb) and the power consumption is a smaller 1.4W.

Since filament lamps heat their elements to produce light, around 90% of the power consumed by the bulb is dissipated as heat – a clear fire risk. So, you have to be careful that you don't fit too many into a closed location (e.g. inside a building) without adequate ventilation.
Some users deliberately run their bulbs at less than their quoted voltage rating. This results in less heat, a warmer glow and an extended life.
Here is a comparison of incandescent bulbs to LEDs:

Pros

- A more natural white light
- Colour more suited to lamps of period layouts,
- Very thin leads – great for positioning, compared to stiff leads on LEDs

Cons

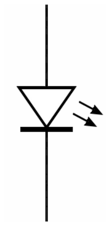
- More expensive
- More fragile
- Run hot
- Consume too much power

Light Emitting Diodes

LEDs have been mentioned a few times in other chapters, since we have all come across them in many different domestic devices.
They have many advantages over using filament bulbs:

- Longer life
- Consumes far less current (some as low as 3mA)
- Run cool
- Available in many colours
- More robust
- Cheap
- Available in high intensity versions
- Rapid switching on and off does not decrease their life.

To make best use of them in a layout, we should look at how they work and how they can be wired.
The symbol for a LED is shown in the illustration. It looks similar to the symbol of a diode because it acts like a diode – it passes current in one direction only. In addition, it emits light when an appropriate amount of current passes through it. Inside the epoxy resin case, there is a small piece of semiconductor material that emits photon energy. This is called *'electroluminescence'* and consumes very little power and generates very little heat, compared to filament bulbs.

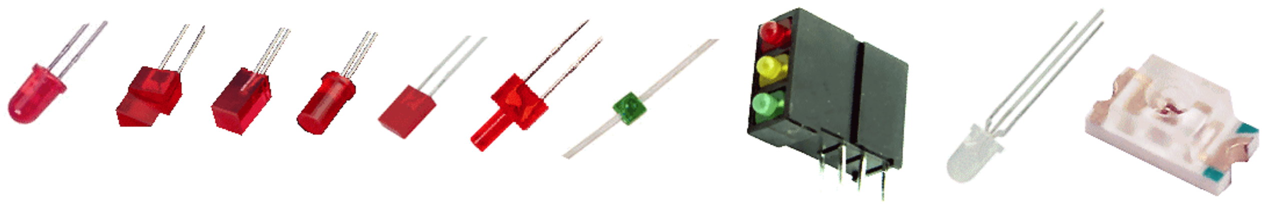


LED types

LEDs are available in a range of sizes, colours, shapes and features.

Shapes

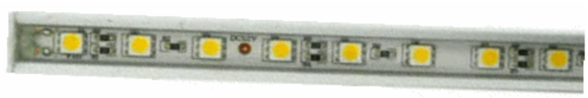
This images shows some of the types you are likely to use.
They are not shown to scale. The last image on the right, for example, is the smallest of all.
They are produced in diameters of 1.8mm, 3mm, 5mm. 8mm and10mm



From left to right:
Standard round topped, triangular, square, cylindrical, rectangular, lighthouse, sub-miniature, PCB mount, tri-colour, surface mount.

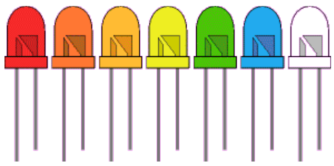
Most of the ones shown are known as *'through hole'* LEDs, as they are intended to be mounted on some kind of panel (in our case, a mimic panel). Others, like the one with three LEDs and the one on the far right, are intended for mounting on a PCB.

LED strips



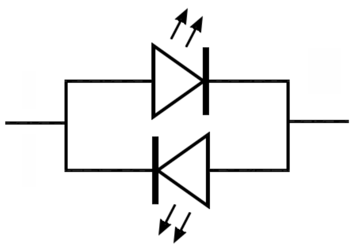
This image shows a LED strip which can be bought by the metre or in 5m rolls. It runs on 12V (a few run on 5V) and can be cut into smaller lengths. They are available in warm white and cool white, and a range of colours such as red, amber, green, blue, purple, etc.
They are ideal for illuminating large areas or large buildings. They are also handy for fading between strips (sunny day to dull day, daytime to dusk, etc.).

Colours



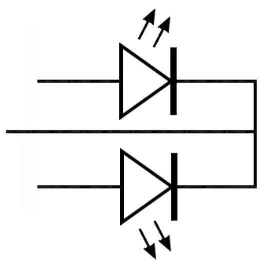
A LED's colour comes from the semiconductor material used, not from additional filters or a coloured epoxy casing.
The colours include red, pink, orange, yellow, amber. Green, blue, white and warm white.
They are available in versions known as diffused (a frosty casing that results in a wider viewing angle) or clear encapsulation (produces a viewing narrower angle but a more intense brightness).Coloured LEDs have many uses in ground signals, traffic lights, police cars, etc. The warm white version is useful for representing incandescent bulbs, with cool white used for fluorescent lights. They can also be used on control panels to great effect.

Bi-colour LED



This is just two different-coloured LEDs built into the one casing, wired in reverse of each other. It has only two connecting leads. If you connect the power one way, the top LED lights. If you reverse the voltage, the lower LED lights. To the user, the LED seems to change between the two colours.

Tri-colour LED



This also has two differently-coloured LEDs inside a single casing but this time they are not wired in reverse. It has three wires, with two of them commoned to the negative lead of the supply. Connecting any one of the remaining LED leads to the positive supply, via a limiting resistor, lights that particular LED – giving two possible colours. Now, if the positive supply is connected to *both* leads, the colour mix produces a third colour. The most common combination is red and green LEDs that produces a yellow colour when both are lit at the same time. Varying the illumination level of each LED provides additional colour variations.

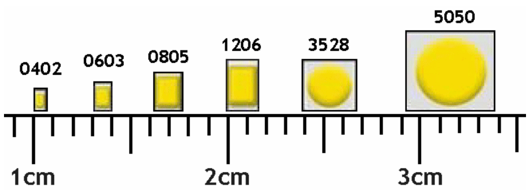
Flashing

This LED has a built-in chip that makes the LED flash, usually at 1Hz, 2Hz or 6Hz. You cannot alter the rate of the flash. There is no need to build electronic circuits to flash your LEDs, unless you need a different rate of flash.

Flickering

This LED has a built-in chip that makes the LED flicker. Designed for use in electronic candles, these are handy to emulate gas lamps, fires, ash pits, etc.

Surface mounted LEDs

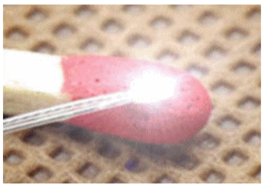


These are designed to be mounted on printed circuit boards but their very small sizes makes them useful for smaller gauge railways. Their measurements are given in inches.
For example, a 0603 LED measures 0.06in by 0.03in.
The most common individual LED sizes are:

Type	Length (mm)	Width (mm)
0402	1.0	0.5
0603	1.6	0.8
0805	2.0	1.25
1206	3.2	1.5

The 3528 and 5050 versions are found on LED strips.

Pre-wired Micro Litz



The problem with the smallest LEDs is soldering leads on to them. At a price, you can purchase pre-wired tiny 0402 LEDS in various colours. The picture shows one of them compared to the head of a match. They use very thin flexible Micro Litz leads, allowing easier installation in vehicles, signals, traffic lights, etc.

LED characteristics

Not all LEDs are the same; they operate at different voltage levels, have different brightness levels, etc. Here are the characteristics of a typical 3mm red LED from Kingbright:

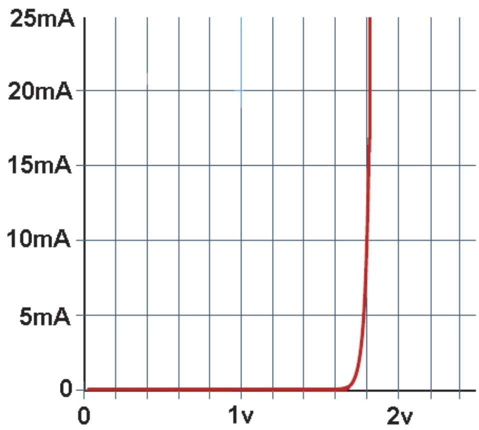
Forward voltage (typical)	1.85V
Forward voltage (maximum)	2.5V
DC forward current (maximum)	30mA
Reverse voltage	5V

The *'forward voltage'* is the voltage at which current passes through the LED and produces illumination.

