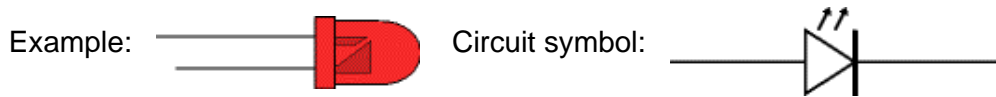


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# Light Emitting Diodes (LEDs)



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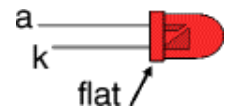


## Function

LEDs emit light when an electric current passes through them.

## Connecting and soldering

LEDs must be connected the correct way round, the diagram may be labelled **a** or **+** for anode and **k** or **-**

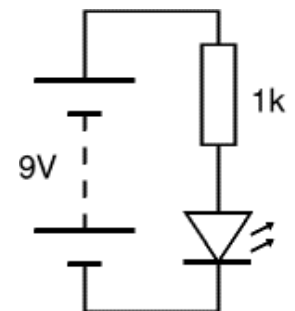


for cathode (yes, it really is k, not c, for cathode!). The cathode is the short lead and there may be a slight flat on the body of round LEDs. If you can see inside the LED the cathode is the larger electrode (but this is not an official identification method).

LEDs can be damaged by heat when soldering, but the risk is small unless you are very slow. No special precautions are needed for soldering most LEDs.

## Testing an LED

**Never connect an LED directly to a battery or power supply!**

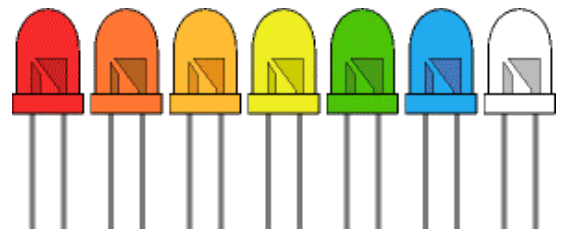


It will be destroyed almost instantly because too much current will pass through and burn it out.

LEDs must have a resistor in series to limit the current to a safe value, for quick testing purposes a 1k $\Omega$  resistor is suitable for most LEDs if your supply voltage is 12V or less. **Remember to connect the LED the correct way round!**

For an accurate value please see [Calculating an LED resistor value](#) below.

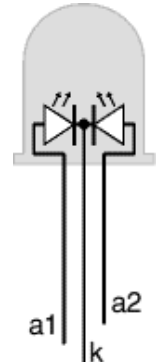
## Colours of LEDs



LEDs are available in red, orange, amber, yellow, green, blue and white. Blue and white LEDs are much more expensive than the other colours.

The colour of an LED is determined by the semiconductor material, not by the colouring of the 'package' (the plastic body). LEDs of all colours are available in uncoloured packages which may be diffused (milky) or clear (often described as 'water clear'). The coloured packages are also available as diffused (the standard type) or transparent.

## Tri-colour LEDs



The most popular type of tri-colour LED has a red and a green LED combined in one package with three leads. They are called tri-colour because mixed red and green light appears to be yellow and this is produced when both the red and green LEDs are on.

The diagram shows the construction of a tri-colour LED. Note the different lengths of the three leads. The centre lead (k) is the common cathode for both LEDs, the outer leads (a1 and a2) are the anodes to the LEDs allowing each one to be lit separately, or both together to give the third colour.

## Bi-colour LEDs

A bi-colour LED has two LEDs wired in 'inverse parallel' (one forwards, one backwards) combined in one package with two leads. Only one of the LEDs can be lit at one time and they are less useful than the tri-colour LEDs described above.

## Sizes, Shapes and Viewing angles of LEDs



LED Clip

Photograph © [Rapid Electronics](#)

LEDs are available in a wide variety of sizes and shapes. The 'standard' LED has a round cross-section of 5mm diameter and this is probably the best type for general use, but 3mm round LEDs are also popular.

Round cross-section LEDs are frequently used and they are very easy to install on boxes by drilling a hole of the LED diameter, adding a spot of glue will help to hold the LED if necessary. LED clips are also available to secure LEDs in holes. Other cross-section shapes include square, rectangular and triangular.

