The LED rundown

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The life of a light-emitting diode (LED) isn't as simple as some advertisers may lead you to believe. Manufacturers offer numbers like 100,000 hours as the expected lifetime of high-powered LEDs, but those numbers reflect calculations done using optimum conditions and specification points.

The truth is LED light output declines over time. The eye requires a change of at least 3 dB before the difference is discernible. That means a 30 percent change in output. If the life of the LED is rated for a 50 percent decline for end-of-life purposes, the real-world life will be less, possibly much less when factoring in the toll temperature takes on LED life.

High-quality LEDs are rated for a 20 percent decline at end-of-life. The life rating is indicated by the number following "L" – which stands for lumen depreciation. For example, an end-of-life decline in light output by 50 percent would have an "L50" life rating. For a 20 percent light output decline in end-of-life rating, look for the "L80" lifetime. You also need to consider color shifts with age and environmental temperature where color temperature and/or color is important.

Causes of output decline

Heat and current are the two main causes of LED light output decline. For heat, the critical number is the junction temperature, which determines life. Case temperature, the base from which junction temperature is determined, depends on the environment, heat-sink capability, and the amount of heat generated by the LED. The general environment, though important, is not as significant as the environment in which the LED and its heat sink are mounted. When it comes to temperature, an enclosed case can be more problematic because it lowers life and, in some cases, can change the color of the LED. Keep in mind that heat itself can lower light output and that an enclosed case will result in a higher temperature.

However, since some applications like street lights, lights in an automotive, outdoor, food supply, dusty, or explosive environment generally require enclosed casings, they will need additional cooling. You can try adding more LEDs to an enclosed system to help distribute heat production, but otherwise heat must be a consideration when looking at fixtures.

Power output is also not a strict function of input power for LEDs. Light output declines with increasing power, even for LEDs where the light output strictly follows the input current because the voltage across the LED rises somewhat with increasing current.

Additionally, current flow causes degradation, not just from the heat produced, but from electro-migration — the movement of conductor material — which leads to various LED junction defects, further reducing light output.

LED power
High Power LEDs — often referred to as HB or High Brightness — use 1 to 10 Watts and when run at full power, require metal core PCBs. In addition, heat sinks — which can be natural convection, fan cooled, and even liquid-cooled depending on the application, space available, and budget — are a must.

The designer must consider the tradeoffs. Sometimes, standard LEDs — surface-mount or through-hole with power ratings from 20 mW to 100 mW — produce a low-cost design. Alternatively, sometimes using mid-range 1/4-W to 1/2-W LEDs or HB LEDs — even with the metal core PCB and heat-sinking requirements — will give the low-cost design.

One thing to consider is standard LEDs are generally more efficient than HB LEDs, but you'll need more of them. If the LEDs are driven in a series-string configuration, the failure of any one LED—if it fails open—will cause the whole string to go dark. This could be countered by adding zener diodes with the appropriate voltage rating in parallel with each LED in a series string adding to final cost.

Colors and viewing angle
LEDs, except for white LEDs, are monochromatic devices. You pick the color by selecting an appropriate LED. However, temperature and current variations can shift the color.

White LEDs can be made by mixing red, green, and blue light in the right proportions. These are called RGB LEDs and can be used to produce almost any desired color. The other way to produce white light from LEDs is the phosphor method. The light from a blue LED is directed at a phosphate mixture designed to produce all the other colors required to make white. The white light produced by a blue LED has a more continuous spectrum than that produced by the RGB LEDs.

When you specify LEDs, you need to call out the viewing angle because it will vary depending on the application. For area lighting, a wide angle should be specified; but for indicators, a narrow angle may be better. For indicator applications, like backlighting an overlay, take into consideration light bleed from adjacent LEDS.

You can also use optics to control the dispersion of the light, which may be required if you need even dispersion from a few LEDs. But optics, whether lenses for concentrating the light or other materials for dispersing it, are expensive if they are custom-designed for low-volume applications.

Drivers and AC line dimmers
LEDs are current-driven devices, so output rises with increasing current. Analog constant-current drive is relatively low efficiency but allows for more regulation of the light output. Switch mode constant current drives are more efficient but generate electrical noise, which will need filtering and shielding, depending on the application.

Constant-current drive can be resistive, which is low-cost, but very inefficient and light output will vary with the input voltage. Constant-current dives can also be variable-current drives. They are controlled by a pulse width-modulated signal or an analog voltage depending on the drive-circuit topology.

Triac dimmers, originally designed for incandescent light bulbs, chop incoming voltage to vary the power of a bulb. The bulb itself averages the power, so the individual pulses — 120 Hz in a 60-cycle system — are not discernible. LEDs, as noted above, are current-driven devices and because of that chopping, the line input voltage will not vary the light output of ordinary LED devices with constant-current drive. Special chips that measure the chopping angle are required to dim LEDS in household circuits that use triacs.

Using modern high-power LEDs isn’t easy. The current used, heat generated, operating temperature, and the drive require planning. Failure to consider these issues will result in a subpar product that will lead to failure in the most critical area: the marketplace.

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