The *'max voltage'* is known as the *'forward voltage drop'* and is the voltage across the LED when it is running with its maximum current, providing its maximum brightness and specified colour. Increasing the forward voltage beyond its maximum will destroy the LED.

Unlike a filament bulb, a LED only operates over a small voltage range; too low a voltage and it won't illuminate, too high a voltage and it is destroyed.

This graph shows how the current through an example LED changes with increasing voltage.
If you connected a variable voltage supply across a LED and slowly increased the voltage from zero, for some time nothing would happen.
Then, suddenly, current would start to flow at an ever increasing rate for very small voltage increases.
The point at which this occurs depends on the characteristics of the LED. It is about 1.7V in the example but can vary between LEDs of different colour and even within the same batch of LEDs.



The *'forward current'* is the amount of current that will flow through the LED when it is illuminating.

Note

> You don't have to work the LED at its maximum current. A modern LED will happily illuminate at a much lower forward current than its maximum (e.g. as low as a few mA).

An LED is a type of diode; it is also designed to pass current in one direction and not the other. The *'reverse voltage'* is the maximum voltage you can subject it to, in the reverse direction, before it breaks down. For a standard diode such as a 1N40001 the maximum is 50V but for LEDs the level is much lower (e.g. 5V).

Brightness

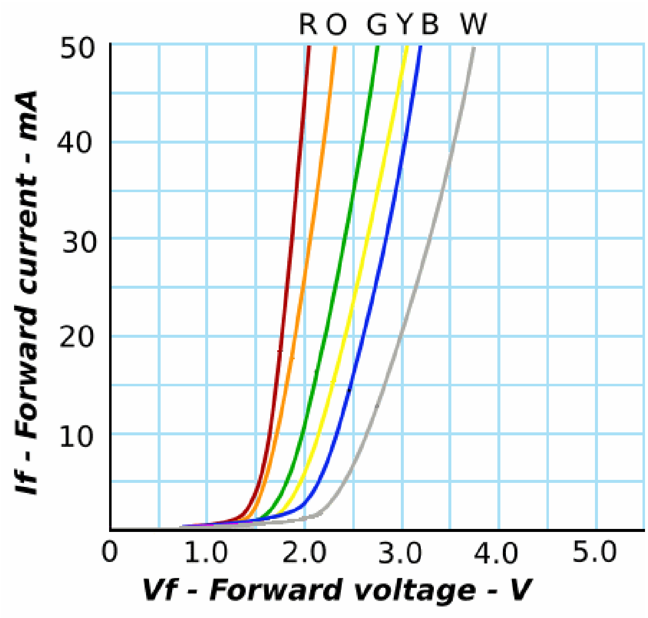
The brightness of LEDs is measured in millicandelas (mcd), being one-thousandth of a candela, so higher values of mcd mean brighter output.
As mentioned, LEDs can be designed for different viewing angles, depending on whether you want a spotlight effect of a general illumination effect. Viewing angles can vary from 15º degrees to 120º degrees

Here are some typical specifications taken from suppliers' material.

Colour	Max voltage	Max current	Viewing angle	Brightness
Blue	3.2V – 3.8V	20mA	20º	10,000 mcd
Green	3.5V	20mA	20º	6,000 mcd
Red	1.8V – 2.2V	20mA	60º	5.000 mcd
Orange	2V	20mA	20º	4.000 mcd
White	3.5V	20mA	45º	100,000 mcd

It is important to recognise that these are *examples,* intended to stress that the specifications vary between different manufacturers and different products. For example, while one LED might use a 3.8V potential across it to illuminate, that might be enough blow a different LED. If in doubt, error on the side of caution or, even better, read the specification.

This graph shows the relationship between current and forward voltage for a range of average LEDs of different colour.

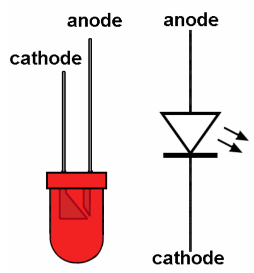


Other LEDs

Apart from those already mentioned, LEDs are available that produce infrared or ultra-violet radiation.

Wiring LEDs

A LED has two leads, called the anode and the cathode.
The cathode lead is the shortest and goes to the negative side of a supply.
The epoxy casing often has a flat edge along the cathode side.
The anode connects to the positive side of the supply.



If you are using a pre-used LED, the leads will have been cut. If your LED does not have a flattened surface, you can always look inside the LED, as shown in the illustration. The larger, wedge-shaped, piece is the cathode.
If all else fails, you can just use the trial and error method – it will only illuminate when wired the correct way round.

LEDs are current driven devices, which means that their brightness level increases as the current through it increases, with two provisos:

- A LED will only start to illuminate after it reaches certain critical voltage level.
- A LED cannot be given more than its maximum rated current without affecting its performance and eventually destroying it.

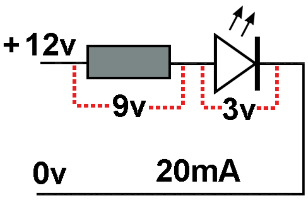
From the earlier table of typical LEDs, we can see that they work from voltages that are not common on model layouts.
5V and 12V versions of LEDs are available, as they have a resistor already built or wired into them.
However, most LEDs need to use an external series resistor.
So, we have to reduce the voltage by placing a resistor in series with the LED. A 1k resistor is a good starting point for many LEDs but you can make more precise calculations.

Resistor calculations

To work out the required resistance, you need to know:

- The voltage of your supply
- The forward voltage drop of the LED
- The maximum current of the LED

Consider the example shown in the illustration.
It uses a 12V supply and the LED needs a maximum voltage across it of 3V. That means the resistor must drop 9V across it. Since we know the maximum current of the LED, we can calculate the resistor value by Ohms Law thus:



$R = V/I \quad R=9/0.02 \quad R= 450$ ohms.

Since you can't buy a 450 ohm resistor, you would always choose the nearest *higher* value of resistor in the preferred series (to avoid excessive current). You would use a 470 ohm resistor in this example.

If you are technical, the formula is

$$R = (V_S-V_F) / I_F$$

where R is the resistance being calculated, V_S is the supply voltage, V_F is the forward voltage of the LED and I_F is the maximum LED current.

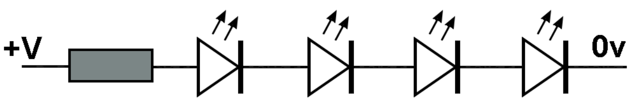
If you are not technical, you can use an on-line calculator to do the sums for you. Look, for instance, at:

`http://led.linear1.org/1led.wiz/`

These calculations are based on running the LED at its maximum specification. In practice, LEDs can often be run at much lower current levels (5mA or even lower) and still produce satisfactory illumination.

LEDs in series

LEDs can easily be wired in series, as shown in the illustration.



The same current flows through all the LEDs and the resistor, but the LEDs may have different forward voltages and this has to be taken into account when calculating the resistor value.
The formula for LEDs in series is:

$$R = (V_S-(V_F1 + V_F2 + V_F3)) / I_F$$

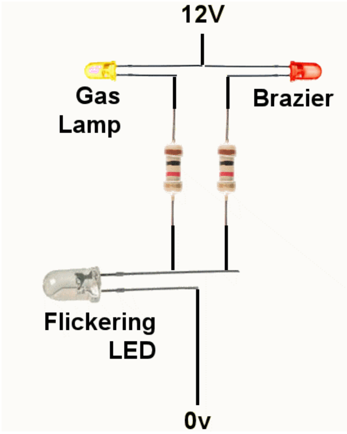
As an example, let's look at wiring four LEDs to a 12V supply.
All four LEDs run at 25mA but have different forward voltages of 3.5V, 2.2V , 2V and 3.8V.

