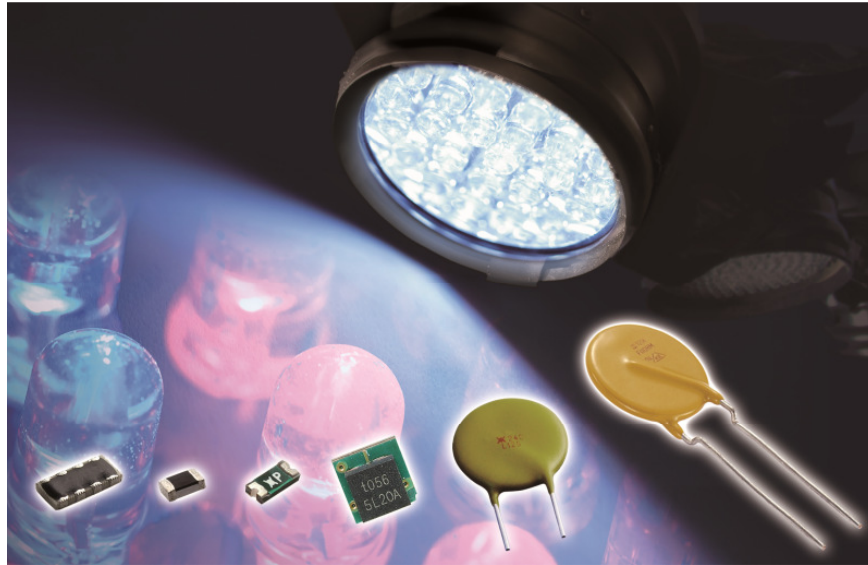


Coordinated Circuit Protection for LED Lighting

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LED technology has advanced rapidly, with improved chip designs and materials facilitating the development of brighter, more energy-efficient, and longer-lasting light sources that can be used in a wide spectrum of applications. In spite of the technology's growing popularity, LED light manufacturers continue to wrestle with the fact that LED luminaires are extremely heat-sensitive. Excessive heat or inappropriate applications can dramatically affect their lifetime and performance.

Resettable polymeric positive temperature coefficient (PPTC) devices have demonstrated their effectiveness in a variety of LED lighting applications. Like traditional fuses, they limit current after specified limits are exceeded. However, unlike fuses, PPTC devices have the ability to reset after the fault is cleared and the power is cycled.

A variety of overvoltage protection devices including metal oxide varistors (MOVs), electrostatic discharge (ESD) surge protection devices, and polymer-enhanced Zener diodes can be used in a coordinated scheme with PPTC devices to help improve LED performance and reliability.

Heat Conduction Comparisons

A lighting fixture using a 60W incandescent light bulb produces approximately 900 lumens of light and must dissipate 3W of heat via conduction. In comparison, using typical DC-LEDs as the light source to achieve the same 900 lumens would require about 12 LEDs. Assuming a V_F (forward voltage) of 3.2V and current of 350mA, the input power to the LED fixture could be calculated as:

$$\text{Power} = 12 \times 3.2V \times 350mA = 13.4W$$

In this scenario, approximately 20% of the input power is converted to light and 80% to heat; dependent on various factors and heat-generation that can be related to substrate irregularities, as well as phonon emissions, binding, materials used, etc.

Of the total heat generated by the LED, 90% is transferred via conduction. Figure 1 shows that, to dissipate heat from the junction of an LED, conduction is the principle channel of transfer since convection and radiation only account for about 10% of overall heat transfer. For example, an LED may convert close to 10.72W of heat (13.4W x 0.80). Of this, 9.648W (10.72W x 0.90) of heat is transferred or removed from the junction via conduction.

Source	Efficiency (%)	Efficacy (lumens/watts)	Heat Loss (%)		
			Radiation	Convection	Conduction
Incandescent	2	15	90	5	5
Fluorescent	15	90	40	40	20
High Intensity Discharge	20	100	90	5	5
LED	20	75	5	5	90

Figure 1. Heat dissipation comparison of various light sources.

Without adequate thermal management, heat can degrade the LED's lifespan and affect color output. Also, since LED drivers are silicon devices, they can fail short. This means fail-safe backup overcurrent protection may be required.

