LED drivers are the technological equivalent to ballasts for fluorescent or HID lighting systems and convert system voltage from AC mains to a DC end device. The drivers isolate lighting systems from high voltage, which mitigates the shock hazard, and regulate system power to counter inevitable line-voltage fluctuations, which can damage LEDs. To optimize operation, LED drivers deliver either a constant-current or constant-voltage output to a lighting system’s LEDs, depending on individual bulb and application requirements. Most LED drivers are capable of powering nearly any commercially available LEDs, although some manufacturers offer device-specific models as well. Like ballasts, LED drivers enable high system efficiency that, when graphically realized, increases linearly with output voltages, which have lower currents and fewer line losses. The average life expectancy of most LED drivers is around 50,000 hours, matching the life expectancy of most LEDs; however, manufacturers are starting to produce drivers with longer measured life spans.

**Constant-Voltage vs. Constant-Current**

LED drivers are available in two basic formats: constant-voltage and constant-current. Before LEDs were widely used in indoor, outdoor, parking, street, architectural, wash, and display lighting, they were one of the predominant lighting technologies for illuminated signs. Constant-
voltage LED drivers provide the flexibility to connect incremental LED segments up to the maximum power rating and are widely available in low-voltage outputs, which is ideal for the sign industry. Sign illumination applications have historically incorporated low-power LEDs (well under 1W each) connected in incremental segments with a current-limiting resistor above them in order to help protect the LEDs in each segment from voltage source variation. This configuration led to the widespread specification of constant-voltage LED drivers for illuminated sign applications. Consequently, design engineers and installation technicians tend to be more familiar with the constant-voltage technology and it tends to costs less, which can be an added benefit.

LED strip designs have improved over time and current-limiting resistors have come to be replaced with onboard constant-current regulators, which feature advanced feedback-monitoring circuitry to enhance efficiency and incorporate current balancing and smart protections. As LEDs gained market share in more general lighting applications, it became apparent that constant-voltage power supplies were not versatile enough to meet their demands. Constant-voltage LED drivers are subject to losses in current limiters, which decreases the efficiency of the higher-power LEDs typically used in general illumination applications. Constant-voltage LED drivers also require an additional conversion stage, and thus a greater number of components to power multiple LED strings. Consequently, since each additional component within a system increases the potential for system failure, constant-voltage LED drivers can reduce the reliability of general illumination lighting fixtures. Additionally, constant-voltage LED drivers are not a reliable solution for driving white LEDs. Voltage source deviations as small as 5% (i.e. from 3.3 to 3.5V), which are a normal occurrence when using constant-voltage drivers, can elicit a 100% difference in forward current (i.e. from 350 to 700mA), violating the LEDs’ absolute maximum current rating. When driven at currents in excess of their specified load range, LEDs emit brighter light and generate additional heat, which degrades their light output at a faster rate and significantly reduces their useful lifespan.

Conversely, constant-current LED drivers are not subject to losses in current limiters and are able to connect directly to a single LED string, providing greater system reliability for general lighting applications. Additionally, constant-current LED drivers avoid violating the absolute maximum forward current specified for a system’s LEDs, maximizing light output without overstressing LEDs. This ensures that each LED provides predictable, matched luminous intensity and chromaticity, which is essential for white LEDs, display illumination, and backlighting applications. Consequently, the lighting market has been engaged in an overall shift towards specifying constant-current driven luminaires for a wide range of illumination applications in residential, commercial, and industrial settings. Though most widely available in the 350mA to 700mA output range, emerging constant-current drivers are being manufactured with outputs greater than 1A, which enables them to provide energy-efficient power at both high and low voltage inputs. Despite their several advantages, though, constant-current LED drivers are not replacing constant-voltage drivers for all LED lighting applications, but they are quickly becoming the go-to power source for a broad array of lighting installations.
UL Ratings: Class 2 vs. Class 1

As components of LED systems, LED drivers are recognized by UL, but not listed separately, as UL certifies fixtures as a whole. As such, UL recognizes LED drivers as Class 1 or Class 2. Historically, most LED drivers have been recognized as Class 2 devices, which means that they are compliant with UL1310 and do not require any major safety protection at the LED or luminaire level, but must provide electrical isolation from the AC input voltage to ensure safe handling during operation. To qualify as a Class 2 device, power supplies may not exceed an output of 100W and an output current of 5A. Additionally, if the power supply unit is intended for dry use only then the output voltage may be as high as 60VDC; however, if it is also intended for use in any variety of damp or harsh environment then the output voltage must be restricted to 30VDC.