The calculation is

$$R = (12 – (2.5 + 2.2 + 2 + 3.8)) / 0.025$$
$$R = (12 – 10.5) / 0.025$$
$$R = 1.5 / 0.025$$
$$R = 60 \text{ ohms}$$

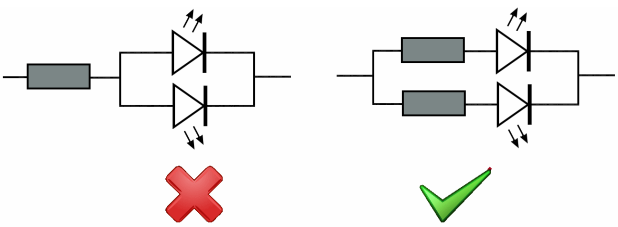
Therefore a 62 ohm or 68 ohm resistor would be used.

In this example, a modeller has a flickering LED of the wrong colour for its purpose. So it is wired in series with other LEDs of the desired colour(s). For example, a white flickering LED can be located under the baseboard while a normal red LED is used above board to simulate a brazier, a bonfire, etc.



Parallel LEDs

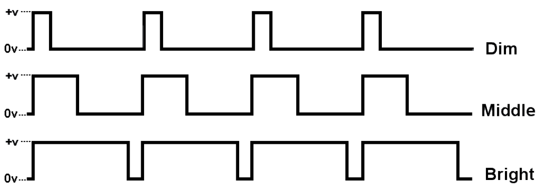
Wiring LEDs in parallel should be avoided.
The problem with a bunch of LEDs in parallel is that they will all have different voltages at which current starts to flow. If you set the voltage sufficiently high to ensure that the LED with the highest forward voltage passes current, then the others are passing too much current. The LED with the lowest forward voltage then passes most current and finally dies. This results in the LED with the next lowest forward voltage passing even more current … and so on.
On the other hand, if you set the supply voltage to a level that is correct for the LED with the lowest forward voltage, it illuminates but the rest don't.
If you need to have LEDs close to each other, simply wire them in series. If there is not enough voltage to handle a couple of LEDs, then use a separate resistor in each LED, to match the individual LEDs, as in the right hand diagram. Also true for bi-colour LEDs. The left hand diagram should be avoided.



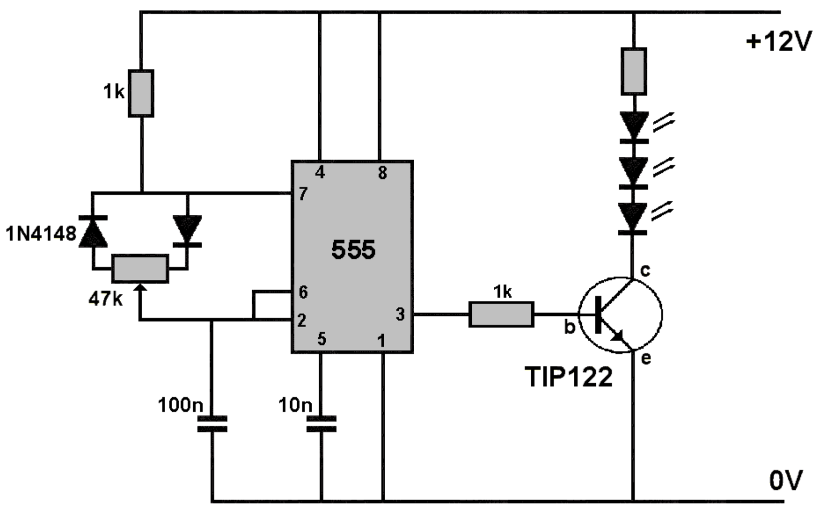
Fading LEDs

If you look at the earlier graph, you see that eventually very small voltages increases result in large current increases.
This makes altering LED brightnesses very difficult simply by using voltage changes. So, for example, you could not dim a LED by placing it in series with a variable resistor.

In the chapter on loco controllers, we looked at pulse width modulation as a means of controlling the current through a motor. The same principle can be used to control LED brightness.
Firstly, the resistor value is calculated for the required maximum brightness.
Then power to a LED, or a string of LEDs in series, is delivered as a succession of on/off pulses. If the pulse period is long, with hardly any off time, the lamp illuminates brightly.
Conversely, if the on period is short, with long periods off, the LED will be perceived as being dim.
In other words, altering the pulse width changes the LED brightness. The rate at which the pules repeat has to be fast enough to prevent the LED simply flashing on and off.



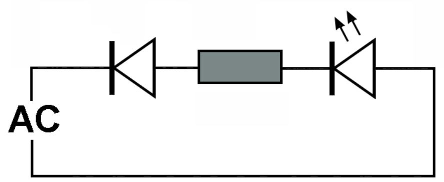
The device that sends the pulses can be built from a simple 555 IC, as in this example, or a PIC chip. It can be a commercial dimmer (see Microminiatures) , or a complex DMX controller that handles all kinds of devices such as fog machines and moving lights.



Even at its simplest, the ability to simulate dusk, dawn, sunsets, etc., opens up ways to bring interesting effects to a layout.

LEDs on AC

Some loco controllers provide a 15V AC socket for running accessories and this could be used to illuminate LEDS, with some precautions.

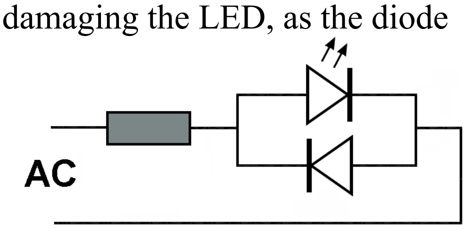


The diagram shows a single LED connected to an AC supply, with the usual dropper resistor to set the current level.
The problem with AC in this case is:

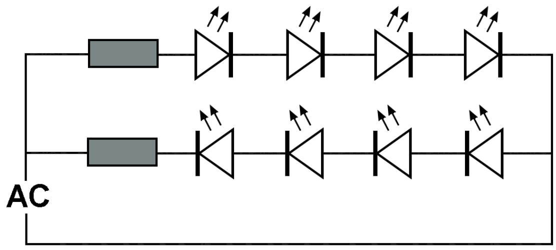
- It is not always at a constant level
- It reverses polarity

In chapter 1, we showed a AC supply as a sine wave, constantly changing both its amplitude and direction.
Since the LED is a diode, it will ignore voltages that swing in the opposite direction to its conducting polarity. That means that the LED is not lit for half the time when it is forward biased. It is turning on and off at the frequency of the mains supply (e.g. 50Hz in the UK). Some users can detect the flicker.
Even when the supply is connected during the correct polarity, the amplitude is always changing. If we set the resistor value to switch on during the highest point in the voltage swing, it will not be illuminated for the rest of the half-cycle. If we lower the resistance value, the LED stays illuminated longer but we risk reaching currents at the peak which will destroy the LED. In short, we cannot achieve the optimum LED brightness with AC.

The earlier diagram shows a diode wired in series with the supply.
This is fitted to prevent excessive reverse polarity voltage damaging the LED, as the diode can tolerate a much higher reverse voltage than a LED.
This diagram shows an alternative approach, using a diode (e.g. a 1N4001) being connected across the LED but in reverse polarity. The diode and resistor then absorb the power when the voltage is reversed.



This can be used on a layout that has a light in a building in a remote part of the layout. The DCC from the track can be used to power the LED.



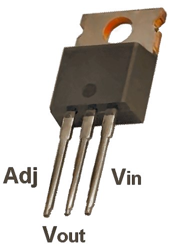
This diagram takes the idea a little further by wiring two sets of series LEDs, such that one set illuminates during one half cycle of the sine wave and the other set illuminates on the opposite half cycle.

