# An Introduction to Light Emitting Diodes

## While consumers today think of LEDs primarily in terms of lighting or display technologies, they are useful in myriad other applications such as commercial, industrial, automotive, and scientific.

Light emitting diodes (LEDs) have become ubiquitous in recent years due to their increasing use in lighting and display products. LEDs are electronic semiconductor devices (diodes) that emit light at different wavelengths depending on the substrate semiconductor material used when an electrical current is applied. LEDs can be constructed to produce light at many different wavelengths, both visible and invisible. While consumers today think of LEDs primarily in terms of lighting or display technologies, they are useful in myriad other applications such as commercial, industrial, automotive, and scientific.

## History of LEDs

Visible wavelength light emitting diodes (LEDs) have been commercially available for less than 60 years. When first developed for commercial use, they were extremely expensive and quite modest in capabilities — limited colors

available, brightness, power efficiency, and so on. Because of this, the only practical uses for early LEDs were in expensive laboratory and test equipment. In the late 1960s, LEDs were first broadly commercialized as display and indicator lights, but it was not until the early 1990s, with the invention of high-brightness blue LEDs, that LED usage increased rapidly. High-brightness blue LEDs were used to create white light, which has allowed LEDs to become known as the "fourth generation" of lighting sources, after flames, incandescent bulbs, and fluorescent lamps.

# How LEDs Work

LEDs are semiconductor devices that combine a P-type semiconductor (larger hole concentration) with an N-type semiconductor (larger electron concentration). Applying a sufficient forward voltage will cause the electrons and holes to recombine at the P-N junction, allowing current to flow and releasing energy in the form of light. Fundamentally a diode, current only flows in one direction through the device, being blocked in the opposite direction.

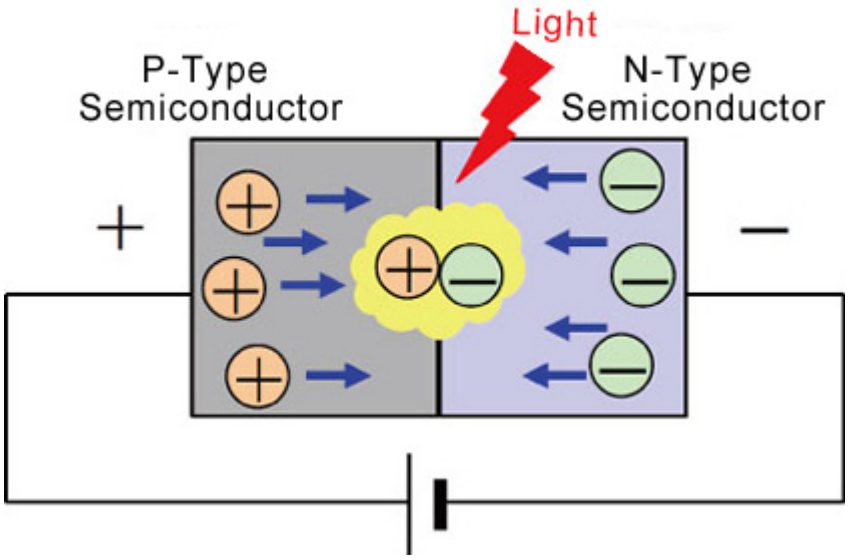

**Image courtesy of ROHM.**

While conventional light sources first convert electrical energy into heat, and then into light, LEDs convert electrical energy directly into light, delivering efficient light generation with much less energy lost to unwanted heat.


**Image courtesy of ROHM.**

The color of light emitted by the LED is determined by the materials used for the semiconductor substrate. Different semiconductor materials emit light at different wavelengths which correspond to different colors perceived by our eyes. New color LEDs are created by discovering or creating new semiconductor materials or doping existing materials with other substances. Unlike other forms of colored lighting that start with a white-ish light and then filter out the colors they do not want, LEDs can be made to emit specific desired color wavelengths directly.

White LEDs are a special case because white light is actually the combination of all the visible light wavelengths. There are two primary methods for creating white LEDs.

# White LEDs by Adding Phosphor

One way to create a white LED is to take an LED of a certain color and then add layers of a light-emitting phosphor coating to create a white light.

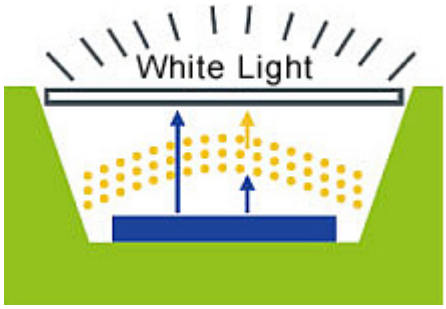


**Image courtesy of ROHM.**

These light emitting phosphors serve to broaden the spectrum of light passing through them, thus creating a visibly white light.  Most commonly, high-brightness blue LEDs are used to create white LEDs by this method.

# White LEDs by RGB Combination

The addition of red, green, and blue light creates white light. RGB LEDs, therefore, have the capability of creating most colors of the rainbow, including white.

