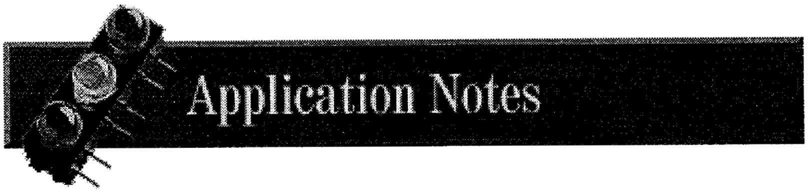


Getting to Know LEDs, Application and Solutions

Light-Emitting Diodes (LEDs) are a reliable means of indication compared to light sources such as incandescent and neon lamps. LEDs are solid-state devices requiring little power and generating little heat (see **Fig. 1**). Because their heat generation is low and because they do not rely on a deteriorating material to generate light, LEDs have long operating lifetimes. One of the alternatives, incandescent bulbs, consume much more power, generate a great deal of heat, and rely on a filament that deteriorates in use. Neon bulbs, on the other hand, rely on an excited plasma which, along with its electrodes, can deteriorate over time.

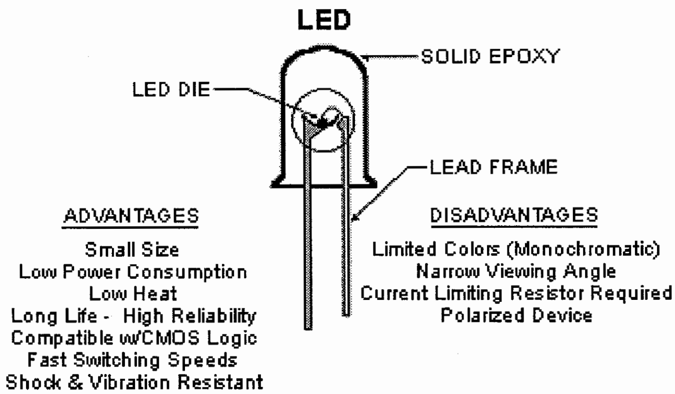


Fig. 1

The venerable incandescent bulb has been the predominant light source of choice in indication applications since there were things to indicate. It consists of a heated metal filament that radiates light inside a clear bulb (see **Fig. 2**). The radiated light is white, consisting of a wide spectrum of electromagnetic radiation. Incandescent bulbs generate high-intensity light for a short operating lifetime, and are susceptible to damage from vibration.

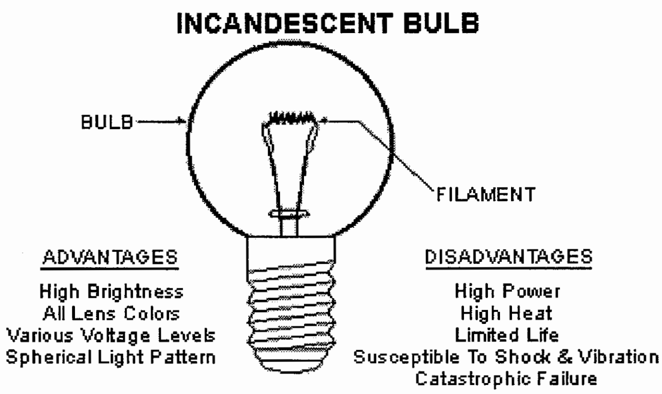


Fig. 2

Neon bulbs consist of electrodes encased in a glass bulb with a phosphorescent gas (see **Fig. 3**). They offer relatively long operating lifetimes (compared to incandescent bulbs) with lower power consumption and better resistance to shock and vibration. However, they must run at a high-voltage and incorporate a current-limiting resistor. The light these lamps provide spans a relatively narrow portion of the color spectrum, and is weak in comparison to incandescent bulbs and the brightest LEDs.