LED drivers recognized as Class 2 simplify the luminaire UL certification process, which has encouraged their widespread specification. The UL recognition process is far less rigorous than the UL listing process and allows the end-user to complete portions of the UL testing process prior to seeking UL certification for the end application. However, while beneficial for lighting applications with fewer LEDs, and required for sign illumination applications, the electrical restrictions governing Class 2 LED drivers limit the number of LEDs that may be powered by each driver, which makes them less advantageous for many other applications.

Since several LED lighting applications – such as parking, street, architectural, and wash lighting – require maximum power outputs outside Class 2 specifications, many manufacturers are now producing a variety of Class 1 LED drivers, which comply with UL1012 just as fluorescent and HID ballasts do. Class 1 power supplies can feature high-voltage outputs that require additional safety protection within the fixture. Additionally, Class 1 LED drivers also significantly increase the number of LEDs that may be powered by a single driver, which enables greater driver efficiency since a higher voltage translates into lower current and fewer losses.

Special Features

LED drivers are available with several value-added features, including dimming, color changing, sequencing, unique thermal protection, and remote control capabilities. Of these, dimming is the most commonly available feature.

Many LED drivers come equipped with standard 0-10V dimming. LEDs operate at the same voltage and current when dimmed as when fully lit so, unlike dimmed fluorescent lighting, there is no loss of efficiency. In fact, dimming may actually lengthen the useful lifetime of LEDs because dimming can reduce the operating temperature inside the light source. Pulse width modulation (PWM) is the most popular method for dimming LEDs, as it enables hundreds to hundreds of thousands of modulations per second, which results in continuous illumination – avoiding any flicker or color shift – and is compatible with digital controls. Other dimming methods include amplitude modulation, trailing edge, and leading edge dimming. Triac dimming, which is widely used for legacy incandescent or halogen lighting, is available but not often recommended due to the fact that it is resistance-based and, since LEDs typically do not offer much resistance, it may cause the diode to flicker and diminish its useful lifespan. Color
changing and sequencing, which are both achieved by dimming a mix of LEDs in an array, are also fairly common features in LED drivers.

Newer LED driver features can include unique thermal protection and remote control capabilities. One such feature is thermal foldback, which is an emerging thermal protection method that uses thermal sensors to detect and respond to overheating by reducing the drive current. LED drivers equipped with thermal foldback will dim the lights to reduce higher than average ambient temperatures instead of shutting down automatically to protect the circuitry. Additionally, many LED drivers recently developed are compatible with commercially available 0-10V control devices and systems, including: occupancy sensors, photocells, wallbox dimmers, remote controls, architectural and theatrical controls, and building and lighting automation systems. Some newer LED drivers are also compatible with devices governed by the digital multiplex (DMX) protocol, a wired communications control typically used in industrial applications like state and exhibition lighting, and the digital addressable remote lighting interface (DALI) protocol, a wired communications control originally specified for fluorescent lighting ballasts and typically used in home and office lighting applications. Wireless controls are another added function increasingly offered by some manufacturers. Protocols such as ZigBee, ZWave, and IEEE802.11 can be built directly into LED drivers and operated via wall, remote, or even voice activations. The primary advantage of wireless controls is that electricians need only connect equipped luminaires to the mains, which reduces the cost of installation.

Other LED driver features currently being experimented with include adjustable drive current and optical feedback. The adjustable drive current feature is designed to use a sensor on the LED board to set and regulate current outputs. For example, when a fixture is brand new, a user could set a constant-current LED driver to drive the current at 80% of the LED’s optimal current range, which would cause a counter inside the driver to clock how many hours it has been in operation and slowly increase the drive current over time in order to compensate for natural degradation in luminous intensity. As LEDs age they lose brightness, so the adjustable drive current feature, which reduces the current initially and later increases it to compensate for inevitable dimming, allows users perceive continuous luminosity. Similarly, the optical feedback feature has an optic sensor to detect changes in the light output and adjust the power throughout the life of the fixture in order to maintain the desired color mixing levels. Currently, advanced control functions tend to only be available for OEM products, as they need to be customized to end users’ specifications; however, more and more manufacturers are starting to offer them on special order products as well.

**Specification Tips**

Although critical for the performance, aesthetics, and longevity of a fixture, LED drivers are often one of the last system components to be designed in. Typically, a designer will design the fixture, choose how many LEDs are required to reach the desired brightness, decide how to dissipate the heat produced by the LEDs in order to maintain luminosity over the fixture’s lifetime without losing efficiency, identify the current at which the manufacturer recommends driving the LEDs, account for any application- or installation-specific requirements, and then choose an LED driver. LED manufacturers often specify an LED driver made by the same company, but users can evaluate third-party drivers by comparing the product specifications.
Regardless of where a designer purchases an LED driver, though, there are a few general and application-specific concerns that should be considered prior to specification.

