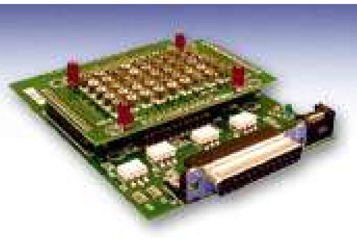
Application Notes



What is an LED?

A light-emitting diode (LED) is a solid-state semiconductor device that converts electrical energy directly into light. On its most basic level, the semiconductor is comprised of two regions. The p-region contains positive electrical charges while the n-region contains negative electrical charges. When voltage is applied and current begins to flow, the electrons move across the n region into the p region. The process of an electron moving through the p-n junction releases energy. The dispersion of this energy produces photons with visible wavelengths.

LED Colors

Human beings perceive different visible wavelengths of light as colors including red (longest wavelength), orange, yellow, green, blue, and violet (shortest wavelength). The color emitted from an LED can be identified by its peak wavelength (λ_{pk}). Peak wavelength is defined as the single wavelength of saturated color at the peak of the radiated spectrum (Figure 1). The nanometer (one-billionth of a meter) is the measurement unit for peak wavelength.

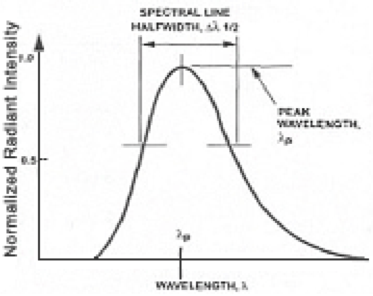
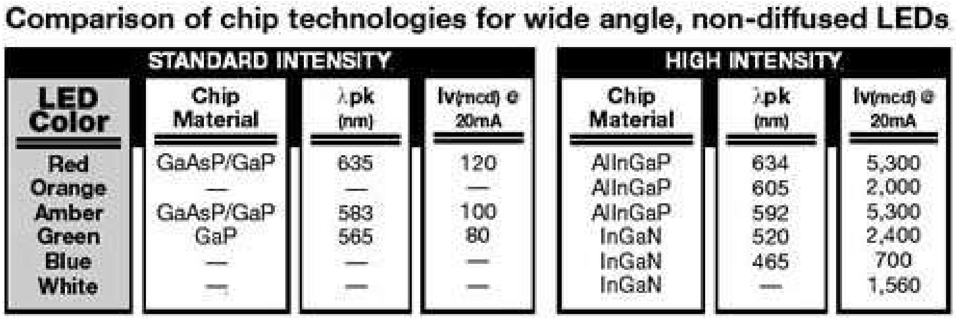


Fig. 1

Different LED chip technologies produce distinct colors. The color of the light depends on the chip material used. LED chips are made from gallium-based crystals that contain one or more additional materials such as phosphorous. For example, AlInGaP and InGaN, are used for creating high brightness LEDs in all colors from blue through red.



Comparison of chip technologies for wide angle, non-diffused LEDs

	STANDARD INTENSITY			HIGH INTENSITY		
LED Color	**Chip Material**	**λpk (nm)**	**Iv(mcd) @ 20mA**	**Chip Material**	**λpk (nm)**	**Iv(mcd) @ 20mA**
Red	GaAsP/GaP	635	120	AlInGaP	634	5,300
Orange	—	—	—	AlInGaP	605	2,000
Amber	GaAsP/GaP	583	100	AlInGaP	592	5,300
Green	GaP	565	80	InGaN	520	2,400
Blue	—	—	—	InGaN	465	700
White	—	—	—	InGaN	—	1,560

As a result of the LED fabrication process, peak wavelength can vary ±5 nm; however, it may not be detectable. The sensitivity level of the human eye is highest in the 565 to 600 nm wavelength range of the visual light spectrum (Figure 2). Therefore, it is easier to perceive color variations in yellow and amber LEDs than other colors.

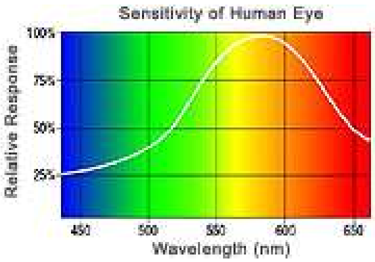


Fig. 2 - Human Eye Sensitivity

White LED Technology

Because red, blue, and green lights, mixed in varying quantities, can duplicate any color sensation, they are called primary additive colors. Equal intensities of all three lights added together produce the sensation of white light. However, to achieve this combination with a mixture of red, green, and blue LEDs requires a sophisticated electro-optical design to

Fig. 3 - Phosphor Coating

control the blend and diffusion of colors. Variations in LED color and intensity further complicate this approach.

DDP's White LED product line is based on a single InGaN blue LED chip with a phosphor coating. Phosphor emits white light when struck by blue or ultraviolet photons (Figure 3). (Fluorescent bulbs work by a similar principle; ultraviolet emission from an electric discharge in the tube causes the phosphor to shine white). Although the InGaN white LED process produces various hues, variation can be controlled through screening. DDP's white LED products are screened based on four specific chromaticity coordinates nearest to the center of the CIE diagram (Figure 4). The CIE diagram depicts all possible color coordinates on or inside the horseshoe curve. Pure colors lie on the curve, whereas the white point is in the center.

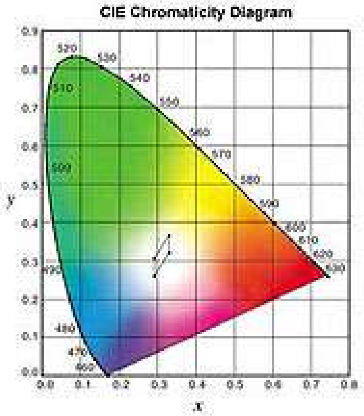


Fig. 4 - CIE Chromaticity

The four points depicted in the center of the graph represent the white LED output color. Although the four x/y coordinates are close to pure white, white LEDs are generally not effective as a universal light source to illuminate colored lenses. White LEDs are primarily useful to backlight opaque, white, or clear lenses. As this technology continues to improve, white LEDs will surely gain popularity as a source of illumination as well as indication.