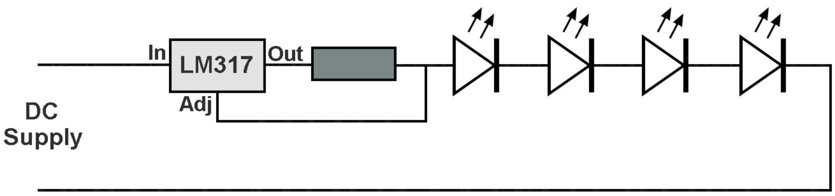
Another factor to bear in mind with a 15V AC supply, is that the value is stated as an RMS value (see chapter 1). The peak value is 1.4 times higher, so during the 'on' half cycle, there is actually a peak voltage of 21V being supplied.
This must be factored into the calculation for the resistor value, otherwise the LEDs will be destroyed.

The other approach is to take the AC supply, turn it into a DC supply using a bridge rectifier, then smooth it with a capacitor, before using it to power LEDs (see the section on power supplies in Chapter 1).

Constant current supplies

Since LEDs are current-driven devices, and we know the current we want for any particular LED or set of LEDs, we can build a simple circuit that always provides that exact amount of current.
The circuit uses a *'constant current regulator'* and a widely used example is the LM317, which is a simple 3-wire device.
As the diagram below shows, it is inserted in series with one or more LEDs, and has its 'Out' and 'Adjust' leads connected across the resistor.





There is a very simple equation for calculating the resistor value:

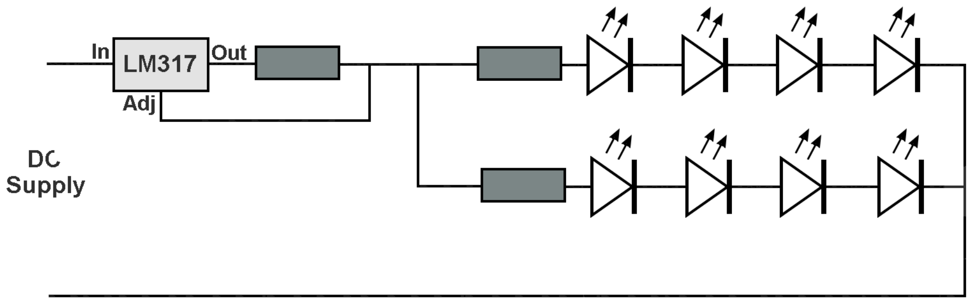
R = 1.25 / LED current

So, for example, if the required LED(s) current was 25mA, the equation is:

R = 1.25 / 0.025
R = 50 ohms

The resistor value is not dependent on the voltage of the supply.
However, you do have to ensure that the supply voltage is sufficient to handle all the LED forward voltages, plus an allowance of 3V for losses in the regulator.
If the above circuit used a 12V DC supply and the LEDs each had 2.2V forward voltage, then the circuit could handle four LEDs in series.

If you wanted to use multiple strings of LEDs, the following circuit is required, with each string having its own limiting resistor. The LM317 regulates the current to total current draw from each string. So, if the upper series used 25mA and the lower series used 20mA, the value of the resistor for the LM317 would be selected to provide 45mA.

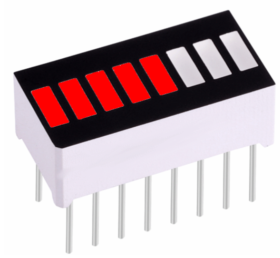


The specification for the LM317 regulator states that it can handle up to 1.5A, with an input voltage between 3V to 40V.
If you use this circuit with a much higher input voltage than that required by the regulator and LEDs, the excess voltage is dropped across the regulator.
Also, if you use the circuit to control high-power LEDs, or many strings of LEDs, the current through the regulator will be high.
In both these cases, you would have to ensure that the LM317 did not overheat.
Fitting a heatsink to the regulator, or bolting the regulator to a metal chassis (suitably insulated) helps prevent overheating.

Less common sources of lighting

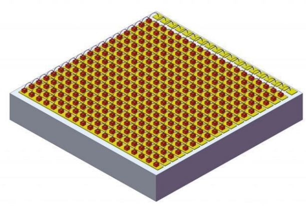
We have covered single LEDs, bi-colour LEDs and tri-coloured LEDs.
In addition to these, layouts could benefit from a whole range of other light sources.

LED arrays



These are commonly found on older hi-fi systems, displaying volume, bass and treble levels, etc.
The illustration shows eight separate LEDs encased in a single unit.
The LEDs are usually all red, all amber or all green, while some include two different coloured LEDs
The image shows an eight LED model but they are also available from Rapid Electronics in 10 bar and 20 bar versions.
Each LED can be individually lit, often driven by a circuit that translates an incoming voltage into multiple outputs, each driving one of the LEDs in the array (e.g. an LM3914 chip). This could be used to monitor a battery's voltage level or the current voltage on the track from a loco controller.
If used with a sequencer module, it would indicate which stage of a sequence was currently active.

COBs



COB (Chip-On-Board) LEDs pack multiple LEDs directly on to a single material surface, without the need for each LED to have its normal large casing. The LEDs can then be packed much closer together than normal LEDs or even SMD LEDs.
A COB LED is a single module with only two power connections.

One manufacturer demonstrates that a COB LED on a substrate of 10mm by 10mm would accommodate 342 LEDs, compared with 40 SMD LEDs and only 9 normal through-hole LEDs.

A COB LED's advantages are:

- Greatly increased lumen output per square inch.
- Uniform light due to close packing of LEDs.
- Increased viewing angle.
- Reduced risk of failure (only two connections compared to multiple connections with multiple separate LEDs).
- Less heat generated (no LED chip enclosures and an aluminium or ceramic substrate packaging, can reduce the heat generated from each LED chip.

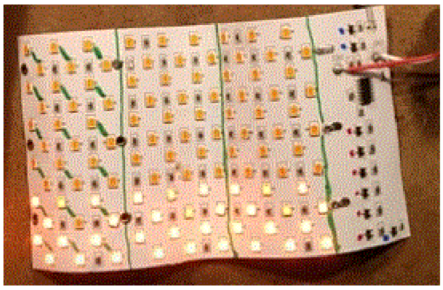
This is an image of a 12V 1W COB.
It measures 12cm x 3.6cm (4.72" x 1.41")
and provides a very even light for illuminating a layout.
It is light and durable, and a row of them on a gantry would be an ideal way to illuminate exhibition layouts.

Flicker flame bulb

This is sold as a mains powered bulb that simulates a flame.

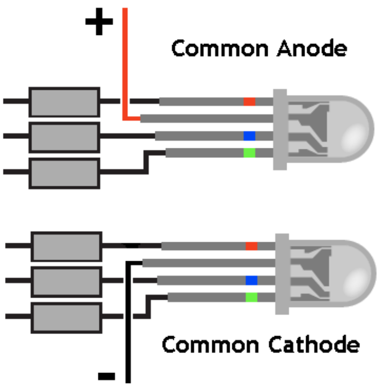
Inside is a step-down module and a flexible plastic sheet contains on which is mounted multiple LEDs and a microprocessor to control them in a sequence that mimics the movement of flames.

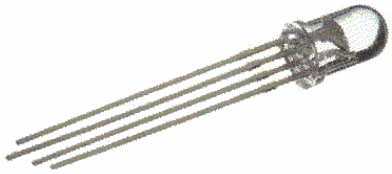
The plastic sheet is rolled into a tube and is easily unrolled as shown in this image.



In this image, the flattened strip has been glued to the rear of the model bank and makes a very realistic impression of a building on fire.

RGB LEDs



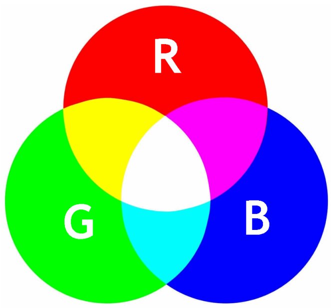


An RGB LED has three LEDs (red, green and blue) in the one package. It has four leads, one for each LED and one that is common to all LEDs.
They are available as *'common cathode'* where all the LED's cathodes are connected together internally or as *'common anode'* where all the LED's anodes are connected together.

