

Properly protecting LED light strings keeps them working for a lifetime.

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Introduction

The industry trend in lighting is a growing adoption of LEDs. Consequently, there is a boom in product designs incorporating LEDs. Part of their appeal is that they are low cost, high performance, require virtually no maintenance, and can theoretically last forever. They are increasingly being used in harsh outdoor lighting environments, which is different from their original use mainly as indicator lights.

However, their benefits are not realized if they are not properly protected. LEDs are very fragile, solid-state devices and must be protected from surges, transients, and other conditions that could shorten their useful life. Until recently, there were no reliable solutions to protecting LEDs in such harsh conditions.

However, new technologies are now available that make LED designs more reliable, yet many engineers know little about them or fail to implement them properly. This article looks at a total lighting protection solution which may include MOVs, diodes, open LED protection devices as well as other protection methods and techniques including other circuit protection devices.

Market Drivers

Commercial availability of LEDs has dramatically increased. In particular, there are an abundance of 1W to 3W high brightness white LEDs that are used in a number of high profile lighting applications.

One reason for their popularity is their lower operating cost. While efficiency measurements are not standardized, LED lighting systems are generally seen as more efficient than incandescent lighting. Part of the reason may be their lower heat generation. This in turn leads to longer life, particularly if the heat is managed. The durable construction is attractive to municipal and institutional users. For lighting manufactures, lighting end products can command higher prices because they can be offered with long-term warranties. Green initiatives are another reason for the interest in LED lighting, especially with CFL mercury issues.

Failure Modes

LEDs are fragile solid-state devices. 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.

Types of Protection

Figure 1 is a schematic of a typical LED lighting system. In any LED lighting application, there are several areas where effective circuit protection will increase the reliability of the lighting. Those three areas are the AC portion of the circuit prior to DC rectification, a DC section, and the protection for the LEDs themselves.

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 such as MOVs and PLEDs.

DC

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 during a lightning surge event.

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”.

Open LED Protection

Vibration, heat or aging may cause an LED wire-bond to fail. A single LED failure can cause an entire string to no longer “light-up”, resulting in product returns, the tarnishing of the brand name, and incurring warranty expenses.

One new solution to this problem is an open-LED protection device. Open LED protection is designed as an electronic shunt which provides a current bypass in the case of an open circuit caused by a single LED 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 when it is placed in parallel with the LED. This protector also features built-in surge immunity which helps protect the LED from surges induced by nearby lightning strikes or ESD events.

Such devices will turn on and conduct current around an open LED. The result is that the remaining LEDs stay illuminated. Replacing the failed LED will restore the original function. In many applications, the failure of a single LED will cause an entire string of LEDs to turn off. In high-reliability applications, an open failure cannot be tolerated. The PLED6 device from Littelfuse, provides both overvoltage protection and continued string function if a single LED fails open.

Ideally, there is one open LED protector for each LED. However, sometimes a budget LED protection scheme can work, too. For instance, it’s possible to cover two LEDs with one protection device. One LED failure will result in two LED’s going dark. This also cuts protection costs in half.

Open-LED protection devices also work well with various brightness control methods for LEDs. The brightness of LEDs is best controlled by pulse width modulation (PWM) with the switching frequency typically between 60Hz and 1000Hz. Dimming via DC current can cause unwanted color shifts and using a linear power control would lower energy efficiency. Either way, the protection scheme should not interfere with the dimming strategy employed.

The PWM control technique is not universal, however. Doing dimming with PWM preserves color integrity with no shift in color. Ultimately, the goal is to not have the switching of the PLED interfering with color shift nor with the current waveform.

Conclusion

As LEDs enter more high-reliability applications such as safety critical lighting, designers of LED lighting systems must pay more attention to safety and reliability. The first line of defense is a good circuit-protection scheme, 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 open LED, insuring that the remaining LEDs stay illuminated.