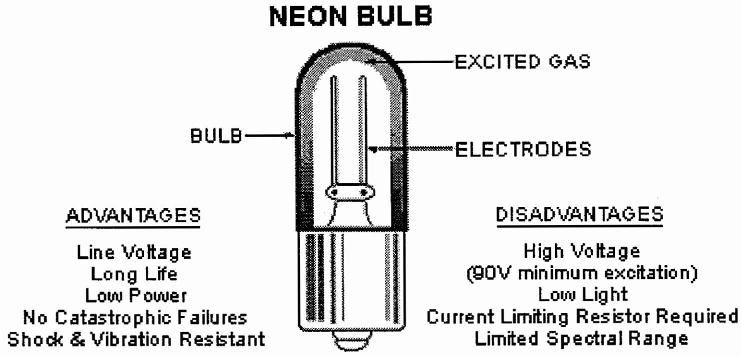


Fig. 3

LEDs have extremely long operating lifetimes, low current draw from DC voltage lines, low heat dissipation, tremendous resistance to shock and vibration, and much smaller size than neon and incandescent bulbs. In addition, LEDs can be pulsed at very high switching speeds, and can be made to turn on and off with logic-level voltage signals. To be fair, however, LEDs produce monochromatic light (a single-color), are available in only a few colors, and have relatively narrow viewing ranges. Still, for a growing number of applications, LEDs provide an extremely effective solution.

The State of LED Technology

LEDs are available in both visible colors and infrared. The visible colors include blue, yellow, green, white, red; and fall into the spectral wavelength region from 400 to 700 nm (see **Fig. 4**). The human eye is most sensitive to green light at a wavelength of 563 nm. Bicolor LEDs are manufactured by combining two different LED chips within a common LED housing. Positive and negative voltages are applied to turn on either LED. Infrared LEDs, commonly used in remote controls for televisions and a wide variety of sensing and data communications applications, reach wavelengths of 940 nm and higher. The color of an LED is determined exclusively by the semiconductor compound used to make it, not by the color of the surrounding epoxy lens.

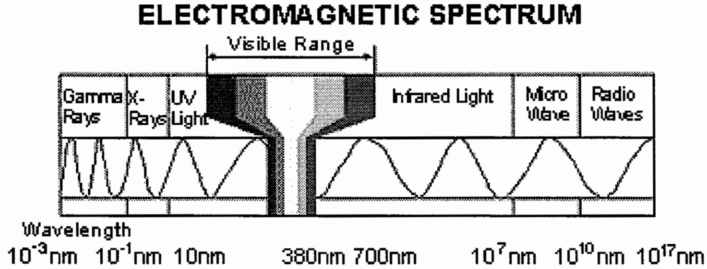


Fig. 4

For most of the period since the LED was first introduced in 1969, red LEDs were by far the most efficient and produced the greatest light output. However, research by companies including Cree, Hewlett-Packard, Siemens, Toshiba, and Nichia has produced significant advances in the efficiency of blue, green, and yellow LEDs (see **Fig. 5**). Today, yellow, green, and blue LEDs match the performance of red LEDs. These advances have great importance for the application of LEDs, and with greater efficiency, more applications can be served that have been traditionally served by incandescent lamps.

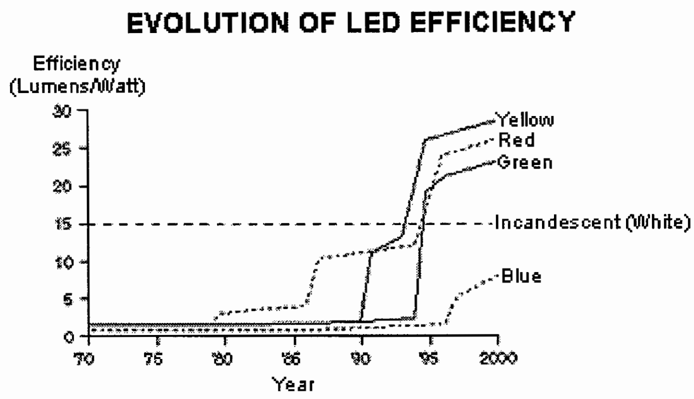


Fig. 5

For example, a stated goal of the automotive industry is to eliminate the incandescent bulb from as many places as possible, whether in the dashboard or in turn signals and brake lights. Current models from most automakers today use LEDs in the high-mounted center brake light, and work is being conducted to gain acceptance of LEDs in standard brake lights as well. The increase in efficiency of yellow LEDs now puts them in contention for use in turn signals as well.