Each LED can be lit individually by bringing its pin high (with common cathode) or low (with common anode).
Each pin can also have its intensity varied by PWM.
The three LEDs are located very close to each other, so our eyes perceive the resultant colour as the combination of colours.

This illustration and table shows the basic colours that are available.

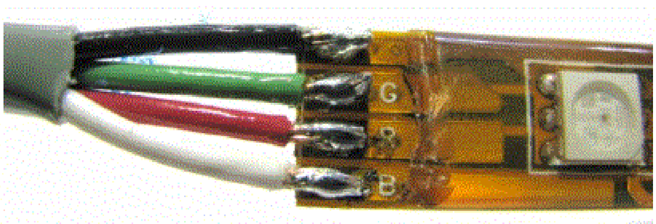
Active pins	Colour produced
None	No illumination
Red	Red
Green	Green
Blue	Blue
Red & Green	Yellow
Blue & Green	Cyan
Red & Blue	Magenta
All three	White



If we use PWM to vary each LED's intensity we can achieve many more colour variations.

RGB LEDs are also produced in strips.
They are used in TV backlighting and can be used in layouts to simulate changing day to dusk effects, or sunny to dull lighting effects.

Some, like the ones you buy in DIY stores have plug and socket end connectors.
If the strip has no connector, you can solder directly on to the ends of the strips as shown here.

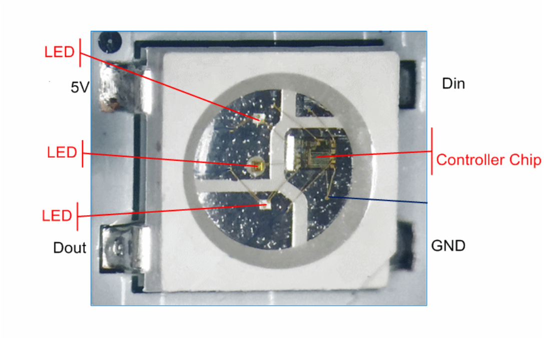


Note
LED strips wire all the RGB LEDs in parallel. That means you switch all LEDs in a strip to the same colour. You cannot have different colours illuminating in different LEDs at the same time.

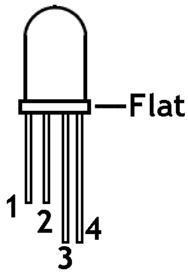
Addressable LEDs

You may need more control over individual LEDs, with some being different colours from others and still able to change colour when required.
This is solved by using addressable LEDs, where you can control the colour of any individual LED in a chain of LEDs.

Such LEDs are the WS2812b range, commonly known as *'NeoPixels'.*
They are available as individual LEDs, strips, rectangular blocks, circles, etc.



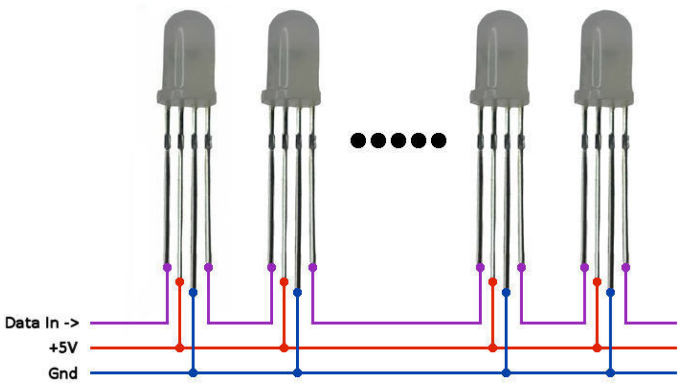
Each NeoPixel has three LEDs (red, green and blue) and its on built in controller chip.
It has four connections. Two of these are for a 5V power supply. One is for incoming data and the other is for outgoing data.



The connections for a stand-alone LED are:

1 – Data In
2 - +5V
3 - GND
4 - Data Out

A single Neopixel can be used on its own but they are at their best when used in a chain. The output pin of the first NeoPixel connects to the input pin of the next NeoPixel, and so on. In this way, many LEDs can be placed round a layout with a minimum of wiring
As this illustration show, only three wires need run round a layout no matter how many LEDs are installed.



On power up, each NeoPixel automatically knows its number in the chain.
An example command might be:

```
pixels.setPixelColor(7, amber);
pixels.show();
```

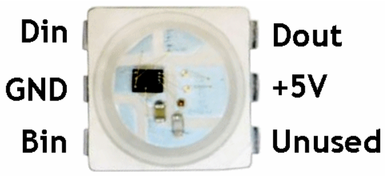
and this would turn on NeoPixel LED number 7 in the chain with an amber illumination.

Downsides

- A NeoPixel uses 60mA when all three LEDs are at full brightness. With multiple NeoPixels installed on a layout, the total maximum current requirements need to be taken into account.
- Unlike other LEDs, NeoPixels involves programming so that they can be controlled by a PIC, Arduino or Raspberry Pi.
- Low refresh rate (you can't switch LEDs on and off very rapidly).
- Since all LEDs are connected via a single wire, any LED failure or connection failure stops the entire chain working.

Look here for greater details:
https://learn.adafruit.com/adafruit-neopixel-uberguide

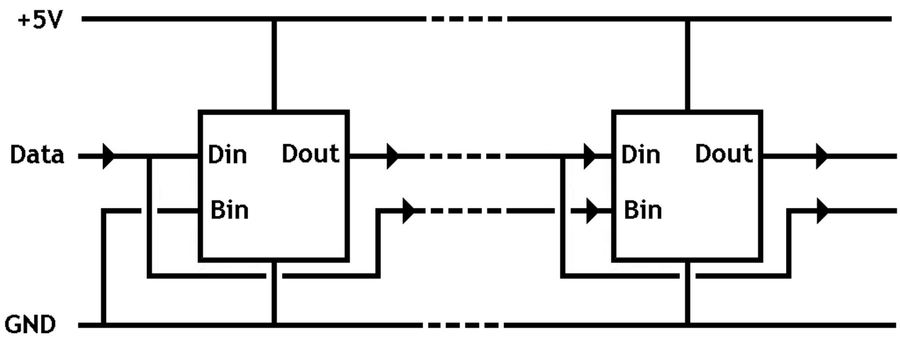
WS2813



The WS2813 units work in the same way as WS2812b units. They use the same controllers and the same code, they have the same power requirements, and so on.

However, WS2813 units have an improved refresh rate of 2kHz compared to only 400Hz for WS2812b units. This allows for faster colour changes and improved display effects.

The main benefit of WS2813 LEDs is their greater reliability. If one LED in the chain fails, the rest of the chain carry on operating.
They use four wires between units instead of three for WS2812b. The fourth wire is an extra data connection.



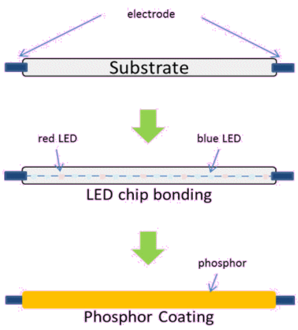
In normal operation, any messages from a controller enter the LED via the Data In pin and passed on to the next LED via its Data Out pin, and so on down the chain.
If a LED fails, it no longer passes the data but the following data can instead use the message coming via is Bin (Backup Data In) pin. It would require two adjacent LEDs in the chain to both fail before the chain stopped operating.

WS2813 LEDs are available as individual units or in strips.
Ws2815 are available as 12V versions.

LED filaments

E27 Filament Bulb

LED filament bulbs are sold as replacements for normal filament bulbs, with the look and feel of an era long gone. The LED filament is made up from multiple LEDs connected in series on a transparent substrate (known as *'Chip-On-Glass'*).



You can buy these elements separately and they supply a warm white light from a 12V supply with a suitable dropper resistor.

