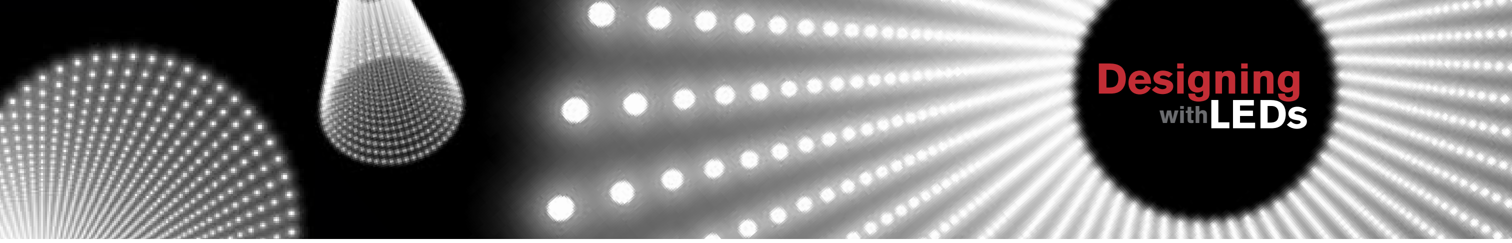

BY JEFF PERRY, NATIONAL SEMICONDUCTOR

A fail-safe approach to LEDs

Choose the right high-brightness LED and protect it from overtemperature conditions.

Spurred by the increasing cost of energy and concerns about climate change, governments and industry are pushing for higher-efficiency lighting. HB LEDs (high-brightness light-emitting diodes) provide an excellent option due to their high efficiency and long lifetime. At the same time, LED technology is undergoing a period of rapid change and innovation.

Fortunately, online tools for LED selection and implementation make it easier to choose an LED and an LED driver. But, even with these tools, the user should have an understanding of the parameters affecting LED selection.

The first step is choosing a color for the LED. Colored LEDs are characterized by their dominant wavelength and are available in wavelengths from UV (ultraviolet) to IR (infrared). Manufacturers specify white LEDs by their color temperature, with warm-white LEDs, often used for room lighting, in the 2800 to 3500K range. An ordinary tungsten-filament light bulb offers about 3000K. Also available are cool-white LEDs in the 6300 to 7500K area and white LEDs in the mid-range of 3600 to 6200K.

HOW BRIGHT SHOULD IT BE?

Luminous flux, in units of lumens, is the usual measurement for the brightness of LEDs. It indicates the amount of light emitted in the spectrum to which the human eye is sensitive. **Table 1** shows typical luminous-flux values for some light sources.

HB LEDs typically have luminous-flux values of less than 100 lumens, although this figure is climbing rapidly. So designs typically combine LEDs into arrays to achieve higher brightness values. You can arrange multiple LEDs in parallel strings using one current-control driver, but doing so can lead to differences in brightness in the strings due to the slight variance in each LED's forward voltage and thus current in each string. Therefore, it is preferable to use LEDs in series for consistent brightness and color. However, the series voltage gets higher with more LEDs, affecting which driver topology you can use: buck or boost.

Also keep in mind that LEDs are directional in nature, according to the viewing angle, or the point at which the brightness falls to 50% intensity. In directional applications, the actual brightness you perceive will be higher than a point source of light with a spherical emission pattern. Conversely, if you desire a spherical emission pattern, you must design the array accordingly.

A measure of efficiency of lighting elements is luminous efficacy, which is measured in units of lumens per watt. With the explosion of LED R&D, parts with values of 75 lumens/watt are readily available, and LEDs with 115 lumens/watt are new

TABLE 1 TYPICAL FLUX VALUES FOR COMMON LIGHT SOURCES

Type	Brightness (lumens)
40W tungsten bulb	500
100W tungsten bulb	1500
25W compact fluorescent	1500
55W halogen auto headlight	1500
35W high-intensity-discharge auto headlight	3250
150W projector bulb	5000
180W low-pressure sodium streetlight	27,000

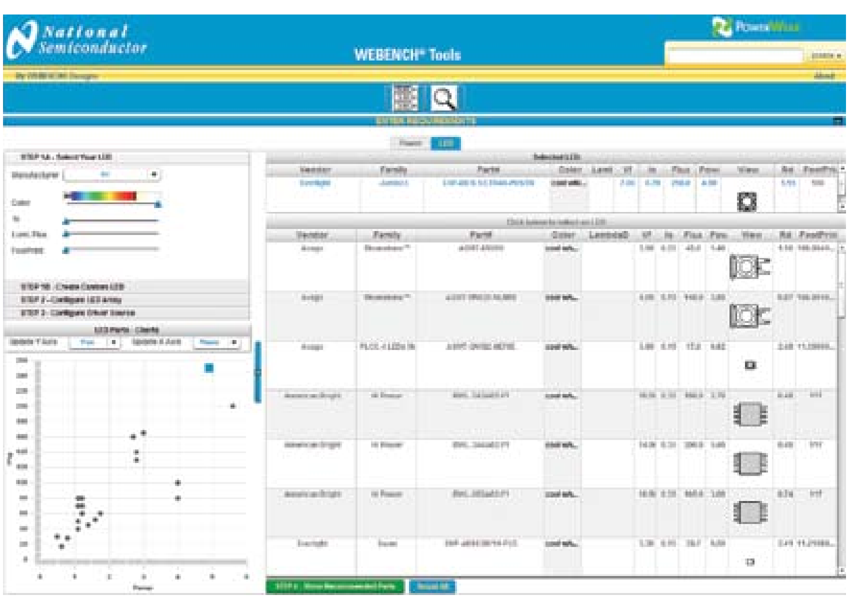

FIGURE 1 Comparing luminous flux with power aids in selecting the proper HB LED (courtesy National Semiconductor).