As well as a variety of colours, sizes and shapes, LEDs also vary in their viewing angle. This tells you how

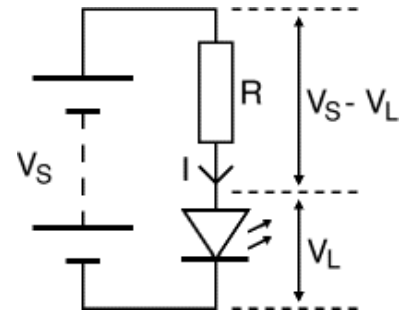
much the beam of light spreads out. Standard LEDs have a viewing angle of 60° but others have a narrow beam of 30° or less.

### [Rapid Electronics](#)

stock a wide selection of LEDs and their catalogue is a good guide to the range available.

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## Calculating an LED resistor value



An LED must have a resistor connected in series to limit the current through the LED, otherwise it will burn out almost instantly.

The resistor value,  $R$  is given by:

$$R = (V_S - V_L) / I$$

$V_S$  = supply voltage

$V_L$  = LED voltage (usually 2V, but 4V for blue and white LEDs)

$I$  = LED current (e.g. 20mA), this must be less than the maximum permitted

If the calculated value is not available choose the nearest standard resistor value which is **greater**, so that the current will be a little less than you chose. In fact you may wish to choose a greater resistor value to reduce the current (to increase battery life for example) but this will make the LED less bright.

### For example

If the supply voltage  $V_S = 9V$ , and you have a red LED ( $V_L = 2V$ ), requiring a current  $I = 20mA = 0.020A$ ,  
 $R = (9V - 2V) / 0.02A = 350\Omega$ , so choose  $390\Omega$  (the nearest standard value which is greater).

### Working out the LED resistor formula using Ohm's law

Ohm's law says that the resistance of the resistor,  $R = V/I$ , where:

$V$  = voltage across the resistor (=  $V_S - V_L$  in this case)

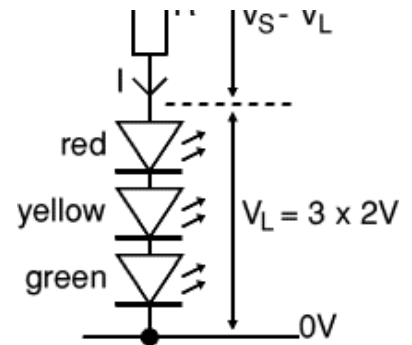
$I$  = the current through the resistor

So  $R = (V_S - V_L) / I$

For more information on the calculations please see the [Ohm's Law](#) page.

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## Connecting LEDs in series



If you wish to have several LEDs on at the same time it may be possible to connect them in series. This prolongs battery life by lighting several LEDs with the same current as just one LED.

All the LEDs connected in series pass the **same current** so it is best if they are all the same type. The power supply must have sufficient voltage to provide about 2V for each LED (4V for blue and white) plus at least another 2V for the resistor. To work out a value for the resistor you must add up all the LED voltages and use this for  $V_L$ .

#### Example calculations:

A red, a yellow and a green LED in series need a supply voltage of at least  $3 \times 2V + 2V = 8V$ , so a **9V battery** would be ideal.

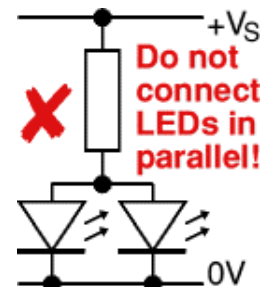
$V_L = 2V + 2V + 2V = 6V$  (the three LED voltages added up).

If the supply voltage  $V_S$  is 9V and the current  $I$  must be  $15mA = 0.015A$ ,

Resistor  $R = (V_S - V_L) / I = (9 - 6) / 0.015 = 3 / 0.015 = 200\Omega$ ,

so choose  $R = 220\Omega$  (the nearest standard value which is greater).

### Avoid connecting LEDs in parallel!



Connecting several LEDs in parallel with just one resistor shared between them is generally not a good idea.