LEDs have significant benefits in these applications. In brake lights, turn signals, and in-dash indicators, the devices may never need to be replaced throughout the life of the car. For in-dash applications, this is an even more appealing virtue because removing the dashboard in today's automobiles is a difficult, time-consuming, expensive procedure.

Work on producing high intensity blue light LEDs has produced several generations of even brighter LEDs. Introduced around 1990, LEDs based on the Silicon Carbide die material produced luminous intensities that rarely exceeded 15 millicandelas. As a comparison, the brightest of the Transparent Substrate (TS) type red LEDs produced more than 15,000 millicandelas. Blue LEDs based upon the newer Gallium Nitride die material currently produce typical luminous intensities of 2,000 millicandelas and higher.

Gallium Nitride technology has produced new bright blue-green (up to 6,000 millicandelas typical) and bright white LEDs. The new blue-green LED has made possible the advent of solid state traffic lights, and are finding their place in other critical lighting applications.

The bright white LED is constructed by utilizing a blue die and surrounding it with white phosphors. This approach is more efficient than using red, green, and blue dice in a single package to achieve a white color. This method also has the advantage of producing a white color that works well behind colored lenses. In their current packages, white LEDs exhibit typical luminous intensities up to 3,000 millicandelas.

Combining light pipe technology with the ready availability of LEDs of every color, it will be possible to produce solid state dashboards and instrument clusters, as well as solid state lamps for interior illumination.

The automotive, truck, and bus industries are examples of high-volume marketplaces that are now accessible to the LED.

Operating Principles and Specifications

How do LEDs emit light? The process is based on the change in energy levels when holes and electrons combine in the negative (N) region of a positive-negative (PN) semiconductor diode. During these shifts in energy, photons are generated, some of which are absorbed by the semiconductor material and some of which are emitted as light energy (see **Fig. 6**). The wavelength of the light depends on the difference of energy levels in the recombination process as well as the type of semiconductor material used to form the LED chip.

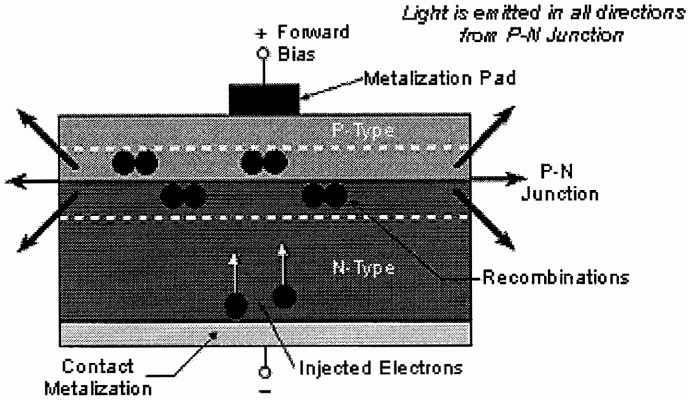
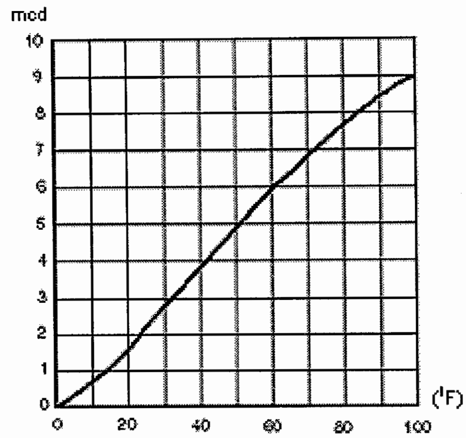


Fig. 6

Brightness and Efficiency

An LED's brightness or luminous intensity is dependent upon the amount of forward bias current applied to the diode and the viewing angle (see **Fig. 7**). An LED specified for a certain brightness with 20mA current will provide less illumination at 10mA. Luminous intensity is usually characterized in terms of millicandelas (mcd). A candela (1,000 mcd) is the amount of light that shines through a 1/16-inch square centimeter hole in one side of a ceramic box that has been heated to 1,772° C. Most LED manufacturers provide data sheets with minimum and typical values of luminous intensity. The human eye can generally only detect a doubling or halving in light intensity.