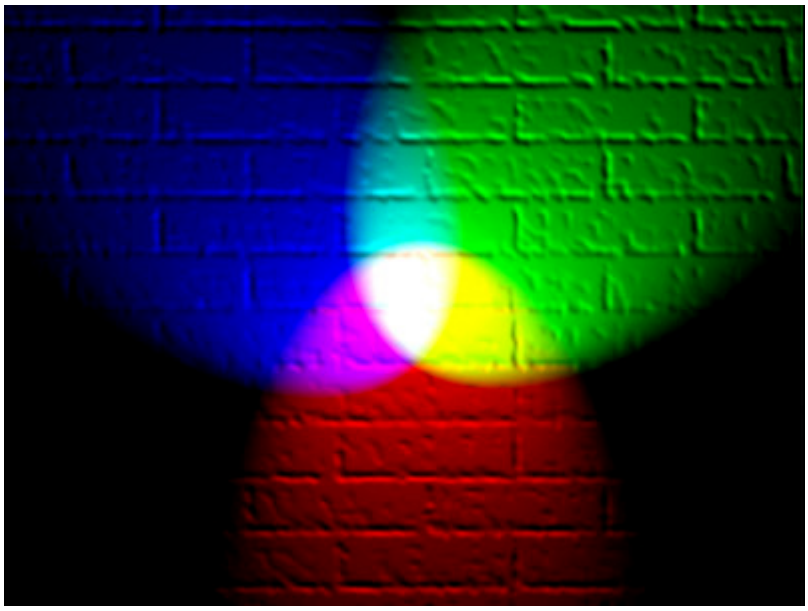

**Image courtesy of ROHM.**

However, due to variations in emission patterns of LEDs that can lead to the color balance changing at different viewing angles, RGB LEDs are rarely used for white lighting. However, because they can mix so many different colors, they still have many applications.

# Key LED Characteristics

There are many variables and characteristics that define LEDs. A few of the most key characteristics are luminosity, wavelength, and forward voltage drop.

## Emission Luminosity

The brightness of an LED, when viewed at a specific angle, luminosity is measured in candelas (cd). Because it is measured at a specific angle, the luminosity measurement can be presented as a graph of luminosity across different angles, or it can be measured and presented at just the angle important for the system in which it is designed. Additionally, lenses can be added to LEDs to focus luminosity in the desired direction. When comparing technical data, it is important to consider the viewing angle along with the luminosity. Generally, the luminosity of an LED decreases as the junction temperature of the diode (Tj) increases.

## Dominant Wavelength

The dominant wavelength of an LED is generally defined as the wavelength of the specific color visible to the human eye that the LED produces. This is different from other technical details of the spectrum of wavelengths emitted by the LED, or the highest wavelength light emitted (peak wavelength). The wavelengths of visible light are presented in nanometers (nm). The dominant wavelength of an LED is also affected by temperature (Tj), with different semiconductor configurations being more or less sensitive at different wavelengths.

## Forward Voltage

The forward voltage of any diode, including LEDs, can change with current and temperature. The forward voltage drop for a specific LED is defined by the semiconductor material in use (the wavelength), and the specific construction of the device (semiconductor bandgap). Because forward voltage can be different for different devices and can change with temperature, it is important to consider in circuit design. If driven with a constant current source, LEDs can be operated somewhat independently of their forward voltage drop.

# Types of LEDs

There are many types, packages, and arrangements of LEDs.

## Single Bin Rank LEDs

ROHM's single bin rank LEDs are offered in light red through yellowish-green colors. They are high brightness and high reliability, based on an AlGaInP substrate.


**Image courtesy of ROHM.**

The binning process is a way of sorting devices into similar characteristics to guarantee that any selection out of a single bin rank will be similar to any other in that same rank.  Accordingly, these single bin rank LEDs are all going to be visually identical to each other.

## Color Universal Design LEDs

ROHM’s color universal design LEDs, part numbers SMLD12E2N1W and SMLD12E3N1W, are blue-green chip LEDs that are ideal for Color Universal Design (CUD) applications. Color is one of the most important means of communicating or signaling information, but it is estimated that more than 200 million people worldwide cannot distinguish between green and red.

Color Universal Design (CUD) is a subset of the Universal Design effort to increase accessibility in the design of products and systems to make them more usable for people regardless of age, disability or other factors.

