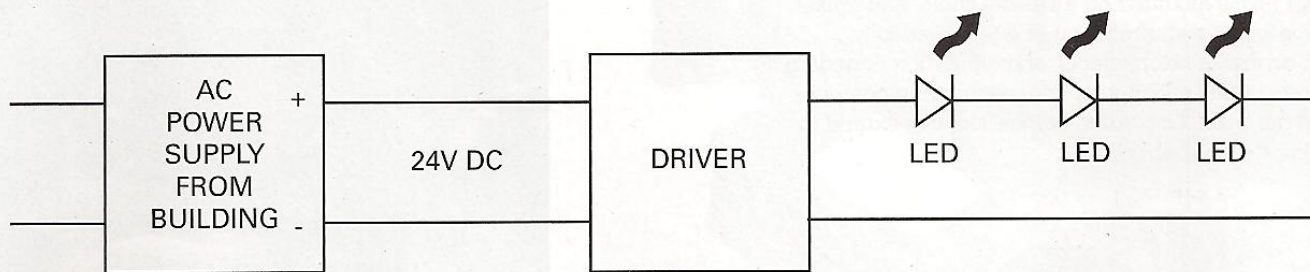
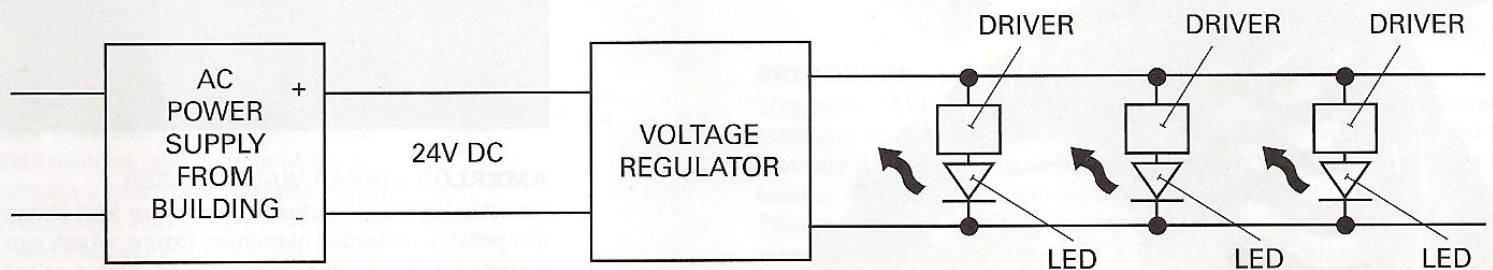


# Drivin' Them LEDs

JIM BENYA LOOKS AT BASIC LED CIRCUITS



CONSTANT-CURRENT CIRCUIT



CONSTANT-VOLTAGE CIRCUIT

Diagrams illustrating the relationship of the power supply, LED driver, and individual LEDs for a constant-current circuit (top) and a constant-voltage circuit (above).

**In the brutal world** of high-voltage, high-amperage energy systems operating at high temperatures, there stands alone one small but very useful device—the light-emitting diode (LED), also known as solid-state lighting (SSL). Compared to traditional light sources, LEDs are relatively small and particularly sensitive to voltage, heat, and amps. Realizing all of the promise of LED lighting depends on controlling the thermal and electrical environment much more carefully than we have with any previous light source.

Historically, electrical engineers, contractors, and electricians are used to a brute force sense of energy as it relates to lighting. The typical building electrical system operates at either 120V or 277V AC in the U.S., and the most conventional lighting fixtures connect directly to it. However, LEDs and LED drivers are low-voltage electronic devices, typically operated in systems of less than 30 volts. Somewhere in every LED lighting system there must be voltage transformation, driver current control, and in some cases, a way to dim the LED.

## LED BASICS

A diode is a solid-state electronics device used in all types of electronic equipment to convert AC power to DC power. A typical lighting application is in electronic ballasts, where the building power is rectified to DC using diodes so that the electronic circuits of transistors and other devices can use it. Without the conversion, driver design is difficult. In a normal diode, there is a small energy loss of about 0.7 watt per amp that is dissipated as heat. An LED is a different version that will consume 2.5 to 3.5 watts per amp. Some of this is dissipated as heat, but most of it becomes light.

Unlike fluorescent lighting, where up to 600V of AC may occur at the lamp, the voltage across an LED is usually between 2.5V and 4V DC. The first step in using solid-state lighting is to convert building power to low-voltage DC, which either can occur using a power supply or as part of the driver's electronics. Voltage conversion is a primary reason for the formation of the EMerge Alliance in 2008, "an open industry association promoting the rapid adoption of safe, low-voltage DC power distribution and use in commercial building interiors." Converting high-voltage AC to low-voltage DC adds to the physical size, electrical safety provisions, and cost of LED lighting systems. If a building provided low-voltage DC power, SSL lighting systems would be cheaper and easier to use. Another benefit is being able to use low-cost, Class II wiring, which does not require conduit or armored cable.