Just handle them carefully, as they are easily broken.

Salvaged light sources

Have you ever thrown something away and found a use for it a week later?
Before disposing of broken or outdated pieces of equipment, see if you can find an alternative use for some of the working parts.
For example, printers and scanners have useful motors and stepper motors.

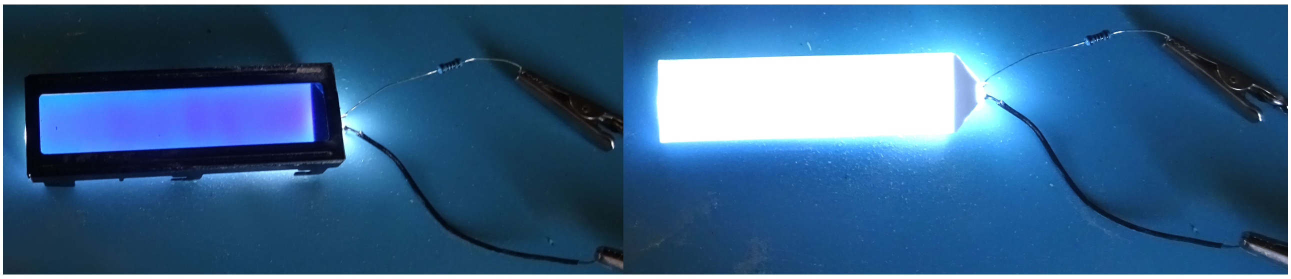
Similarly, we can re-purpose some discarded items that contain lighting elements.

This image is of a cold cathode fluorescent lamp with power supply, salvaged from an old scanner.

The larger image shows it being lit from a low voltage source.
The smaller image shows it embedded in its usual place and with the power unit fed from a 12V supply.
The result is a very bright, even light source.
With a stencilled mask, it makes an ideal sign to advertise MERG, your local model railway club, etc.

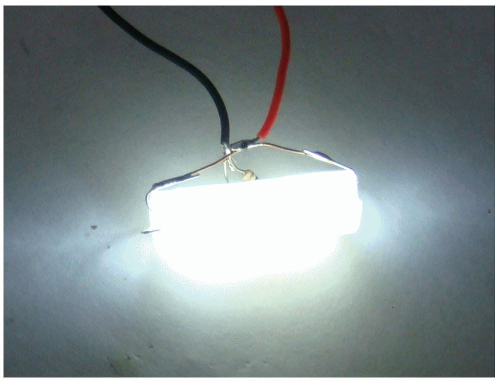
Just be careful of the high voltage generated by the power unit.

We can also recover the lighting element from a 1602 character display module whose electronics has stopped working. Removing the bezel, the coloured layer and the electronic board leaves a block in which is embedded a LED.



When powered from 12V via the usual dropper resistor, you obtain a useful diffused light source.

If you are really adventurous, you can re-purpose the LCD screen from an old laptop, monitor or television. This involves removing all the electronics and fitting LCD strips as the light source while keeping the Fresnel diffuser sheet to produce a large light source.
Have a look at:
https://www.youtube.com/watch?v=Y2KK4YiOO1o



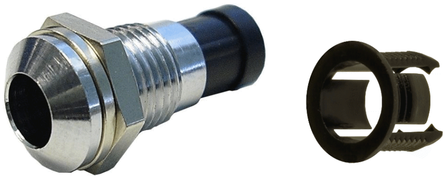
On a more basic level, how about using up that last piece of a glue gun stick?
Drill a hole at either end and insert LEDs.
When illuminated, the light is nicely diffused by the glue stick.

Fitting LEDs

Once you start using lights on a layout, you find all sorts of uses for them.
These are only some suggestions on how to use them. You will find your own uses and your own ingenious ways to fit them.

LED holders

The images show two different methods of attaching LEDs to control panels.
The one on the left is popped into a hole drilled in the panel, the nut is fitted from the rear and the LED is inserted so that is appears on the panel. The other image is of a simpler plastic holder that is a push fit into a hole in the panel. It is a matter of taste, although many prefer the less intrusive look of the simpler holder.

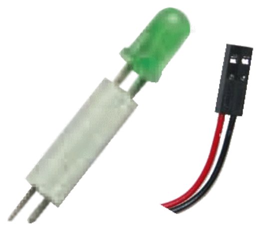


Panels lights can be used for:

- Indicating that the panel is powered.
- Confirmation of which direction a point is switched.
- Reporting back track occupancy information (see later chapter).
- Indicating which blocks / sections are switched.

LED mounts

Apart from control panels / mimic panels, LED holders are not required.
In many cases, the LEDs are hidden from direct view, illuminating buildings, etc.
The images shows a couple of approaches to attaching LEDs.
These are known as *'LED mounts'* and the LED is plugged into a holder that is connected to the rest of the layout wiring.
You can, of course, solder wires directly to the wires of the LEDs.



Bear in mind that LEDs are heat sensitive and avoid applying the soldering iron for more than about 3 secs when soldering.
Also, don't bend LED lead too close (say 3mm) to the case, to avoid damage.
Finally, don't forget that you can buy LEDs pre-mounted on strips with self-adhesive backing. They can be used in long runs, or cut into groups of three LEDs and pressed against a surface to hold it in position. Then, you run a 12V supply to it.

Attaching Lights

Before placing lights all over your layout, it is best to have a plan.
That plan should cover what switches, cables, fuses/cutouts, you might need. You might want to be able to switch different areas of light separate from others.
It should cover working out the current loads for different groups of lights and ensuring that the supply can meet your needs and there is no significant voltage drop in cables making long runs.
There is no 'correct' way to attach lights, as circumstances can be different in different parts of your layout.
A variety of methods have been used to attach lights to parts of the layout, depending on the space available, ease of access, etc. These include soldering to existing devices (e.g. relays), using a hot glue gun, double-sided tape, staples, home-brew brackets, choc blocks, terminal strips, tag strips, and so on.

Lights in buildings

While street lights, signal lamps, etc. add to a layout's appeal, it is the illumination of buildings and structures that most gives the impression of life going on.
It is particularly impressive when the house/overhead lights are dimmed and the glow and twinkle of the lights are most evident.

Power

The first task is to decide how a structure receives the power. This is almost always through a hole drilled in the baseboard. If the structure is removable (e.g. for protection during transporting to exhibitions), then a plug and socket arrangement will be most likely.
If the structure is permanently attached to the baseboard, the light can be permanently wired in. Remember, however, to allow for future access to the lights for future maintenance. This is most important when using filament bulbs with shorter lives. A removable back or lift-off roof is the most likely approach.

Sound structure

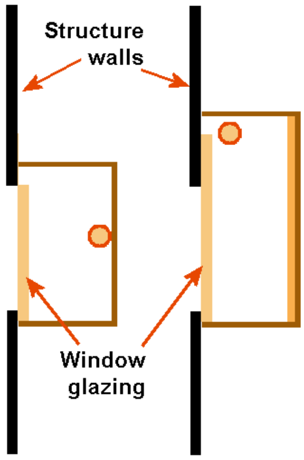
When you add lights to a building, the light should only be visible in the areas you want people to see. You have to ensure that the building's structure meet this need. Plastic kits and some cardboard kits are often sufficiently translucent to make the building look like a lampshade. Even home-built structures can allow light to leak from joints and seams. This is easily checked by placing a light in the building and viewing it in a darkened room. If the walls and/or roof glow then you can either paint the interior walls/roof with black paint, or line them with extra card (leaving holes for the windows). Any gaps in joints can be covered with card or taped over.

