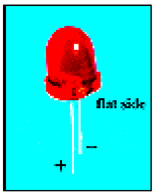
What is Inside an LED?

LED's are special diodes that emit light when connected in a circuit. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. A a clear (or often colored) epoxy case enclosed the heart of an LED, the semi-conductor chip.



LED leads

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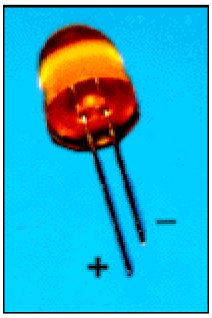
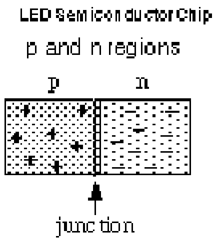
side lead on flat side of bulb = negative

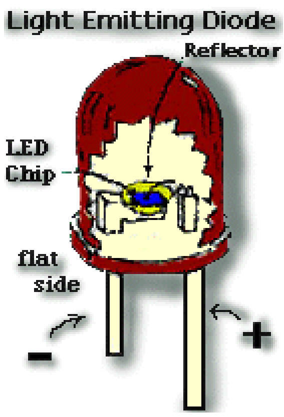


The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit. The *negative* side of an LED lead is indicated in two ways: 1) by the *flat side* of the bulb, and 2) by the *shorter* of the two wires extending from the LED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 *milli*amperes. Voltages and currents substantially above these values can melt a LED chip.



The most important part of a *light emitting diode (LED)* is the semi-conductor chip located in the center of the bulb as shown at the right. The chip has two regions separated by a *junction*. The *p region* is dominated by positive electric charges, and the *n region* is dominated by negative electric charges. The *junction* acts as a barrier to the flow of electrons between the *p* and the *n regions*. Only when sufficient voltage is applied to the semi-conductor chip, can the current flow, and the electrons cross the junction into the *p region*.

In the absence of a large enough electric potential difference (voltage) across the LED leads, the *junction* presents an electric potential barrier to the flow of electrons.



What Causes the LED to Emit Light and What Determines the Color of the Light?

When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the *junction* between the *p* and *n* regions. In the *p region* there are many more positive than negative charges. In the *n region* the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the *n region* have sufficient energy to move across the junction into the *p region*. Once in the *p region* the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the *p region*, the two charges "re-combine".

Each time an electron *recombines* with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colors are made of different semi-conductor materials, and require different energies to light them.

How Much Energy Does an LED Emit?

The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction. The different colored LED's emit predominantly light of a single color. The energy (E) of the light emitted by an LED is related to the electric charge (q) of an electron and the voltage (V) required to light the LED by the expression: $E = qV$ Joules. This expression simply says that the voltage is proportional to the electric energy, and is a general statement which applies to any circuit, as well as to LED's. The constant q is the electric charge of a single electron, -1.6×10^{-19} *Coulomb*.

Finding the Energy from the Voltage

Suppose you measured the voltage across the leads of an LED, and you wished to find the corresponding energy required to light the LED. Let us say that you have a red LED, and the voltage measured between the leads of is 1.71 Volts. So the Energy required to light the LED is $E = qV$ or $E = -1.6 \times 10^{-19}$ (1.71) Joule, since a Coulomb-Volt is a Joule. Multiplication of these numbers then gives $E = 2.74 \times 10^{-19}$ Joule.

Finding the Frequency from the Wavelength of Light

The frequency of light is related to the wavelength of light in a very simple way. The spectrometer can be used to examine the light from the LED, and to estimate the peak wavelength of the light emitted by the LED. But we prefer to have the frequency of the peak intensity of the light emitted by the LED. The wavelength is related to the frequency of light by $f = \frac{c}{\lambda}$, where c is the speed of light (3 x 10^8 m/s) and λ is the wavelength of light read from the spectrometer (in units of nanometers or 10^{-9} meters). Suppose you observed the red LED through the spectrometer, and found that the LED emits a range in colors with maximum intensity corresponding to a wavelength as read from the spectrometer of λ= 660 nm or 660 x 10^{-9} m. The corresponding frequency at which the red LED emits most of its light is $f = \frac{3 \times 10^8}{660 \times 10^{-9}} \frac{ms^{-1}}{m}$ or 4.55 x 10^{14} *Hertz*. The unit for one cycle of a wave each second (cycle per second) is a Hertz.

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