Measuring LED Intensity

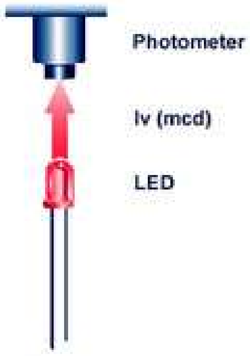


Fig. 5

Since LEDs are highly directional, light output can be measured at a single point (Figure 5). This on-axis luminous intensity value (I_v) is generally rated in terms of millicandela (mcd). The measurement of luminous intensity should not be confused with mean spherical candlepower (mscp) values used to quantify the light produced by incandescent bulbs. Mean spherical candlepower is defined as the average luminous intensity emitted within a sphere surrounding the light source.

LED light output varies with the type of chip, encapsulation, efficiency of individual wafer lots and operating current. Luminous intensity is roughly proportional to the amount of current (I_f) supplied to the LED; the greater the current, the higher the intensity. Of course, there are design limits. Generally, LEDs are designed to operate at 20 milliamps (mA). However, operating current must be reduced relative to the amount of heat in the application.

Visibility Considerations

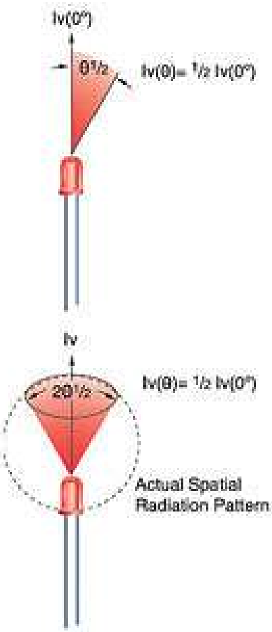


Fig. 6
- LED viewing angle

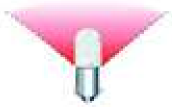
Luminous intensity (I_v) is not the only representation of the total light output from an LED. Both the luminous intensity and the spatial radiation pattern (viewing angle) must be taken into account. If two LEDs have the same luminous intensity value, the lamp with the larger viewing angle will have the higher total light output. LED viewing angle is a function of the LED chip type and the epoxy lens that distributes the light. The shape of the LED encapsulation acts as a lens magnifying the light from the LED chip. The off-axis point where the LED intensity is 50% of the on-axis intensity is known as theta one-half (8½) (Figure 6). Two times 8½ is the LEDs' full viewing angle; however, light is visible beyond the 8½ point. Viewing angles listed in this catalog are identified by their full viewing angle (28½o).

Generally, an LED with high luminous intensity will have a narrow viewing angle. This is because the light is concentrated in a tight beam. If the LED encapsulation is diffused, the light is scattered throughout the encapsulation so it will be visible over a wider area, but the intensity will be lower.

Increasing the number of LEDs in a design and utilizing secondary optics to distribute light can enhance visibility. To illustrate, consider LEDs in four different lamp packages:

MB400-NFX
Wide Angle/Flat-topped

MB400-NWX
High Intensity



MB403
.39" diameter lens

MB402
.59" diameter lens

In each case, the amount of visible light depends on how the LED is being viewed. The high intensity LED would appropriate for direct viewing in high ambient light. The wide angle/flat-topped LED may be better suited to backlight a switch or small legend, while the lensed LEDs may be best to illuminate a larger lens.

LED Lifetime and Reliability

Because LEDs are solid-state devices they are not subject to catastrophic failure when operated within design parameters. By definition, a solid-state device controls current without heated filaments and is therefore very reliable. In comparison, incandescent bulbs radiate much of their energy in the non-visible spectrum, generating heat as well as light. This results in an unpredictable lifetime due to risk of filament burn out.

LED operating life is characterized by the degradation of LED intensity over time. When the LED degrades to half of its original intensity it is at the end of its useful life although the LED will continue to operate as output diminishes. High-quality GaP LEDs will operate upwards of 100,000 hours while InGaN LED lifetime should exceed 50,000 hours.

Voltage and Current Considerations

LEDs are current-driven devices, not voltage driven. Although drive current and light output are directly related, exceeding the maximum current rating will produce excessive heat within the LED chip due to excessive power dissipation. The result will be reduced light output and reduced operating life.

To ensure LED longevity and reliability, we consider heat dissipation and other degradation factors in the design of our LED products. For operation at any given voltage, we build-in a current limiting resistor, a full-bridge rectifier, a protection diode, or other circuitry to protect the LED.

Eye Safety Information

The need to place eye safety labeling on LED products is dependent upon the product design and the application. Only a few LEDs produce sufficient intensity to require eye safety labeling. However, for eye safety, do not stare into the light beam of any LED at close range.

Electro-Static Discharge

InGaN LEDs are class 1 ESD sensitive (MIL-STD-1686). Exceeding absolute maximum ratings may cause damage to, or possible result in failure of these devices. Damaged LEDs can appear dim, dead, short, or with low voltage drop. Use appropriate ESD precautions during handling and operation.

Technical Support

DDP applications engineers are readily available to answer technical questions regarding DDP® LED technology. Whether designing DDP® LEDs into new OEM products or replacing incandescent bulbs with solid-state DDP® LED lamps, Data Display Products will support your efforts with technical advice and free samples for evaluation.

If a custom design is required, DDP will build to your specification or design a product to fit your application.

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