EcoFX
LED lighting solutions

LED's

LED History & Evolution

Light Emitting Diodes or LEDs operate very differently to filament lamps, discharge lamps and fluorescent tubes.

They operate by 'Injection electroluminescence', a phenomenon first observed in 1907 by H. J. Round experimenting with Silicon Carbide. However, as he was really looking for new ways of radiolocation in seafaring, his discovery was completely forgotten about.

It wasn't until 1962 that the first red LEDs were invented.

The first digital watch, the 1972 Pulsar 'Time Computer', used LEDs for its display.

By the mid 70's other colours had joined red including yellow, orange and green, although the efficiency and light output was still very poor.

Between 1970 and 1995 the light output of red LEDs increased by a factor of approx. 45 and between 1995 and 2003 the efficiency of LEDs increased by an average factor of 16 and the light output per LED package by a factor of 430.

LED History & Evolution

The net result is that today LEDs have the efficiency and light output to be considered for many varied applications including traffic signals and signs, large area video displays and car instrument and switch illumination.

Since 2005 further developments have seen a rapid growth in the use of LEDs for higher levels of illumination. For example LEDs will replace incandescent lamps (including headlamps) in cars by 2010.

LEDs are already used for general lighting applications and decorative lighting and will replace some conventional light sources in the near future.

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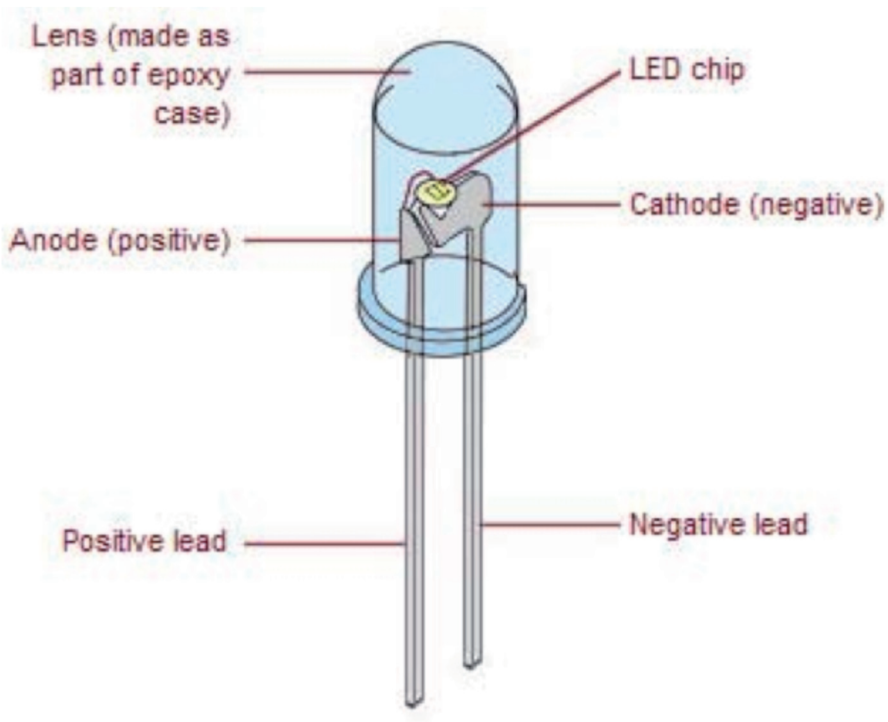
What is a Light Emitting Diode?

A Light Emitting Diode (LED) is a ‘solid state’ electronic component with the characteristics of a diode i.e. it only allows electrical current to flow in one direction through it. When the current flows through an LED in the correct direction, the LED produces light of a specific colour.

LED’s only produce light of certain specific colour. Due to a variation on the method used to manufacture LEDs that emit white light different colour temperatures are available - e.g. 6500K, 5400K, 4700K, 3300K and 2700K.



The component parts of a discrete LED

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Discrete LEDs & LED Modules Discrete LEDs

Individual LEDs are called discrete LEDs.