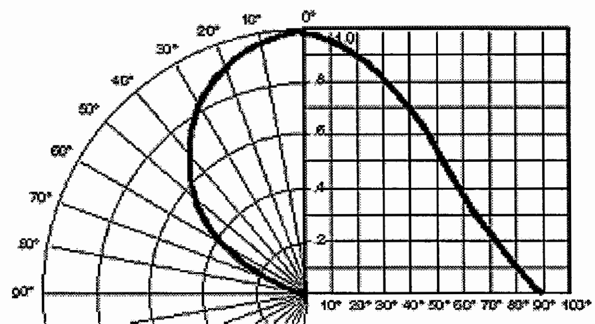
Relative Luminous Intensity
vs.
Forward Current

Fig. 7

An LED's quantum efficiency is based on the amount of light energy generated as a function of the amount of energy applied to the LED. At elevated temperatures, an LED's quantum efficiency decreases, and this is reversible; however, it also decreases slowly with age, and this is irreversible.

LEDs do not emit light uniformly in all directions, dropping in luminous intensity as a viewer moves away from a direct or on-axis vantage point (see **Fig. 8**). The half-intensity beam angle, given in degrees, is used to characterize how far in degrees from the on-axis perspective a particular LED's luminous intensity drops to 50 percent. For example, given two LEDs with equal luminous intensity, the LED with a half-intensity beam angle of 40 degrees provides a wider viewing angle than the LED with a half-intensity beam angle of only 20 degrees. This is true even though both may generate the same amount of total light for a given supply current.

Relative Intensity



Relative Luminous Intensity
vs.
Angular Displacement

Fig. 8

Factors that contribute to viewing angle include the amount of diffusant (see **Fig. 9**), the shape of the reflector cup which surrounds the LED chip, the shape of the LED lens, and the distance from the LED to the nose of the lens. When there is no diffusant, the viewing angle is ±10 to 12 degrees.; it can be up to ±70 degrees when the maximum amount of diffusant is employed.

DIFFUSED vs. NON DIFFUSED LEDs

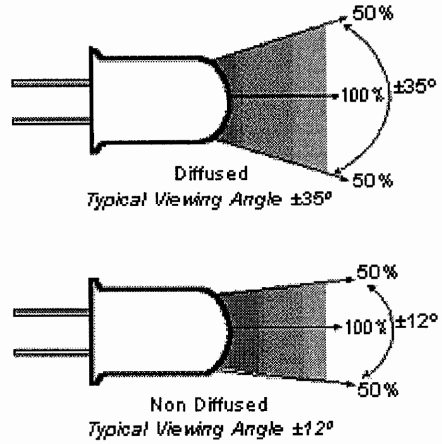


Fig. 9

A diffused LED is recommended when an application requires direct viewing of the LED across a reasonably wide viewing angle. Backlighting applications, however, that require higher intensity would use a non-diffused LED.

LED power dissipation is computed by multiplying the forward voltage by the forward current. For a typical LED with 2V forward voltage that is drawing 5mA current, the power dissipation is 10mW. Power dissipation is a key LED characteristic because it causes the temperature of the LED to increase. Light intensity decreases and wavelength increases with increasing temperature. Low power dissipation not only translates into cost-effective operation, but long operating lifetimes as well.

The amount of current drawn by the LED makes an enormous difference when arrays of LEDs are used. Increased efficiency delivers either more light for a given current or the same amount of light for less current. Incremental increases in efficiency may seem insignificant, but each advancement can open the door to another application that was previously served only by an incandescent lamp.

Reliability data for different LEDs must be compared in terms of the amount of forward current that drives a particular LED. A LED may provide greater luminous intensity at higher current levels, but tend to have a shorter operating lifetime compared to a device running at lower current levels. At higher current levels, LEDs also tend to lose total output power more quickly over time. At forward current levels of 20mA or less, most LEDs are expected to last well over 100,000 hours, or more than 11 years.

Secondary Optics

In addition to the LED itself, some applications require the use of secondary optics to carry the light from the LED to the desired location on the equipment. One popular type of secondary optics employs light pipes (see **Fig. 10**). As their name implies, light pipes simply provide a method of transferring the light generated by the LED from one place to another. They can consist of fiber optics or molded lenses that reflect the light and point it to the viewing location. In the manufacturing process, light pipes require the additional step of attachment to the circuit board or front panel. They are also made of materials that will not survive surface mount process temperatures.