First, designers should ensure that a driver has been evaluated and rated for use with the LEDs they have chosen, that its guaranteed lifetime matches or exceeds the expected useful lifetime of the modules, and that it offers short-circuit protection. They should also pay close attention to the driver’s maximum load, as one of the most common fixture design mistakes is connecting too many LED strings in a series, which can result in under powering the final string. Matching the voltage rating of the LED load to the output voltage of the driver is also crucial, as using the wrong driver could result in complete system failure or operation at higher currents than were intended, significantly shortening the module’s lifespan. Ensuring that the driver can handle extreme temperatures is an important consideration as well. Many commercially available LED drivers are designed for use at room temperatures and may operate erratically or not at all under the thermal conditions present in some lighting applications. Pricing is also a key consideration in the design process, and designers must remember to balance the desire for lowest cost with the desire for quality.

Additionally, there are a few application-specific considerations that should be taken into account when choosing an LED driver. The foremost is environmental conditions. For instance, even though LEDs can operate at temperatures as low as -40°C they draw more power at cold ambient temperatures, which must be addressed and compensated for during the design process. When installed in cold environments, the maximum load on a driver should be de-rated by 10-20% to avoid system conflicts. Moreover, if an LED driver is to be mounted remotely, voltage drops and power losses on the DC wiring must be accounted for to ensure proper operation and thermal optimization. Lastly, if a driver will be located in an area exposed to the elements or prone to dampness, designers must ensure that it is rated for use in harsh environments by consulting the Ingress Protection code on its label. The two-digit IP code identifies whether the device is permeable by solid particles (the first digit) and liquids (the second digit). For example, an IP code of 67 indicates that the unit is dust-tight and waterproof to 1 meter immersion, indicating that it is safe to use in harsh environments. More information about the IP codes can be found by consulting the North American IEC 60529 standard and comparable NEMA standards.

Another thing that lighting designers should consider during the specification process is partnering with an experienced power supply manufacturer, as doing so can help them achieve their desired outcome at the right cost in a timely manner. Working with LEDs is different than working with other types of lighting with regards to thermal management, output power, current, and performance concerns that are essential for realizing LEDs’ inherent benefits. LED drivers are not as widely available through distribution as traditional electronic ballasts, so a customized OEM solution can often be an ideal one. Partnering with a reputable and knowledgeable power supply company can improve the efficiency of the final fixture design, lower the final fixture cost, significantly shorten the design process, and result in longer operating life.
The Phihong Advantage

Phihong is an industry leader in the development of world-class power solutions and a principle supplier to global lighting OEMs. With design labs, manufacturing facilities, and sales support centers in California, New York, the Netherlands, China, Japan, and Taiwan, Phihong is a truly global power supply manufacturer with a proven track record of delivering excellent quality products and services.

Phihong offers a wide variety of both constant-current and constant-voltage LED drivers replete with several standard features, including: high efficiency and reliability, RoHS compliance, UL compliance, over-voltage and over-current protections, short circuit and open circuit protections, power factor correction, and brownout recovery. With regards to special features and applications, Phihong can manufacture custom LED drivers equipped for operation via wireless, remote control, wall-touch, and voice-activated controls. Phihong also offers a unique line of constant-current LED drivers designed as fixed wall-plug adapters, a series of external LED drivers that features extended lifespans of up to 100,000 hours, and a line of bulb-replacement LED drivers for retrofit applications with optional Triac and low-voltage dimming. Additionally, Phihong has a long history of working with OEM customers to produce high-quality power solutions for residential, commercial, and industrial applications.

Summary

As LED lighting continues to gain market share in nearly every illumination application, the number and types of LED drivers designed for both distribution and application-specific OEM solutions continues to expand accordingly. Special functions notwithstanding, constant-current and constant-voltage LED drivers each provide designers with a distinct set of advantages. Constant-voltage LED drivers are well-suited for powering multiple LED strings, like those in sign illumination applications, and offer the advantage of being the more familiar power supply technology. Constant-current LED drivers avoid violating the absolute maximum forward current specified for a system’s LEDs and maximize their light output without overstressing them. This ensures that each LED provides predictable, matched luminous intensity and chromaticity, which is essential for operating white LEDs, as well as for display illumination and backlighting applications. Although LED adoption is no longer in its infancy and fixture designers are better able to identify the unique strengths and weaknesses of constant-voltage and constant-current LED drivers and accurately determine which power supply will best suit a particular application, it is still recommended that designers consult with a reputable power supply manufacturer when switching to LED lighting from more established forms such as incandescent or fluorescent. Working with a power supply manufacturer can help fixture designers identify the best solution for the fixture while maximizing overall efficiency, optimizing costs, reducing the length of the design process, hastening the path to market, and extending the fixture’s useful lifespan.

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