Windows/doors

The placing of lights should reflect their use in real life. So, you might expect all the lights in a factory/restaurant/car showroom to be illuminated but not all the windows in a block of flats. The lobby, hallways and stairways of a hotel would be illuminated but not every room. You could use soft white, yellow or amber lights for period layouts and cool white for modern layouts.
If you have built a kit, it probably included glazing sheets. Often, they are transparent and some of the windows have to be rendered translucent while other are blocked off with card/tape. The Wills pack of plastic windows is supplied in a clear plastic 'blister' pack and you cut pieces from the packaging to glaze their windows.
If you have built your own structures, you can create windows from various materials. A popular option is the clear acetate sheets that are sold for overhead projectors or for laminating machines. To make them translucent, they can be lightly sanded with a fine grade grit paper. Alternatively, the light can be diffused by covering the window material with masking tape or 3M Invisible Tape, depending on the degree of dimming you want.

The picture shows a range of other materials that could be put to use. The 'frosty' sheet and the red plastic sheet at the top of the picture were recovered from the packaging of domestic goods. The orange and yellow crinkly sheets are sweet wrappers and the yellow sheet in the lower right-hand corner is from a plastic folder for storing files. On the right, you can see a piece of clear plastic with its corner sanded to make it translucent.

Care is required when fitting multiple lights in a structure, specially if you use particularly high brightness lights. You may have to fit card partitions between floors or between sections of a floor, to prevent light seeping into unwanted areas.
If a single light can illuminate a number of windows, that's good. Otherwise, you can fit lights to a single window or group of windows,by fitting a container over the window(s), as in the illustration. The box, usually cardboard, prevents light seepage and helps focus on the window.
The drawing on the left shows a LED being mounted at the rear of the box and this may be satisfactory where the window glazing is quite dense; otherwise the LED would be seen as a separate entity. The drawing on the right shows a LED mounted above the window and shining down on the rear wall. The LED is out of sight and all you see is the illumination of the real panel (which should be made from white or reflective material).



Note
You can widen and diffuse the narrow beam of light from a LED by gently filing down its dome end and polishing the flattened surface with toothpaste.

Another little touch is to cut out the silhouette of a person and stand it between the window glazing and the rear wall, casting a shadow. Don't place the cutout directly on the window glazing as this reduces the effect.

Remember, not all windows in all building should have the same degree of brightness – just as in real life. For added realism, you can place curtains or blinds on the windows. In industrial situations, some windows may be boarded up or covered in corrugated iron sheets.

Interior details

To provide additional realism, you can allow people to look into certain parts of a building and see its contents. This may be a room in a home, a shop front, a car dealership, a loading bay interior, a loco workshop, etc.
In these cases, the window glazing is clear and you have to take extra care to provide sufficient even illumination, without the lights being visible.
The visible contents are up to the individual modeller. You can print images, or cut them from magazines, and glue them to the inside walls of the room. You can go further, by adding internal details such as furniture or machinery.

Exterior details

Buildings often have exterior lights in addition to interior lights. Domestic buildings may have porch lights and industrial buildings often have lights under canopies and arches, or over entrances.
Commercial buildings may have lights over their signs or even neon signs. Business signs are easy to make if you have a computer but functioning miniature neon signs are best purchased (e.g. see Express Models).
Express Models also sell a multi-LED strip that looks like a fluorescent panel.

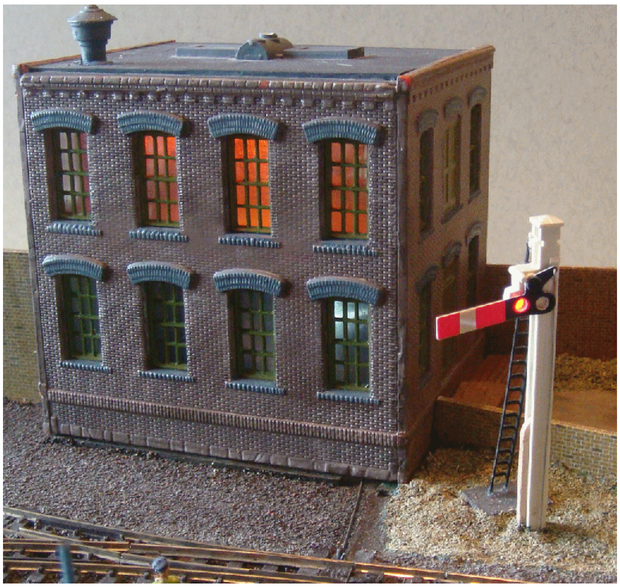
Other effects

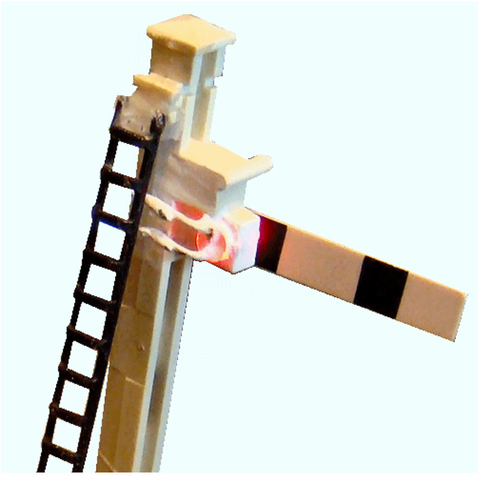
Static lighting can be augmented by lighting that conveys a feeling of activity.
For example, commercial, MERG kits and home-brew circuits are available that simulate the flashing of a welding operation. They switch LEDs on and off in random bursts to achieve this effect. This can be used in various situations – loco shop, car repair shop, fabrication plant, roadside repairs, construction sites, and so on.
Another strategy to convey real life, is to have timers that switch various lights on an off in a random pattern – not too quickly of course.
There are also circuits that allow a LED to slowly increase then decrease its brightness – effective when built into a lighthouse.

Lineside lights

Lighting should not be confined to buildings. There are lots of lineside situations where lighting can be effective. Consider station platform lighting, yard lights, lights in crossing gates and barriers, lamps in buffer stops, etc. While platform lamps and yard lights are available commercially, you may consider it worthwhile fabricating your own.
The image on the left shows a factory building and a semaphore signal. The building's top floor is permanently illuminated and you can just see a welding operation starting on the ground floor. The 'welder' is made from a MERG "Twinkler" kit supported by extra brightness LEDs. The image shows a commercial semaphore signal with two modifications;

- The arm is operated by a servo.
- It uses a bi-colour LED for illuminating the lamp.



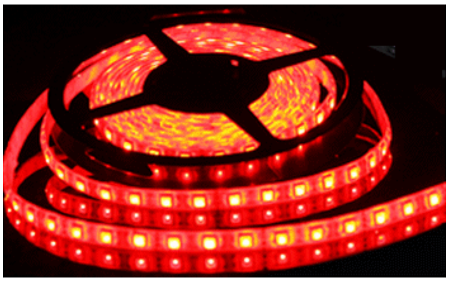


The image on the right shows how the LED is inserted into a hole drilled in the body of the signal. The two connections to the LED are soldered to short lengths of Kynar wire (very thin wire that can easily be hidden) which are fed through the base of the signal.
The LED is a red/green bi-polar type. When fed with its voltage in one direction, the green light illuminates; reversing the voltage illuminates the red light.
The reversal of the LED's polarity could be achieved by a relay, logic chips or a PIC chip. In the example shown, a PIC chip was chosen to provide a delay before switching, to allow the semaphore arm to travel.

Scenic lighting

There are many occasions when you come across lights, other than in buildings or railways. Examples include street lamps, traffic lights, vehicles headlights, flashing beacons in police cars/ambulances/fire engine/breakdown trucks.   Model railway versions can be purchased or built from simple circuits.
A variation on the welding flashes mentioned earlier is to achieve the flickering effect of an open fire. It uses much the same circuit but with different timings and different coloured LEDs.

For the ambitious, there is also the option to install 'mood lighting' on your layout.
Imagine your scenic background being illuminated to simulate different parts of the day and /or different weather conditions.
Different coloureds lights and different light levels could be used to convey mood (bright sunlight, the glow of a sunset, cold or snowy conditions, moonlight, etc.).
It requires multiple lights whose light patterns must overlap, otherwise you simply get a row of light 'spots').   The lights could be hidden behind buildings or walls and angled to shine on to the layout background. If preferred, lights could be hidden behind a valance that skirts the top of the background. An even better approach is to have hills/mountains/low relief buildings set back slightly from the background board; the lights fit in the space and the resultant light appears to come from behind the hills.
The effect can be stunning but requires a lot of lights and electronic controls.
If you want more than one effect, you would have to fit separate rows of lights for each effect – an amber row for sunsets, a blue row for cold mornings, etc.
Fortunately, the LED strips mentioned earlier are available in 5m strips at a relatively moderate price.