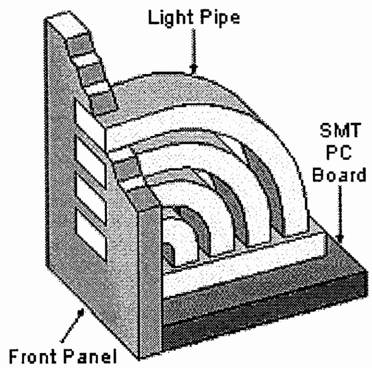


Fig.10

Another technique for adding secondary optics to the LED is found in Dialight's PRISM® CBI® Series. This patented product combines the action of a light pipe with the reflective properties of a prism. It is made of high-temperature materials so it does not require an additional assembly step when used in the surface mount process. The Prism incorporates an LED and a prismatic light pipe in a housing (see **Fig. 11**). The prism refracts the light 90 degrees from vertical to the viewing area. In addition to providing right-angle illumination from a surface-mount LED, the product provides the inherent advantages of a CBI-type solution, including repeatability, precision, pick-and-place compatibility, and the potential to increase manufacturing throughput.

CUTAWAY VIEW
591 PRISM® SERIES CBI

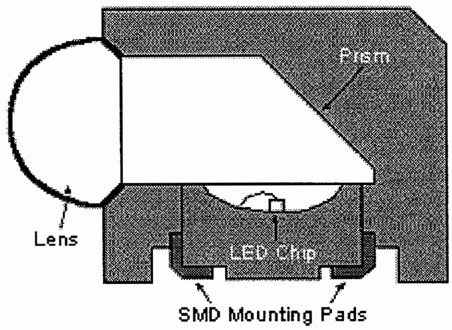


Fig. 11

Backlighting

Backlighting of front panel legends using LEDs is becoming extremely popular because it allows the panel to have a smooth and finished appearance, and reduces manufacturing cost. In backlighting applications, the LEDs are located behind small translucent "windows" that are flush with the faceplate. The light from the LED illuminates the window (see **Fig. 12**). Non-diffused LEDs are recommended for the purpose of reducing stray light.

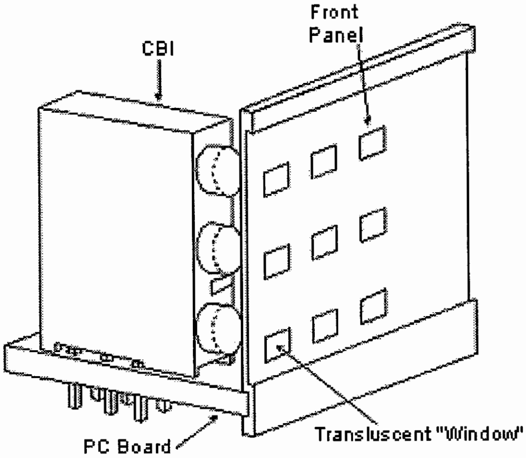


Fig. 12

To minimize this problem for designers, Dialight developed a family of right-angle housings that completely enshroud a high-intensity non-diffused LED (see **Fig. 13**). The combination of the LED and the housing results in zero "crosstalk" as well as an extremely bright on-axis indicator. It provides these attributes with much greater repeatability and ease of implementation than any other method.

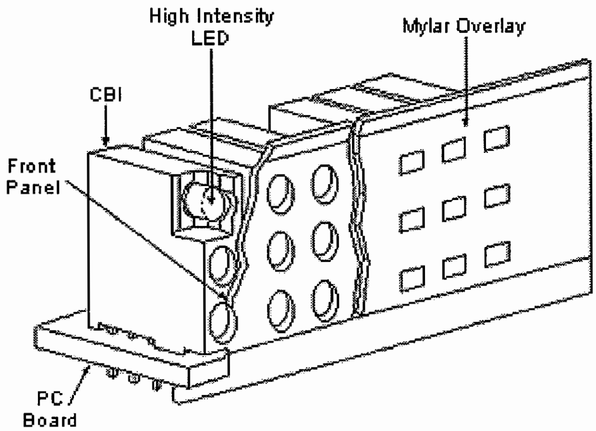


Fig.13

Types of LEDs and Package Configurations

Regardless of the electrical characteristics, the designer basically has a choice of LEDs with a narrow viewing angle or a wide viewing angle. The LED is available with a wide variety of physical and optical characteristics. The basic LED consists of a diode chip or die, mounted in the coined reflector cup of a lead frame, wire bonded and encased in a solid epoxy lens (see **Fig. 14**).