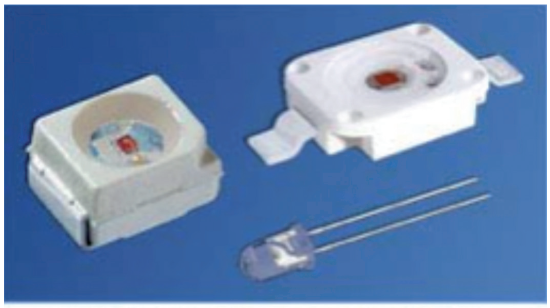
To be of practical use, discrete LEDs are assembled (mounted) onto printed circuit boards (PCBs), usually with additional electronic components to control the current flowing through the LED.

Through Hole or Radial LEDs

There are different types of discrete LEDs. Some have legs that pass through holes on a circuit board and are fixed in place by soldering underneath the circuit board. These are called 'through hole' or 'radial' type LEDs.

Surface Mount LEDs

The more modern type of LED sits on the top of the circuit board and is soldered automatically so that the solder joint is on the top of the circuit board. These are called 'surface mount' LEDs. Surface mount LEDs range in size from tiny LEDs that measure only 0.5 x 1.5 x 0.3mm (used in space efficient equipment like mobile phones) to 'power' LEDs measuring 20 x 20 x 2.5mm or larger.



State of the art surface mounted LEDs TOPLED, Golden DRAGON and radial LEDs

Discrete LEDs & LED Modules LED Modules

An assembly of one or more discrete LEDs in a unit for lighting or display is a modular LED. Although it is possible to construct a module using radial LEDs, they are usually made using surface mount LEDs using automated techniques.

Part of an OSRAM LINEARlight Colormix module. The discrete surface mount LEDs are the white rectangular components.

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How do LEDs work?

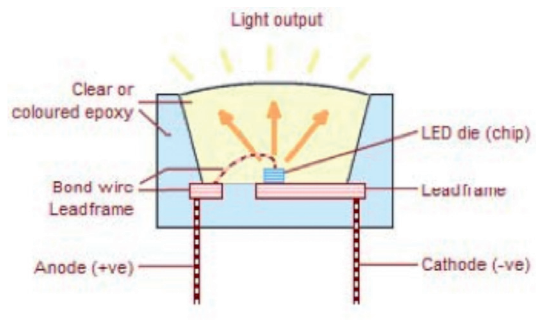
At the heart of every LED there is a very small piece of semi-conducting material called the LED 'die'. The die can be considered in the same way as the filament in a lamp, because it is the die that produces the light. The size of a high power LED die is approximately a 1mm cube and for other LED types much smaller.

The base of the die is glued or soldered into a fine metal framework (the leadframe). A very fine wire called a bond wire is attached to the top of the LED die, which has a very fine conductive metal pattern on it. The wire is attached to the other side of the leadframe.

When electricity of the correct voltage and polarity is applied to the LED via the leadframe contacts, current flows through the die.

The different properties of the layers in the die cause between 50 and 90% of this electrical energy to be converted into light at the junction by a process called 'injection electroluminescence'. This process is significantly more efficient than virtually any other light source!

Injection electroluminescence does not require heat like a filament lamp (incandescence) or chemicals that glow like those used for a fluorescent tube (fluorescence). It is a phenomenon that is caused entirely by atomic differences in the material caused by doping (see next page).



Basic LED structure

Efficiency

Unfortunately, a large proportion of the light produced at the junction does not escape from the die and is reabsorbed, the remainder being converted to heat. As this is an on-going development process efficiency is increasing continuously. Even so, the LED is very efficient compared to conventional light sources. For example, an LED traffic signal will consume only 25 to 30% of the energy of a halogen lamp to achieve the same performance.

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How LEDs are made

An LED die is manufactured in a ‘wafer fabrication plant’. In the plant, different chemicals called dopants are passed over circular wafers of very pure semiconducting material (the substrate) as gasses or liquids at high temperatures. Two different sets of dopants diffuse into the wafer to form two distinct layers with different atomic and therefore different electrical properties. The boundary between these two layers is called a junction, and it is at this boundary that the electroluminescence occurs.

