

As LED prices fall, designers are increasingly using them in their product designs, especially for lighting. LEDs have a reputation for being tireless workers that that never need replacing and require little payment in terms of power. However, the engineer who is familiar with LEDs in their original role as indicator lights may underestimate the need for their electrical protection when the LEDs are used in new, harsher applications such as outdoor lighting.

Despite their reputation for efficiency and reliability, LEDs are actually fragile devices, vulnerable to damaging transient overvoltages and voltage surges. For applications in which LED strings are powered by switched-mode power supplies (SMPSs), the power supply itself also needs circuit protection.

This white paper covers circuit protection of the entire LED portion of a product design, including design tips and guidance on applying protection devices including diodes, MOVs, and open LED protectors.

## Problem: Threats to LED Reliability

An LED is essentially a diode, structured as a P-N junction that emits light when forward biased. The main LED failure mechanisms are mechanical and thermal in nature. They involve thermal cycles, thermal shock, and LEDs operating at high temperatures so the wire bond ages. As the metal oxidizes and becomes brittle over time, the likelihood of an LED failure increases. Another cause of LED open circuits are electrostatic discharge (ESD) events or surges induced by nearby lightning events.

## Solution: Three-Point Circuit Protection

In any LED lighting application, there are three areas that require circuit protection: the AC portion of the circuit prior to DC rectification, a DC section, and the LEDs themselves. Figure 1 is a schematic of a typical LED lighting system. Proper protection will ensure reliable LED operation.

## Protection of the AC Line

Usually, an LED lighting setup involves a switched-mode power supply (SMPS) on the front end. A SMPS has fairly robust needs for protection that aren't needed to

such a degree on linear power supplies or other inputs. UL safety listings require these robust protection circuits. Proper sizing of the AC line fuse prevents safety violations.

An important first place to start is with the AC line fuse selection. The AC inputs are very susceptible to nearby lightning surges. It must be robust enough to withstand lightning surge requirements, usually 3KA, but sometimes up to 6KA, and also fast enough to protect against component failure.

The criteria for selecting the line fuse for the AC input include the voltage, current, and the  $I^2T$  rating. This parameter is related to the amount of energy the fuse element can withstand instantaneously without opening. Time delay fuses have higher  $I^2T$  ratings than fast acting fuses. Also,  $I^2T$  values generally increase with the current rating of the fuse.

The other component of SMPS protection is the transient voltage suppressor (TVS) and metal-oxide varistor (MOV). MOVs protect the line rectifier by suppressing an overvoltage event caused by nearby lightning surge events.

The main difference between fuses, which are overcurrent devices and MOVs, which are overvoltage devices, is that fuses are specified as safety requirements, while MOVs and over-voltage protection devices are normally thought of as reliability devices. This demand is driven largely by designers wanting more reliability. However, even UL safety listings have requirements that can only be met with the use of overvoltage devices.

## Protection of the DC-DC Converter

LEDs are connected in series and driven by a constant current source to drive them to full brightness, color, and intensity. This series circuit provides better control of LED group brightness as well as a more uniform LED to LED brightness. The constant current source has a maximum (open circuit) output voltage called the "compliance voltage".

A critical component in the DC section is the high-voltage DC fuse. Its function is to open during overcurrent events. The TVS device in the DC section protects the oscillator in the DC-DC converter from surges generated by nearby lightning strikes.

## Protection of the LED

As mentioned previously, vibration, heat or aging may cause an LED wire-bond to fail. An open circuit in a single LED in a string can cause the entire string to go dark, resulting in product returns, a tarnished brand name, and warranty expenses. If the product is used in a critical application, such as an airport runway light, the results could be catastrophic.

Fortunately, this problem can be avoided by placing an open-LED protection device in parallel with each LED on the string. An open LED protector is an electronic shunt which provides a current bypass in the case of an open circuit, thus saving the LED string from partial or complete failure. It is an internally triggered two-terminal device which automatically resets if the LED heals itself or is replaced. This protector is a voltage-triggered switch with low leakage on the order of microamps that becomes a low-impedance switch when it is triggered on, which minimizes power consumption. Once an LED fails open, there is sufficient circuit voltage to trigger the protector to the on-state. This protector also features built-in surge immunity which helps protect the LED from surges induced by nearby lightning strikes or ESD events.

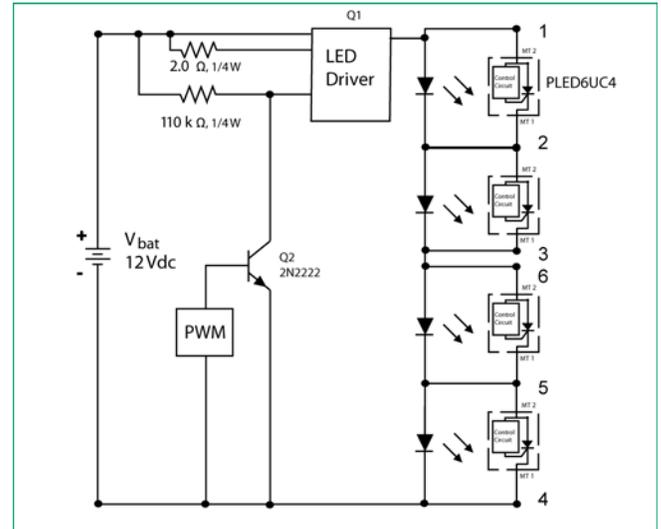
The PLED series from Littelfuse provides both overvoltage protection and continued string function if a single LED fails open. Devices in this series also protect LEDs from accidental reversed voltage.

## Conclusions

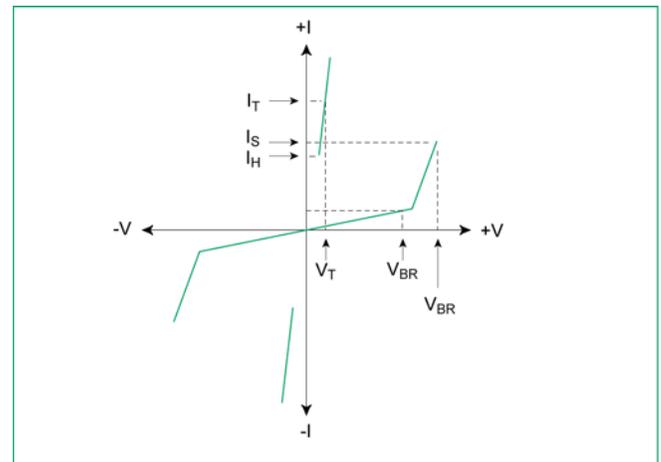
Product designers are switching to LEDs for lighting because of their low cost, high performance, minimum maintenance, and the fact that they can theoretically last forever. However, as LEDs enter harsh environments outside of their traditional role, circuit protection becomes critically important, stretching from the input power supply to individual LEDs.

## Graphics and Captions

**Figure 1** – A typical LED lighting system showing areas of circuit protection for the AC portion, the DC portion, and the LEDs themselves.



**Figure 2** – Open LED protection devices turn on and conduct around an LED with an open circuit, insuring that the remaining LEDs in the string stay illuminated.



Written by Kurt Wattelet and Phillip Havens

## Littelfuse, Inc.

8755 West Higgins Road, Suite 500  
Chicago, IL 60631 USA  
Phone: (773) 628-1000  
www.littelfuse.com