Commercial lamps

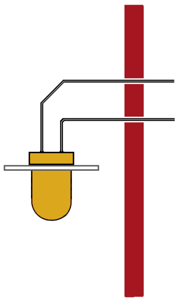
The images below show a range of commercially-available lamps (they are not to scale). They include gas lamps and electric lamps, old lamps and modern. They are available as wall lamps, street lamps, platform lamps, yard lamps, etc.   Most use LEDs but some are still produced using grain of wheat bulbs.

Manufacturers include Busch, Viessmann, Brawa – and unknown brands available on eBay. Double check before you buy, because some street lights, such as those from Faller and Ratio, are dummies.   They are cheap but contain no bulbs or LEDs.

Home-brew lamps

Some of the commercial lamps are quite intricate and would take a lot of effort to replicate.
However, they are quite expensive and it is quite easy to make some other types yourself.
The image on the right is of a commercial lamp using a filament bulb. The image on the left is a partly-made lamp using an LED. It is cheaper than the commercial version, uses a longer lasting lamp and its construction is quite straightforward.
The pole is a thin copper tube, which also acts as one of the conductors to the LED. The other conductor is a length of fine Kynar or Litz wire that is threaded down inside the tube. One lead from the LED is soldered directly on to the mast, with the other being soldered to the Kynar or Litz wire.
The mast is made from copper wire, or paper clips.
Ornate swirls are associated with period lamps, while modern lamps are more plain.
Similarly, you may select a yellow, white or ultra-white LED, depending on the period in which the layout is based.
A washer is glued to LED to appear as a lampshade; the top of the LED would be painted to prevent unwanted light being seen above the lamp.
The lamp is left unfinished to make it easier to see how it is constructed.
A hole would be drilled in the baseboard and the copper tube would be inserted and secured in the hole. The wire and the copper tube protruding under the baseboard would be wired to the lighting circuit.

This image shows a wall light made from an LED.
Again, a washer is glued to the LED and the LED area above the washer is painted to exclude light.
The wires from the LED are bent as shown in the sketch, to represent the lamp's bracket.



Two tiny holes are drilled in the wall of the building and the two wires are inserted into the holes.
After soldering the two wires to the leads of the lighting circuit, the wires can be secured in place behind the building wall. A simple bend of the LED's leads will stop the lamp from moving but you can always use glue or a glue gun if you prefer.

For very small lamps, or for smaller railway gauges, you could consider using surface mount LEDs. These are very small indeed (down to 1mm x 0.5mm).
They are also suitable for fabricating railway lamps for wagons and coaches, buffer stops, guard's lamps, etc. Their extra small size allows them to be fitted into seriously small spaces that other lamps could not use.

Fibre optics

Fibre optic filaments are used to transmit light over distances as, for example, in carrying data over telephone phone lines. The light source is attached at one end of the fibre strands and the light bounces along the strands.
The separation of light source from the eventual point of light is very useful for railway modellers, as it allows lights to be fitted where filament bulbs or even LEDs cannot be located.
Example uses of fibre optic lighting include:

- Headlights in small gauge vehicles.
- Headlights in locos.
- Guards' lanterns.
- Miners' helmets.
- Signs.
- Fluorescent tubes.

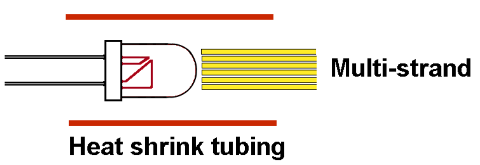
As one light source can handle multiple individual strands, it is ideal for places where many small lights are required. How about a star-lit sky, or the the city lights of a background scene?

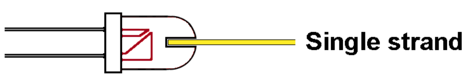
Fibre optics are produced in glass and plastic – we would use the polymer-based versions. These are sold either in single strands or as multi-strand cables.
You can buy single strands in different diameters ranging from 10mil to 120mil (e.g. 0.25mm to 3mm), depending on how much light you want to shift and how much space is available. You can also buy multi-strand versions, where 32 or 64 strands are contained within a single covering.

While any light source can be used, ultra bright white LEDs are commonly preferred. Unlike bulbs and LEDs, a single fibre optic strand does not project much of a beam of light; its light is meant to be looked at, not used for illuminating other things (unless you use a bundle of strands).

At the LED end

The strand(s) to be used should be prepared prior to fitting. The ends should be flat for maximum light transmission. A scalpel will normally cut a length of fibre strand neatly. If not, the end can be gently rub on a piece of wet and dry paper, fine grit paper or emery board. You can take it further by polishing the end by rubbing it with toothpaste.
The strand(s) should be fitted close to the LED's body.
If using a single LED, a hole the same diameter as the strand can be drilled through the LED's epoxy casing (as deep as possible without damaging the LED elements).
Ensure that the hole is drilled as close to the centre of the dome as possible; alignment is more important than proximity.
The strand is inserted into the hole and secured using any plastic-friendly glues. This includes a glue gun, epoxy, silicone glue, polyurethane glues but not Super Glue or any Cyanoacrylate (CA) as these will attack the plastic of the strand(s).



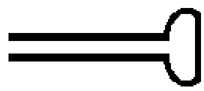


A multi-strand cable can be attached to the LED by covering both with a length of tape or, better still, a length of heat shrink tubing. If using heat shrink tubing, make sure you avoid overheating the fibre strands inside, as this will degrade their light transmitting properties. You can make your own multi-strand fibre cables, using as many strands as you need. You would bundle them together using a suitable diameter length of heat shrink tubing. Then you would cut and polish for best effect before encasing the bundle ends with the LED in a larger diameter length of heat shrink tubing.

At the light end

Single strands are so thin that they can be easily routed in most layouts. The LED can be located under the baseboard or in a lineside structure. The strand can be routed through a hole in the baseboard or structure and is flexible. It can bent to a radius of around 9mm radius for thinner strands or 20mm for thicker strands, although over-bending may result in some loss of light. Because they are so thin, they can be routed above the baseboard; under grass, roadways, track (there are no mutual interference problems). Strands can be painted with no ill effects on the fibre strands.

Fibre optic strands do not give a very wide viewing angle – you have to be looking directly at the end of the strand.
This can be improved by shaping the end of the strand.
The first drawing shows creating a 'bell end', by briefly touching the end of the strand against the stalk of a soldering iron and gently pushing into the strand. The end now offers an improved viewing angle.



If you heat the end of the strand and then, before it cools, flatten it with any tool. This produces a disc-like illuminated surface that can be viewed side-on instead of the usual end-on. See the second drawing.

Other effects

The light zig-zags along the fibre strand, bouncing off the smooth wall surfaces. If you scratch the strand surface, you will lose some of the light.
This can be a problem but is also an opportunity.
If you scrape the outer surface of a length of fibre strand, using wet-and-dry or fine grit paper, you create an illuminated length that looks very much like a fluorescent tube. If you want to take it further, you can light the strand from a LED that is driven by a 'twinkler' circuit, and you get the effect of a flickering fluorescent light. The same approach can be used to create neon signs, using coloured LEDs.

How about making your own sign? Take a piece of plastic sheet, drill holes where you want the lights to be and insert strands into each hole. The sign can be your own design, using as many strands as are required from a multi-strand source. Even better, you could animate the sign by having two or more sets of LED-fed strands and switching between them.

Lastly, for those with the eyesight and necessary skills, how about lighting figures on your layout? Station staff holding lanterns, miners' helmets, etc. are possible.
Once more, your imagination can add to the effects listed above.