## DRIVERS

Once converted to low-voltage DC, power then passes through the LED to generate light. But as with a fluorescent lamp, there must first be a circuit that regulates the amount of energy—or the lamp will blow up. For a fluorescent lamp this circuit is called a ballast; for solid-state lighting it is called a driver. The typical contemporary white LED is designed to operate at either 0.35A, 0.70A, or 1A depending on watts, brand, and model. It is the driver's job to regulate the DC power for the specific LED. An added complication is that seldom in lighting is one LED enough, and it is common to have several LEDs mounted and wired together. For example, a basic downlight might employ 20 or more 0.25W or 0.5W LEDs.

Regulating the current through each LED is essential because the light output, lamp life, and light color are all affected. An LED is optimized to produce light meeting the desired lumen output, efficacy, and color at an appropriate level that, with proper heat sinking, will also provide normal functionality. Change either amps or temperature and the LED performs differently.

Drivers vary tremendously. The simplest driver is nothing more than a resistor that restricts current. This is used in simple SSL strings such as holiday lights. However, this is an inefficient system in which the resistor loses more than half of the energy as heat. More commonly, an electronic circuit using integrated circuits, transistors, and other components regulates the current to an LED by rapidly switching the lamp on and off. These more-advanced electronic circuits allow significantly more precise control of the diode itself, but the efficiency of the electronic driver is still only 70 percent.

In application, there are two primary circuit types: constant-current and constant-voltage. In a constant-current system, the driver delivers a regulated current of either 0.35A, 0.70A, or 1.05A and it is up to the luminaire designer to wire individual LEDs in series and/or parallel to ensure that the correct amount of current reaches each diode. For example, when connecting three 0.35A diodes in parallel, a 1.05A driver will be sufficient; or a 0.35A driver can be used with the same diodes in series. Either way, each LED gets 0.35A. Constant-current drivers are best for high-power (0.5W and greater) white LEDs.

In a constant-voltage system, there is a power supply that produces a fixed DC voltage, typically 8V to 24V. Each LED then has a dedicated driver next to it on the circuit board. Constant-voltage circuits are more commonly used for lighting systems with varying numbers of LEDs such as string lights—if you cut the string anywhere, the system will continue to work. For reasons of cost and simplicity, constant-voltage systems are generally used with low-wattage LEDs.

#### DIMMING AND RGB/RGBA

Both dimming and RGB/RGBA control requires varying the current to each LED. The process of dimming LEDs is not as simple as installing an incandescent dimmer. Most SSL dimming systems are special versions of drivers in which the ratio of “on-off” time is varied; the longer the “on” time, the brighter the LED.

LED color-varying systems use either RGB (red-green-blue) or RGBA (red-green-blue-amber) color mixing of LED lamps of each color. RGB/RGBA control is similar to dimming, except that a dimmable driver must be provided for each color in each pixel. A pixel is the smallest addressable cluster of red, green, blue, and amber LEDs. In order for SSL systems to “chase” or display low-resolution video, this means you need to employ many drivers as well as require communications wiring and electronics.

For the purpose of architectural lighting, some manufacturers of SSL luminaires use drivers that can be dimmed with ordinary incandescent-style dimmers. But because simple incandescent circuits can experience interaction problems with SSL power supplies, better dimming range and smoothness often can best be obtained using dimmable drivers that are controlled by DALI, 0- to 10-volt, or DMX (theatrical) control circuits. Note that most of these circuits use special dimming circuits that are installed between the constant-voltage driver and those LEDs that the circuit is intended to regulate.

#### MAKE IT SIMPLE, PLEASE

Just as in the early days of compact fluorescent lamps, the LED industry is a long way from standardization. For the time being it will be up to the individual lighting designer, engineer, or contractor to figure out the intent of the often poorly written literature from the manufacturer. We are sometimes seduced by attractive, state-of-the-art products only to discover that it takes an electronics engineer to make the lighting perform properly. But it is hard to blame the luminaire manufacturers when the problem lies with the makers of the components.

We need standards in solid-state lighting that go well beyond the lumen measurement, efficacy, and life testing that have dominated solid-state lighting discussions to date. For instance, due to their poor 70 percent efficiency, drivers are often avoided when the energy efficiency of solid-state lighting is discussed. This is unfortunate. If we’re going to take full advantage of LEDs, we need standardized and more manageable control components that make sense in the existing world of 120V and 277V AC power, the National Electric Code, energy codes, and the skills of electricians and contractors. As it is, LEDs have already developed a reputation for failing to meet rated performance and life. If the wiring and dimming remains complicated, there will be an almighty push back that will make us all hope for the invention of a high-efficiency incandescent lamp. **JAMES R. BENYA**

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