Junction Temperature Effect

The optical behavior of an LED varies significantly with temperature. The amount of light emitted by the LED decreases as the junction temperature rises and, for some technologies, the emitted wavelength changes with temperature. If drive current and junction temperature are not properly managed, the LED's efficiency can drop quickly, resulting in reduced brightness and shortened life.

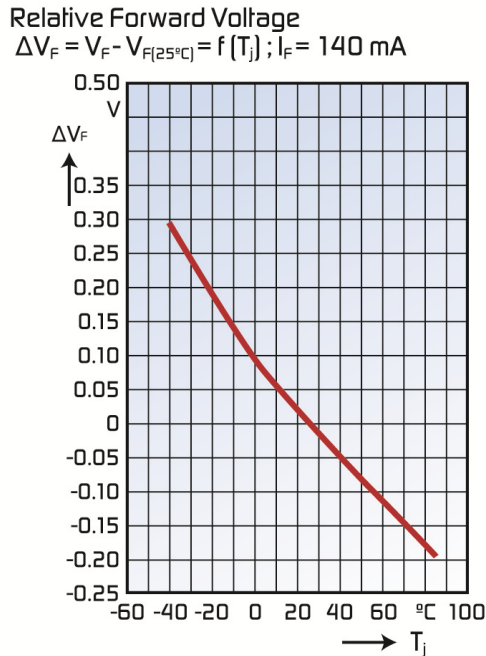


Figure 2. Forward voltage drops as junction temperature rises.

Another LED characteristic, related to junction temperature, is the forward voltage of the LED (Figure 2). If only a simple bias resistor is used to control the drive current, V_F drops as temperature rises and the drive current increases. This can lead to thermal runaway, especially for high-power LEDs, and cause the component to fail. It is common practice to control junction temperature by mounting the LEDs on metal core PCBs to provide rapid heat transfer.

Power line coupled transients and surges can also reduce LED lifespan and many LED drivers are susceptible to damage resulting from improper DC voltage levels and polarity. LED driver outputs may also be damaged or destroyed by short circuits. Most LED drivers include built-in safety features, including thermal shutdown, as well as open and short LED detection. However, additional overcurrent protection devices may be needed to help protect integrated circuits (ICs) and other sensitive electronic components.

LED Driver Input and Output Protection

LEDs are driven with a constant current, with the forward voltage varying from less than 2V to 4.5V, depending on the color and current. Older designs relied on simple resistors

to limit LED drive current, but designing an LED circuit based on the typical forward voltage drop as specified by a manufacturer can lead to overheating of the LED driver.

Overheating may occur when the forward voltage drop across the LED decreases to a value significantly less than the typical stated value. During such an event, the increased voltage across the LED driver can result in higher total power dissipation from the driver package.

Today, most LED applications utilize power conversion and control devices to interface with various power sources, such as the AC line, a solar panel or battery power, to control power dissipation from the LED driver. Protecting these interfaces from overcurrent and overtemperature damage is frequently accomplished with resettable PPTC devices.

The PPTC device has a low-resistance value under normal operating currents. In the event of an overcurrent condition, the device “trips” into a high-resistance state. This increased resistance helps protect the equipment in the circuit by reducing the amount of current that can flow under the fault condition to a low, steady-state level. The device remains in its latched position until the fault is cleared. Once power to the circuit is cycled, the PPTC device resets and allows current flow to resume, restoring the circuit to normal operation.

While PPTC devices cannot prevent a fault from occurring, they respond quickly, limiting current to a safe level to help prevent collateral damage to downstream components. Additionally, the small form factor of PPTC devices makes them easy to use in space-constrained applications.

Figure 3 illustrates a coordinated protection scheme for switch-mode power supplies (SMPSs) and LED driver inputs and outputs. As shown on the left-hand side of the figure, a PPTC device, such as a PolySwitch™ device, can be installed in series with the power input to help protect against damage resulting from electrical shorts, overloaded circuits or customer misuse. Additionally, an MOV placed across the input helps provide overvoltage protection in the LED module.

The PPTC device may also be placed after the MOV. Many equipment manufacturers prefer protection circuits combining resettable PPTC devices with upstream fail-safe protection. In this example, R1 is a ballast resistor used in combination with the protection circuit.

