

The future is growing brighter for lighting based on light-emitting diodes (LEDs), thanks in part to falling prices and global government mandates to reduce energy consumption. High brightness LEDs are now being used in many different lighting applications, from outdoor display boards and TV LED backlights to traffic signals and airport runway lighting. LED lighting offers many advantages, including extreme long life, high efficiency, and a broad color palette.

Even with less expensive LEDs, the engineers who design lighting products must be concerned with reliability. Reliability is especially important in applications where maintenance is difficult and where the failure of LED strings could jeopardize safety.

The Problem: LEDs Are Fragile Devices

LEDs are fragile solid-state devices. An LED is essentially a diode, structured as a P-N junction that emits light when forward biased. One of the major causes of an electrical open in an LED is thermo-mechanical stress on the wire bonds. Other causes of LED open circuits are electrostatic discharge (ESD) events or surges induced by nearby lightning events. These threats are especially high in outdoor applications.

Devices such as MOVs, fuses, and TVS diodes are essential components of a circuit protection strategy, because they can prevent transients and surges from damaging delicate LEDs. However, none of these traditional circuit protection devices can prevent an entire string of LEDs from going out if a single LED fails.

The Solution: Open LED Protection Technology

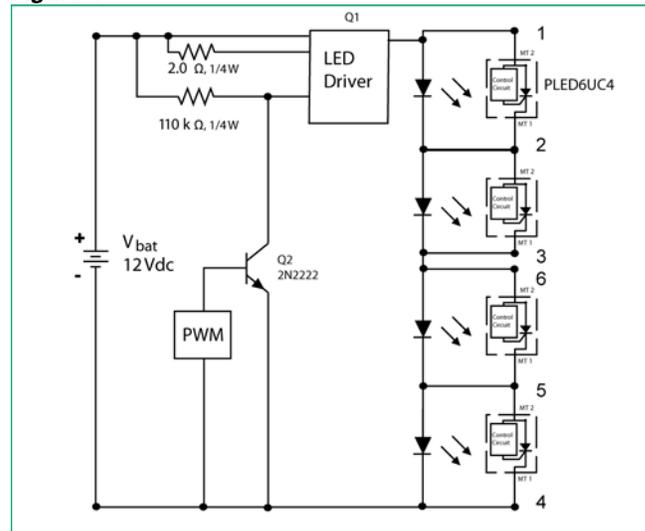
Open LED protection is designed as an electronic shunt which provides a current bypass in the case of an open circuit caused by a single LED failure. It is an internally triggered two-terminal device which automatically resets if the LED heals itself or is replaced. The protector is a voltage-triggered switch with low leakage on the order of microamps that becomes a low-impedance switch when it is triggered on, which minimizes power consumption. An LED in the on-state drops approximately 0.7V, which is not sufficient to turn on the protector device. 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.

Applying Open LED protection

Open LED protection is simple to employ into any design. Typically, a protection device is placed in parallel with each LED in a string. A single LED failing by opening in a string of LEDs can cause a partial or full loss of the entire string. Open LED protection provides a shunt current bypass around the open LED, thus saving the LED string from partial or complete failure.

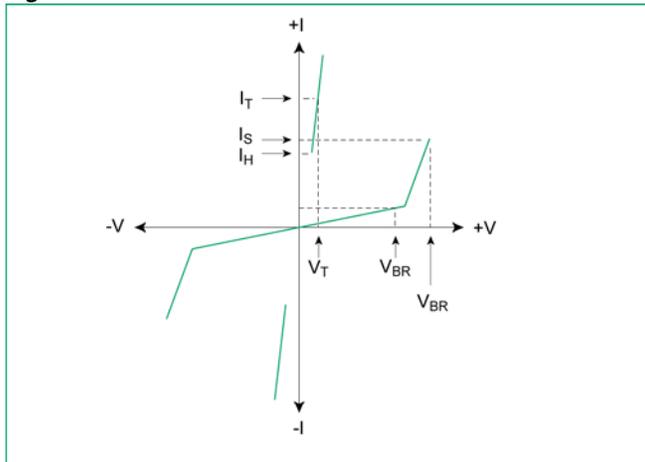
The circuit schematic Figure 1 shows a typical LED circuit with open LED protection provided by Littelfuse PLED Series devices. Open LED protection devices usually have low on-state voltage, typically 1.5V, and a low off-state current. Such devices are compatible with one-, two-, or three-watt LEDs that have a nominal 350mA, 3V forward voltage characteristic, but can support LED applications up to 1000mA

Figure 1



Ideally, there is one open LED protector for each LED. However, two LEDs in parallel can sometimes be protected with one protection device, as a way to lower production cost. In this case, one LED failure would result in two LEDs going dark, but production costs would be cut in half. The trigger voltage of the open LED protection device must be matched to the number of LEDs protected. For example, Littelfuse's PLED6 device has V_{drm} trigger voltage of 6V suitable to protect one typical LED, and the PLED13 has V_{drm} trigger voltage of 13V suitable to protect three typical LEDs.

Figure 2



Key parameters for the Littelfuse PLED device are V_{BR} , I_S , I_H , I_T , and V_T , as shown in the V-I curve (Figure 2). V_{BR} is the region from off-state voltage to breakdown rating of the device. In the off-state, V_{BR} is the continuous peak combination of AC and DC voltage that may be applied to the device with less than $5 \mu A$ conducted through the device. I_S is the value of current that causes the device to switch from the off-state to the on-state when a minimum V_{BR} is applied. Holding current (I_H) is the minimum current required to maintain the device in the on state. On-state voltage (V_T) is the maximum voltage across the device during full conduction. I_T is the maximum rated current that can be conducted through the device during the on-state for two seconds.

Having wide operating temperature ranges, from -40 to $+150C$, PLED Series protection devices can be used in extreme environments often with minimal derating. Another important feature is that such devices are compatible with LED switching speeds up to $10kHz$, which eliminates accidental turn on in some high-frequency circuits.

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 to have the

switching of the PLED interfering with color shift nor with the current waveform.

Conclusions

Because LEDs are susceptible to failure due to surges and other transient conditions, these failures can result in the loss of LED lighting strings. As LED lighting becomes more popular, there will be applications where high reliability and quality of the lighting must be maintained. Open LED protection devices can help LED lighting manufacturers provide products that are highly reliable.

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