In SSL, It's the Little Things That Count

By Murray Slovick

There is a lot of enthusiasm, most of it justified, some misapplied—about solid-state lighting (SSL). At the heart of the matter is a desire on the part of the lighting industry to reduce its energy appetite, driven largely by concerns over climate change and a global effort to use energy resources more efficiently.

LEDs are correctly perceived as friendly to the environment and, while they shouldn't be viewed through reality-distortion glasses—a switch to LED lighting, even on a massive scale, is not going to cure all of our environmental ills--it is fair to call SSL a truly disruptive technology as it offers considerable advantages over traditional lighting sources. Some of these are:

- Extremely long life; typically 100,000 hours for LEDs versus 1,000 hours for incandescent bulbs and 10,000 hours for fluorescent bulbs.
- High efficiency. LEDs are 7- to 10-times more efficient at producing light (as measured in lumens/watt) than incandescent bulbs. They are also more efficient than compact fluorescents (CCFs), which top out around 60-65 lumens/watt. LEDs have risen steadily from 40 to 60 lumens/watt a few years ago to 100 and even 150 lumens/watt devices today.
- Design flexibility. LEDs have the ability to generate unique colors and to provide white light in a variety of color temperatures.

For all of these reasons LEDs are ideal choices for a wide variety of lighting applications from flashlights to vehicle brake lights to display backlights for LCD TVs and cell phones to visual indicators providing operations status in instruments and computers.

It's a slam-dunk, right? Well, for all the good things about LEDs if they have one notable flaw it is that they are not plug-and-play. Unless you want to make a total hash of it you have to consider complex heat, optical and electrical issues very early during the design process, especially given the fact that there aren't a lot of engineers with substantial experience in designing SSL systems out there.

At a minimum, SSL designs require careful attention not only to the emitters themselves but to drivers, thermal management-- similar to that employed in designing a CPU-- PCB design, power supply and conversion, and optics (various lenses and reflectors).

An LED lighting "solution" can quickly become more of a problem than a solution unless it is designed properly. Consequently, my mission in this month's column is to concentrate on design elements that often don't get enough attention in the rush to take an SSL system out of the oven as early as possible.

The Basics

In its most basic form an LED is a semiconductor device that emits narrow-spectrum light when forward-biased. The color of the emitted light depends on the chemical composition of the semiconductor material used, and can be in the visible, UV or infrared spectral range.

In its early stages LEDs had problems with brightness and color characteristics, but technology developments led to devices with higher efficiency (more lumens of light created for each watt of energy expended) and more consistent color. For basic illumination applications LEDs can run on as little as 4W and last as long as 100,000 hours.

To insure the best possible uniformity of LED-to-LED color and brightness and in this way optimize the appearance of lighting end-products, LEDs are tested and sorted into a unique bin in a process called, appropriately, "binning." Each bin contains LEDs from only one color and brightness group and is uniquely identified by its bin code.

Another term you will need to know: luminous efficacy, a measure of the lumens of light output per watt of power consumption. If one assumes power input of approximately 1w LED efficacy will top 100 lm/w, which makes LEDs more efficient than compact fluorescents (CFLs) that usually check in at around 65 lm/w.

In practice, when you integrate LEDs into a lighting system, since LED light is essentially a point source and thus more directional than light given off by a CFL, the delivered efficacy of the LED system is actually much higher than the specs might indicate.

Speaking of specs you also need to know that from the standpoint of efficacy as well as other data sheet info you have to look at the numbers posted as an advisory and not as an absolute, especially when comparing supplier to supplier to get what you might need for your lighting project.

For one thing, if you look at the typical LED supplier data sheet it's important to note that the stated characteristics are given at a certain temperature, most of the time 25°C and that's hardly the case during actual use; more often LEDs are experiencing closer to 80° or 100°C.

As a result you shouldn't try to determine efficacy until you've put the LED into the application and taken factors such as heat-sinking capability into account; heat sinking and the thermal resistance of the package can have a significant impact on efficacy.