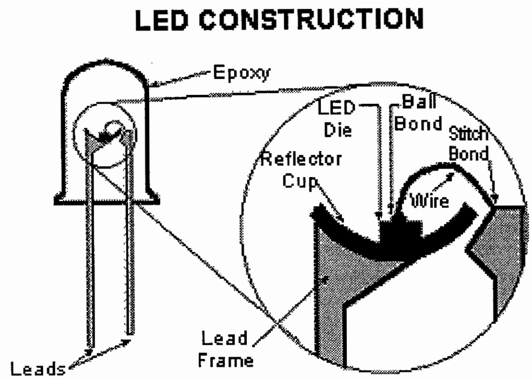


Fig. 14

To summarize the popular types of LEDs, there are:

- *Diffused types*, which have tiny glass particles in the epoxy lens. This spreads the light to a viewing angle of about +/-35 degrees from center. They are recommended for use in direct viewing applications in which the LED protrudes through a hole in the front panel of the equipment.
- *Non-diffused types*, without glass particles in the epoxy, which produce a narrow viewing angle of +/-12 degrees. They are often used for backlighting applications in which the LED light is focused on a translucent window in the front panel.
- *Tinted types*, for indication in the "off"-state of what its color will be when in the "on"-state.
- *Water clear (non-tinted, non-diffused) types*, which have no tint or diffusion in the epoxy, and produce the greatest light output and narrowest viewing angle. They are designed for applications in which very high intensity or colorless LEDs in the off-state are desired.

There are also two popular options for these basic LED types:

- *Integral resistor*, which includes the resistor chip required for current limiting inside the package.
- *Low current types* employing special diodes that draw the least amount of current from the power source (e.g. 2 mA).

(**Fig. 15**) displays some of the key criteria used in the LED selection process.

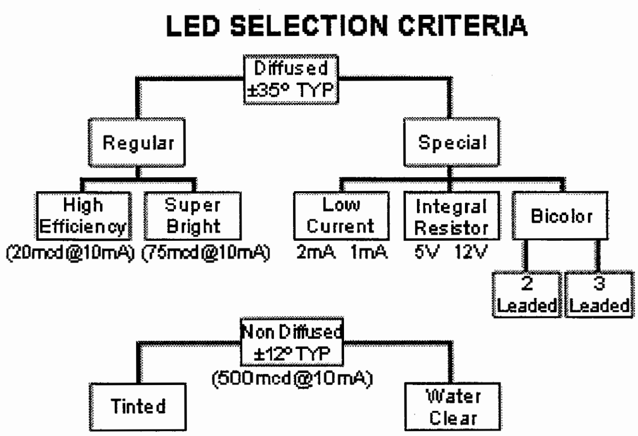


Fig.15

Although LEDs are available in a wide range of shapes and sizes, three popular types are used most often:

- 2 mm (T - 3/4) LEDs
- 3 mm (T - 1) LEDs
- 5 mm (T - 1 3/4) LEDs

There are four basic types of LED mounting configurations:

- Cast epoxy through-hole LEDs designed for circuit board mounting. They are the most common type of LED in use.
- LEDs in a housing designed to deliver light at a right angle from the circuit board. Dialight's CBI Series components are an excellent example.
- Surface-mountable discrete LEDs compatible with tape-and-reel automated assembly equipment for high-volume production. These LEDs are simply a light source and have no optics. Consequently, they require secondary

optics such as a light pipe to get the emitted light to the front panel in an aesthetically pleasing fashion.

- LEDs in right-angle surface-mount compatible packages that employ a prism-type lens structure to direct the light parallel to the circuit board. Dialight's Prism Series components are an excellent example.