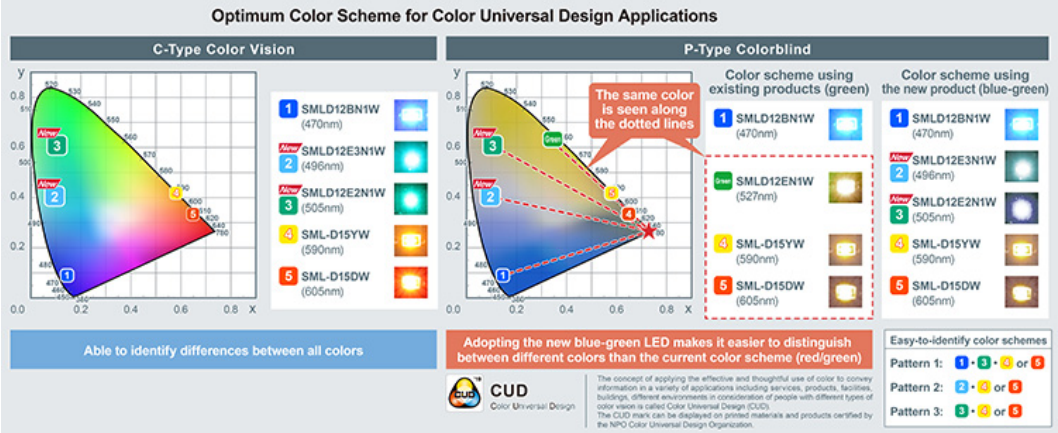


**Image courtesy of ROHM.**

These ROHM LEDs emit light at special wavelengths that make it possible to achieve color schemes and designs that can be easily discernible by everyone.

## Automotive LEDs

ROHM’s automotive-qualified LEDs are offered in a variety of sizes and series.

| Package | | LED type | Series | Emission color (dominant wavelength) [nm] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Size [mm] | | | 630 | 620 | 615 | 605 | 596 | 590 | 585 | 580 | 576 | 572 | 566 | 560 | 527 | 470 | White |
| Mini-mold | 1.6x0.8 (t=0.55) | EXCELED | SML-D12 Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| | | Standard | SML-D13 Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| | | | SML-D14 Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| | | | SML-D15 Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| | 2.0x1.25 (t=0.8) | EXCELED | SML-H12 Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| Reflector | 2.0x1.25 (t=0.8) | Standard | SML-MN Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| Reflector(PLCC2) | 3.5x2.8 (t=1.9) | IF=20mA | SML-Z1/ZN Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |
| Reverse mount available | 3.4x1.25 (t=1.1) | Standard | SML-81 Automotive | V | U | U2 | D | Y3 | Y | W | Y2 | M2 | M | F | P | E | B | WB |

**Qualified to the AEC-Q101 standard, these LEDs can be used in automotive applications.**

## Low Current LEDs

ROHM's low current LED offering consists of both single-color and multi-color LEDs that operate at a current less than or equal to 5mA. Low current LEDs are offered as single-color devices across the visible spectrum, including white, or as either two (blue/red) or three (blue/green/red) color LEDs. Low current LEDs are useful for indicator lights and in low power applications where the LEDs need to be on for much of their life.

## Compact and Low Profile LEDs

ROHM's Mini-mold LED package is tiny, low profile, and useful in applications where space is limited but high-performance LEDs are still desired.

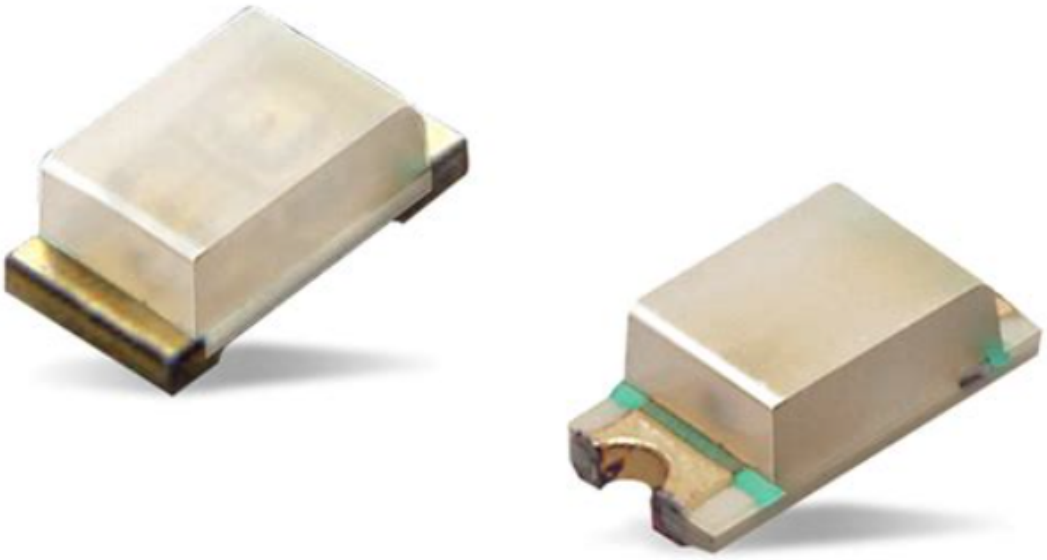

**Image courtesy of Mouser.**

## RGB and White LEDs

Across all these different specialty LED types, and standard LED offerings, ROHM offers both tri-color RGB LEDs and white LEDs. RGB LEDs can be used to create many different colors by mixing red, green, and blue light, including creating white light. White LEDs, on the other hand, are able to directly emit white light, even at high power.

For more information, please visit ROHM.