Thermal Considerations

Because an LED's color and brightness properties are sensitive to temperature, it is essential to have control over the thermal performance of the SSL system. As temperature increases LED light output decreases, wavelengths get longer and forward voltage decreases, all of which affects the color and brilliance of the devices as well as potentially reducing the life of the LEDs.

The only effective on-chip cooling method is to remove heat through the device bottom; highly thermally conductive materials are commonly used to take the heat from the LEDs back side. Typically this is accomplished by a heat sink and sometimes via forced air cooling

For this and other reasons engineers have chosen to deal with thermal issues at the system level, noting that the PCB is the best opportunity to transfer unwanted heat away from these devices. While standard FR-4 glass epoxy PCBs can still be used for some LEDs, larger devices require metallic substrate PCBs using a base layer of aluminum, which acts as an effective heat spreader allowing the heat to move away from the LED. The use of a metallic base also provides a good surface to attach a heat sink to further assist heat management efforts.

Temperature can have an adverse effect on other elements of the SSL system. In an automobile interior, for example, light produced by the LED usually exits via a lens and is then directed via an optical light guide (a “light pipe”) to a specific opening in the center console, door panel or dashboard. This light guide can turn yellow over time when exposed to heat if high-quality heat resistant materials are not used, resulting in inconsistent color indicators within the vehicle or from vehicle to vehicle.

In the Driver’s Seat

LEDs have different electrical requirements than their incandescent predecessors. Rather than using a constant voltage and resistance to maintain a given lighting intensity an LED needs a constant current. This is typically taken care of by the LED driving unit, which handles power conversion and control functions and delivers a constant average current under all conditions (i.e., input voltage change, temperature change, etc.)

For portable, Li-ion battery powered applications, (typically 3.7V output voltage but possibly ranging from 2.8 to 4.2 V), since an individual LED needs 2 to 4V of DC power and higher voltage is required when LEDs are connected in series in an array, a driver has to boost the voltage and regulate the current to get optimal LED output.

In backlighting applications for large displays, such as LCD TVs or commercial signage, LEDs have taken over from conventional cold-cathode fluorescent tube (CCFL) technology and offer reduced power consumption, a longer lifespan and up to 100x better contrast ratios. Here, in addition to providing the required constant current source the driver IC must have a rapid response time to handle dynamic backlight control--varying brightness of individual segments based on image content to give the consumer a more natural viewing experience. The backlighting driver is also responsible for handling high-speed impulsive driving to reduce motion blurring artifacts caused by the liquid crystal’s relatively slow response time.

Making the Right Connections

All of the various elements involved in an SSL system, including the LEDs, optics, PCB and heat sinks make it physically difficult to integrate connectors. A missing or insecure connection can result in, at best, the SSL system mis-functioning. Connecting LED light sources together through improper connectors could lead to potential accidents. You also want to make sure the connectors do not create a shadow, effectively reducing the light output of the low profile SMD LEDs.

The main point here is that connector selection has to be given more than passing thought and shouldn't be left to the end of the design/development cycle. A lack of foresight in this regard can result in expensive alternatives (including cost of materials, cost of assembly and cost of maintenance) afterward.

Unlike incandescent light sources, which use a filament or gas tube to increase illumination, LEDs need to be multiplied to scale up the emitted light. One way of doing that is to connect several LEDs in series to form strands for lettering, signs, and architectural applications.

Since connectors can be used to make wire-to-wire, board-to-board (allows daisy chaining multiple LED boards together in series) and wire-to-device connections matching application requirements to available connectors, with proper consideration given to performance and cost, is essential. In addition to providing trouble-free mating you also want to specify the proper connector housing for the environment in which the LED lighting application will be used to prevent contaminants from interfering with the electrical contacts.

More than Illumination

While high-intensity LEDs for municipal (street and traffic lights), automotive and entertainment lighting are all the rage among SSL vendors these days there is increasing opportunity to produce successful LED-based designs outside the visible light regime, too. While not as exciting as, say, trying to usurp Edison's invention in the home and office, high-speed infrared (IR) LEDs, for example, have carved out a significant niche in data communication in museums and concert halls as well as in surround sound systems and for presence detection (thermal screening). Other major IR LED applications include camera-based surveillance systems and compact remote control units where a wide angle of output intensity is needed.