If the LEDs require slightly different voltages only the lowest voltage LED will light and it may be destroyed by the larger current flowing through it. Although identical LEDs can be successfully connected in parallel with one resistor this rarely offers any useful benefit because resistors are very cheap and the current used is the same as connecting the LEDs individually. **If LEDs are in parallel each one should have its own resistor.**

### Reading a table of technical data for LEDs

Suppliers' catalogues usually include tables of technical data for components such as LEDs. These tables contain a good deal of useful information in a compact form but they can be difficult to understand if you are not familiar with the abbreviations used.

The table below shows typical technical data for some 5mm diameter round LEDs with diffused packages (plastic bodies). Only three columns are important and these are shown in bold. Please see below for

explanations of the quantities.

Type	Colour	I <sub>F</sub> max.	V <sub>F</sub> typ.	V <sub>F</sub> max.	V <sub>R</sub> max.	Luminous intensity	Viewing angle	Wavelength
Standard	Red	30mA	1.7V	2.1V	5V	5mcd @ 10mA	60°	660nm
Standard	Bright red	30mA	2.0V	2.5V	5V	80mcd @ 10mA	60°	625nm
Standard	Yellow	30mA	2.1V	2.5V	5V	32mcd @ 10mA	60°	590nm
Standard	Green	25mA	2.2V	2.5V	5V	32mcd @ 10mA	60°	565nm
High intensity	Blue	30mA	4.5V	5.5V	5V	60mcd @ 20mA	50°	430nm
Super bright	Red	30mA	1.85V	2.5V	5V	500mcd @ 20mA	60°	660nm
Low current	Red	30mA	1.7V	2.0V	5V	5mcd @ 2mA	60°	625nm

**I<sub>F</sub> max.** Maximum forward current, forward just means with the LED connected correctly.

**V<sub>F</sub> typ.** Typical forward voltage, V<sub>L</sub> in the LED resistor calculation.  
This is about 2V, except for blue and white LEDs for which it is about 4V.

**V<sub>F</sub> max.** Maximum forward voltage.

**V<sub>R</sub> max.** Maximum reverse voltage  
You can ignore this for LEDs connected the correct way round.

**Luminous intensity** Brightness of the LED at the given current, mcd = millicandela.

**Viewing angle** Standard LEDs have a viewing angle of 60°, others emit a narrower beam of about 30°.

**Wavelength** The peak wavelength of the light emitted, this determines the colour of the LED.  
nm = nanometre.

## Flashing LEDs

Flashing LEDs look like ordinary LEDs but they contain an integrated circuit (IC) as well as the LED itself. The IC flashes the LED at a low frequency, typically 3Hz (3 flashes per second). They are designed to be connected directly to a supply, usually 9 - 12V, and no series resistor is required. Their flash frequency is fixed so their use is limited and you may prefer to build your own circuit to flash an ordinary LED, for example our [Flashing LED](#) project which uses a 555 astable circuit.

## LED Displays

LED displays are packages of many LEDs arranged in a pattern, the most familiar pattern being the 7-segment displays for showing numbers (digits 0-9). The pictures below illustrate some of the popular designs:



Bargraph

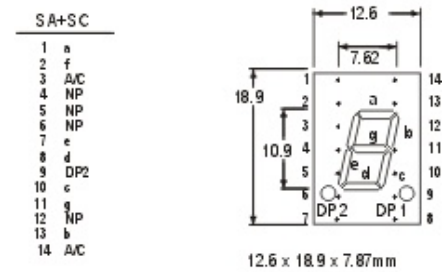
7-segment

Starburst

Dot matrix

Photographs © [Rapid Electronics](http://www.kpsec.freeuk.com)

## Pin connections of LED displays



Pin connections diagram

© [Rapid Electronics](http://www.kpsec.freeuk.com)

There are many types of LED display and a supplier's catalogue should be consulted for the pin connections. The diagram on the right shows an example from the [Rapid Electronics](http://www.kpsec.freeuk.com) catalogue. Like many 7-segment displays, this example is available in two versions: Common Anode (SA) with all the LED anodes connected together and Common Cathode (SC) with all the cathodes connected together. Letters a-g refer to the 7 segments, A/C is the common anode or cathode as appropriate (on 2 pins). Note that some pins are not present (NP) but their position is still numbered.

Also see: [Display Drivers](http://www.kpsec.freeuk.com).

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