When the diffusion process is complete, the surface of the die can then be shaped to help light escape from it by masking and etching the surface. This is followed by the formation of a very fine metal pattern on the top of the die (metallisation) which will be used to carry electrical current.

Finally, the wafer is sawn into individual LED die, sometimes with a shaped saw blade. The sawn wafer is transferred to another facility (backend production) where the LED die are mounted individually with a glue or solder that conducts electricity onto one side of a fine metal ‘framework’, the leadframe of the LED. One end of a very fine wire called a bond wire is then attached to the metal pattern on the top of the LED, the other end being attached to the other side of the leadframe.

The leadframe is then moulded into a solid epoxy block to give the whole assembly strength and a final casting protects the die. The LEDs are then automatically tested and grouped before being packaged and sent to the warehouse.

LED Colours

The light emitted by an LED is of a specific colour and wavelength respectively depending on the dopant chemicals that were diffused into the die and is a virtually monochromatic saturated colour.

Indium, Gallium and Nitrogen dopant chemicals produce LEDs that emit light in bands ranging from blue through to green. These are often called ‘InGaN’ LEDs after the chemical symbols for the dopants (In, Ga and N).

Indium, Gallium, Aluminium and Phosphor dopants produce LEDs that emit light in bands ranging from green to red. These are often called ‘InGaAlP’ LEDs after the chemical symbols for the dopants (In, Ga, Al, P) are rearranged.

At present, commercially available LEDs produce light of certain specific colour. White light is generated by using light of a blue LED and a yellow phosphor which converts a part of the blue light into yellow light. Depending on the ratio between blue and yellow light different colour temperatures can be achieved.

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Multi-colour LEDs

The light from individual LEDs, particularly the primary colours red, green and blue, can be mixed together to produce a wider range of colours than even the highest quality TV!

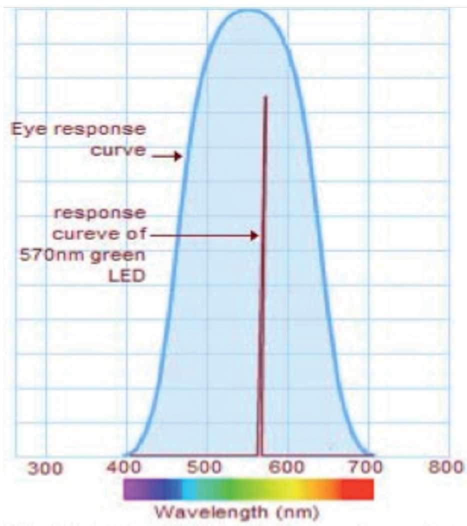
Manufacturers produce a number of LED packages that contain three die rather than one. One of the modules using MULTILED such as the Osram LINEARlight Colormix range which is also available on flexible boards.

By incorporating a red, green and blue LED die into the same package the LED can be used for applications ranging from large area video screens using up to 50,000 LEDs per square metre, to colour changing luminaries for lighting whole buildings. into yellow light. Depending on the ratio between blue and yellow light different colour temperatures can be achieved.

White LEDs

An LED die emits coloured light that is virtually monochromatic, so to produce white light a technique is used that is similar to that used in fluorescent tubes.

In a fluorescent tube, a gas discharge produces ultra violet light which causes a phosphor coating mix on the inside of the glass tube to fluoresce and emit usable white light.



The light of an LED is typically monochromatic - i.e. it consists of just one wavelength.

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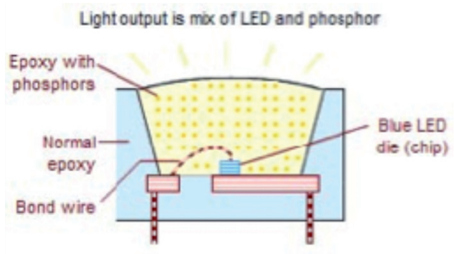
Structure of a single chip white LED:

A phosphor is added to the normally clear epoxy covering the LED die. Alternatively the latest technology provides a more homogeneous white light using chip level conversion (CLC), applying a thin phosphor layer on top of the die. A blue LED die stimulates the phosphor. The phosphor emits a yellowish light. The light from the phosphor and the blue LED combine to produce white light of different colour temperatures.