LED drivers may be susceptible to damage resulting from improper DC voltage levels and polarity. Outputs may also be damaged or destroyed by an inadvertent short circuit. Powered ports are also susceptible to damaging overvoltage transients, including ESD pulses.

The right side of Figure 3 shows a coordinated circuit protection design for an LED driver and bulb array. A PolyZen™ device placed on the driver input offers designers the

simplicity of a traditional clamping diode while obviating the need for significant heat sinking. Developed by Tyco Electronics, this device's unique polymer-protected precision Zener design helps provide transient suppression, reverse bias protection and overcurrent protection in a single, compact package.

As shown in Figure 3, a PolySwitch PPTC device on the driver output can help protect against damage caused by inadvertent short circuits or other load anomalies. To fully leverage the PolySwitch device, it can be thermally bonded to the metal core circuit board or LED heat sink. To help prevent damage caused by an electrostatic discharge (ESD) event, ESD protection devices, such as low-capacitance (typically 0.25 pF), small-form-factor PESD devices can be placed in parallel with the LEDs.

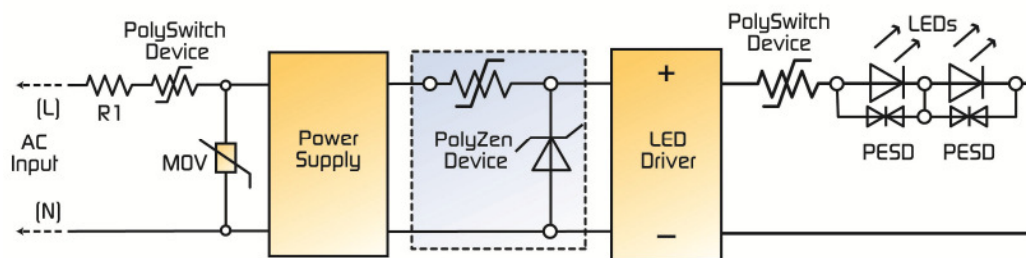


Figure 3. Coordinated protection scheme using PolySwitch PPTC devices and MOV devices for SMPSs (left), and PolyZen, PolySwitch and PESD devices for LED driver inputs and outputs (right).

Meeting Class 2 Power Supply Safety Standards

Utilizing a Class 2 power source in a lighting system can be an important factor in reducing cost and improving flexibility. Inherently limited power sources – a transformer, power supply, or battery – may include protective devices as long as they are not relied upon to limit the output of the Class 2 supplies.

Non-inherently limited power sources, by definition, have a discrete protective device that automatically interrupts the output when the current and energy output reaches a prescribed limit.

A variety of circuit protection devices can help provide operation of Class 2 power sources for LED lighting applications. Figure 4 illustrates how a coordinated circuit protection strategy, employing an MOV on the AC input and a PolySwitch device on an output circuit branch, can help manufacturers meet the requirements of UL1310 paragraph 35.1 overload test for switches and controls.

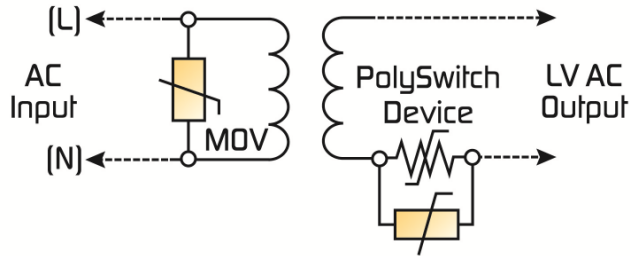


Figure 4. A coordinated protection scheme for Class 2 power sources.

Summary

Resettable PPTC devices help protect against damage caused by both overcurrent and overtemperature faults in LED lighting applications. MOV overvoltage protection devices help manufacturers meet a number of safety agency requirements and provide high current-handling and energy absorption capability, as well as fast response to overvoltage transients.

ESD protection devices help protect against ESD events and provide low capacitance; while Tyco Electronics' PolyZen devices help provide protection against damage caused by the use of improper power supplies, as well as transient suppression, reverse bias protection, and protection from damage caused by overcurrent events.

Utilizing these devices in a coordinated circuit protection scheme can help designers reduce component count, provide a safe and reliable product, comply with regulatory agency requirements, and reduce warranty and repair costs.