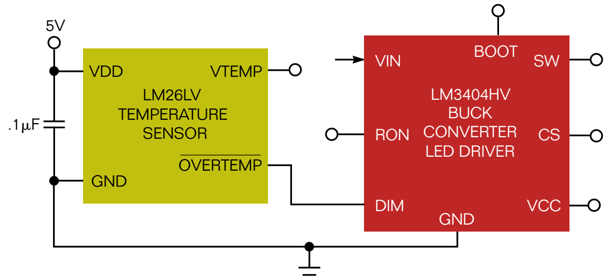

FIGURE 2 AN LM26LV silicon temperature sensor can sense an HB LED's overtemperature condition and throttle back the LM3404HV LED driver.

to the market. Tungsten-filament bulbs offer about 17 lumens/watt, CFLs (compact fluorescent lamps) offer 60 lumens/watt, and low-pressure sodium streetlights offer 100 to 200 lumens/watt (**Figure** 1).

The forward voltage of an LED is a characteristic of the manufacturing process; yellow/orange/red LEDs are in the 2 to 3V range, and blue/green/white LEDs are in the 3 to 4V range. The current through the LED controls the brightness and affects the color. Therefore, LEDs run in a constant-current mode. High-brightness LEDs typically come in currents of 0.35, 0.7, 1, 1.4A, and up. Also, consider the footprint and height of the LED. You must make provisions for heat sinking, which becomes vital in high-current applications. Cost is another critical parameter.

TEMPERATURE CONTROL FOR LEDs

Why do we need temperature control and monitoring for LEDs if they are supposed to be so efficient? Although LEDs are more efficient than tungsten-filament bulbs, they still generate a lot of heat. Incandescent lights generate heat that largely leaves the system as IR radiation. On the other hand, LEDs generate heat in the diode-semiconductor structure in addition to photons. This heat is not part of the radiated spectrum, and it must exit the system through conduction and convection.

If LEDs become hot, a number of issues arise. The brightness of LEDs decreases markedly with temperature. Also, the color of LEDs changes with temperature, which can lead to problems in applications that require consistent color integrity, such as RGB (red/green/blue)-generated white light. Electrical characteristics, such as the forward voltage of the LEDs, drift with temperature—a consideration when designing the driver circuitry. This change can also be an issue if the LEDs share current in parallel configurations. Constant exposure to high junction temperatures accelerates the degradation of LEDs and reduces their life and reliability. Thus, it is essential to design the system so it runs within the temperature specification of the LEDs. You normally accomplish this task using heat sinks, such as large copper areas on the PCB (printed-circuit board). You can also use attached-fin heat sinks, thermally enhanced/metal PCBs to mount the LEDs, or both. Forced airflow is also an option.

However, if an unusual event, such as extraordinary weather-related heat or the failure of a heat sink, occurs, you can implement a fail-safe mechanism. Most buck-topology LED drivers have thermal shutdown. Boost-topology drivers protect themselves but not the load when they shut down, so they require a crowbar circuit or other protection for LEDs. In any case, the LED temperature may be higher than that of the driver, and the LEDs thus require a temperature-sensor and monitoring circuit for fail-safe protection. This temperature-sensor circuit can reduce or turn off the current to the LEDs, turn on a cooling fan, or provide an alert mechanism to the user or maintenance personnel.

In general, temperature-sensor accuracy needs to provide enough margin to be able to detect an overtemperature problem but not trigger a false alarm under normal operating temperatures. For example, if a system is normally operating at as much as 80°C and you want to detect a fault condition at no more than 100°C, a temperature-sensor system with ±2°C accuracy set to trip at 98°C should be fine, but one with ±10°C accuracy set to trip at 90°C would be marginal.

Discrete temperature sensors appropriate for LEDs include thermistors, which change resistance as the temperature changes. Thermistors are inexpensive and have high sensitivity but are nonlinear and require initial calibration. They are available in the desired temperature range of 50 to 150°C. Another choice is a thermocouple. The voltage of these sensors changes as the temperature changes; they also generate a current, so they may not require a power source. They are less sensitive than thermistors but good enough for LED use. They come in a range of temperatures, well beyond what LEDs require, and see wide use in other applications. They cost more than thermistors. Both of these sensors require some analog circuitry either to interface with a microcontroller, which then can take action to correct the temperature problem, or to interface directly to the LED driver through a shutdown or dimming pin.

Silicon temperature sensors, which come in ranges of −50 to +150°C, are also useful for LED applications. These inexpensive sensors provide a variety of options, including analog-voltage output, which is proportional to temperature; temperature-triggered on/off output with hysteresis; and fan control.

TEMPERATURE-SENSOR APPLICATION

Figure 2 shows a simple circuit for interfacing a silicon temperature sensor directly to a buck-LED driver. The temperature sensor should be as close as possible to the LEDs. In this circuit, the Overtemperature pin of the temperature sensor is normally high when the temperature is below the specified value, but the pin goes low when the temperature is high, thus shutting off the LED driver through the Dim pin. When using the sensor's hysteresis feature, as the temperature goes back 5°C below the specified value, then the Overtemperature pin goes high, and the LED driver turns back on.

More sophisticated systems can proportionally reduce current to the LEDs without shutting them down as the LED temperature rises above a threshold. Alternatively, they can turn on a fan and increase speed after the LED temperature exceeds the specification. None of these systems are a substitute for good thermal design for the LEDs, but you can use them as a fail-safe shutdown to enhance LED life and reliability when the normal thermal controls fail.

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