White LED operation

Colour temperature

Because the white light is produced by mixing the light from two sources (die and phosphor) and the proportions of light from the two sources can vary, the colour temperature of a white LED can lie between 2700K and 11000K. Grouping of these LEDs is therefore essential to ensure that there is little perceived difference in colour between individual discrete LEDs or LED modules. Manufacturers can offer their LED modules in three colour temperature groups so that customers can ensure consistency.

Why use LEDs for lighting

LEDs are very small light sources. It currently (in 2006) takes 21 of the highest output white LEDs to produce the same amount of light as a 100 Watt GLS lamp. But their small size can actually be advantageous in the design of small compact light sources and this is one of the many reasons why LEDs are now being used for general lighting applications.

Reliability

Unlike the majority of lamps, LEDs do not suffer 'catastrophic failures' (i.e. stop producing light in normal operation). With an LED, the light output gradually reduces over time, the rate of light output reduction being dependent primarily on the average operating temperature of the LED die (the junction temperature). As the time for the light output of an LED to decline to a level where it is no longer usable could be tens of years, then the agreed method for specifying LED lifetime is the time after which the light output falls to 50% of its original value. Even with this method, the lifetime for LEDs under the right conditions can be as much as 150,000 hours (17 years) continuous operation and the LED is still emitting usable light! As LEDs are solid in their construction and are not made from fragile materials they have a high immunity to shock and vibration.

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Efficiency

As mentioned above, it currently needs 21 white LEDs to duplicate the light output of a 100 Watt GLS lamp, but the power consumption of the LEDs would only be 45 Watts! However, a fluorescent lamp would consume in the region of 20 to 25 Watts to produce the same amount of light. At present (2006) white LEDs can offer energy efficient alternatives in some, but not all applications.

In applications where colour is utilised, LEDs often offer a higher efficiency than filtered white light sources, including fluorescent tubes which reduces heat dissipation, energy costs and the size and cost of power supplies. This in turn reduces the design and construction cost of luminaries as there is no need to accommodate LED replacement or to deal with very high temperatures.

Safe Low Voltage Operation

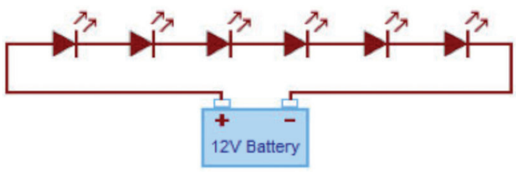
LED modules operate at either 10V, 24V or 350mA or 700mA - well within the limit for safe low voltage operation.

LED Modules

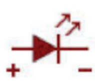
An LED has a turn-on (threshold) voltage between 1.3 and 2 Volts, depending upon the die type. LED’s can be stacked in series like batteries, the threshold voltages will add up e.g. six LED’s in series each with a threshold voltage of 2V gives a total voltage requirement of 6 x 2 = 12V.

Once the threshold voltage of the individual LED or string of LEDs has been reached, the LED(s) will draw current and begin to light. There are very few situations where discrete LEDs can be used reliably without at least one other electronic component to control the current flowing through them, and this task is usually performed by another simple electronic component, a resistor. A resistor in line (series) with the LED will also allow operation from higher voltages than the threshold voltage(s).

Another and more accurate alternative to control the LED current is to use a small integrated circuit (IC) to control the LED current. This is the approach utilised in OSRAM LED modules. LED modules provide users with a ‘ready to use’ LED lighting solution. The circuit boards that form the basis of the LED modules contain strings of LEDs together with the ICs to control the current and operate from 10V, 24V or 350mA and soon 700mA power supplies.



Six LEDs with 2V threshold voltage connected in series to a 12V supply.



The schematic symbol for an LED.

In this circuit an LED with a forward threshold of 1.6V is operated from a 6V supply by using a 220Ω resistor in series.

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