

Light Emitting Diodes - A Primer

Russ Dahl, Opto Diode Corporation

From the Web Exclusive, "Seeing the True Colors of LEDs."

Light emitting diodes (LEDs) are semiconductors that convert electrical energy into light energy. The color of the emitted light depends on the semiconductor material and composition. The LEDs are generally classified into three wavelengths: Ultraviolet, visible and infrared.

The wavelength range of commercially available LEDs with single-pixel-output power of at least 5mW is 360nm to 950nm. Each wavelength range is made from a specific semiconductor material family, regardless of the manufacturer.

Ultraviolet LEDs (UV LEDs): 320nm - 360nm

UV LEDs are rapidly becoming commercialized, specifically used for industrial curing applications and medical/biomedical uses. Until recently, the lower wavelength limitation for high-efficiency die was at 390nm. It has been moved to 360nm and further developments over the next few years will likely see the commercialization of high efficiency die in the 320nm region.

The material primarily used for UV LED's is gallium nitride/aluminum gallium nitride (GaN/AlGaN). At this time the technology does not yield high power LED's and the market is unsettled as several companies are moving to improve their processes.

Near UV to Green LEDs: 395nm - 530nm

The material for this wavelength range of products is indium gallium nitride (InGaN). It is technically possible to make a wavelength anywhere between 395nm and 530nm. However, most large suppliers concentrate on creating blue (450nm- 475nm) LEDs for making white light with phosphors and green LEDs that fall into the 520nm - 530nm range for traffic signal green lighting.

Rapid advancements and improvements in efficiency are noted in the blue wavelength range, especially, as the race to create brighter and brighter, white illumination sources continues.

Yellow-Green to Red LEDs: 565nm - 645nm

Aluminum indium gallium phosphide (AlInGaP) is the semiconductor material used for this wavelength range. It is predominately used for traffic signal yellow

(590nm) and red (625nm) lighting. The lime green (or yellowish-green 565nm) and orange (605nm) are also available from this technology, but they are somewhat limited. The technology is rapidly advancing on the red wavelength in particular because of the growing commercial interest in making red-green-blue white lights.

It is interesting to note that neither the InGaN or AlInGaP technologies are available as a pure green (555nm) emitter. Older, less efficient technologies do exist in this pure green region, but they are not considered efficient or bright. This is due largely to a lack of interest and/or demand from the market place and therefore a lack of funding to develop alternative material technologies for this wavelength region.

Deep Red to Near Infrared (IRLEDs): 660nm - 900nm

There are many variations on device structure in this region, but all use a form of Aluminum Gallium Arsenide (AlGaAs) or Gallium Arsenide (GaAs) materials. There is still a push to increase the efficiency of these devices, but the increases are only incremental improvements. Applications include infrared (IR) remote controls, night vision illumination, industrial photocontrols and various medical applications (at 660nm - 680nm).

Theory of LED Operation

LEDs are semiconductor diodes that emit light when an electrical current is applied in the forward direction of the device. An electrical voltage that is large enough for the electrons to move across the depletion region and combine with a hole on the other side to create an electron-hole pair must be applied. As this occurs, the electron releases its energy in the form of light and the result is an emitted photon.

The bandgap of the semiconductor determines the wavelength of emitted light. Shorter wavelengths equal greater energy and therefore higher bandgap materials emit shorter wavelengths. Higher bandgap materials also require higher voltages for conduction. Short wavelength UV-Blue LED's have a forward voltage of 3.5 volts while near-IR LEDs have a forward voltage of 1.5 - 2.0 volts.

Wavelength Availability and Efficiency Considerations

High efficiency LEDs can be produced in any wavelength range, with one exception - the 535nm to 560nm range. The overriding factor as to whether or not a specific wavelength is commercially available has to do with market potential, demand, and industry-standard wavelengths. This is particularly pronounced in the 420nm - 460nm, 480nm - 520nm, and the 680nm - 800nm regions. Because there are no high-volume applications for these wavelength ranges, there are no high-volume manufacturers providing LED products for these ranges. It is possible, though, to find medium and/or small suppliers offering products to fill these particular wavelengths on a custom basis.

Each material technology has a spot within the wavelength range where it is most efficient. This point is very close to the middle of each range. As the doping level of the semiconductor increases or decreases from the optimal amount, efficiency suffers. That is why a blue LED has much greater output than green or near UV, amber has more than yellow-green, and near IR is better than 660nm. When given a choice, it is much better to design for the center of the range than at the edges. It is also easier to procure products if you are not operating at the edges of the material technology.

Supplying current and voltage to LEDs

While LEDs are semiconductors and need a minimum voltage to operate, they are still diodes and need to be operated in a current mode. There are two main ways to operate LEDs in DC mode. The easiest and most common is using a current limiting resistor (See Fig. 1). The disadvantage to this method is the high heat and power dissipation in the resistor. In order for the current to be stable over temperature changes and from device-to-device, the supply voltage should be much greater than the forward voltage of the LED.

In applications where the operating temperature range is narrow (less than 30°C) or the output of the LED is not critical, a simple circuit utilizing a current limiting resistor may be used as shown here:

A better way to drive the LED is with a constant current source (See Fig. 2). This circuit will provide the same current from device-to-device and over temperature shifts. It also has lower power dissipation than using a simple current limiting resistor.

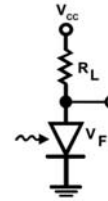


Fig. 1 - The current value is found by applying the equation $I = (V_{CC} - V_F) / R_L$. To be absolutely certain of the current flow in the circuit, each LED V_F would have to be measured and the appropriate load resistor specified. In practical commercial applications V_{CC} is designed to be much larger than V_F and thus the small changes in V_F do not affect the overall current by a large amount. The negative aspect of this circuit is a large power loss through R_L .

Commercial, off-the-shelf LED drivers are available from a number of different sources. Typically these operate using pulse width modulation (PWM) principles for brightness control.

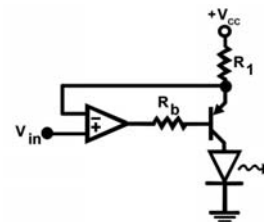


Fig. 2 - An example of an accurate and stable circuit. This circuit is commonly referred to as a constant current source. Note that the supply current is determined by the supply voltage (V_{CC}) minus V_{in} divided by R_1 , $(V_{CC} - V_{in}) / R_1$.

Pulsing LEDs in high current and/or high voltage mode for arrays in series-parallel configuration creates a unique set of problems. For the novice designer it is not practical to design a current-controlled pulse drive with the capability to deliver 5 amps and 20 volts. There are a few manufacturers of specialty equipment for pulsing LEDs (See Fig. 3), such as Gardasoft Vision (www.gardasoft.co.uk).



Fig. 3 - Gardasoft Vision's PP500 Series LED Lighting Controller

