LUXEON Automotive LEDs

Circuit Design and Layout Practices
to Minimize Electrical Stress

Introduction

LED circuits operating in the real world can be subjected to various abnormal electrical overstress situations. Among the most common are:

- Electrical Overstress (EOS)
- Reverse Polarity
- ESD (Electro-Static Discharge)
- Transients

Scope

This paper presents background information on some of these overstress modes and discusses considerations to minimize the potentially destructive effects of electrical overstress on LEDs.

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1. Electrical Overstress

LEDs have rated maximums and minimums for current and voltage, which help ensure long life for LED operation. Electrical Overstress (EOS) is any condition which exceeds these rated limits (see Figure 1).

Electrical Overstress can present itself to an LED array in two forms, either as excess voltage or excess current

Figure 1. Damage to LED wire bond due to Electrical Overstress (EOS).

Because voltage and current are interrelated, it is not always possible to identify whether a high voltage or high current caused a failure.

Currents can flow through an LED array in two ways: differential mode and common mode (see Figure 2). Differential mode currents can be very destructive. However, a well-designed LED driver has built-in controls and protection to eliminate any differential mode fault currents. Common mode currents are more insidious, as they are largely dependent on the circuit board layout, materials used, etc. Most of the guidelines in this paper are geared towards minimizing the potential for common mode fault currents.

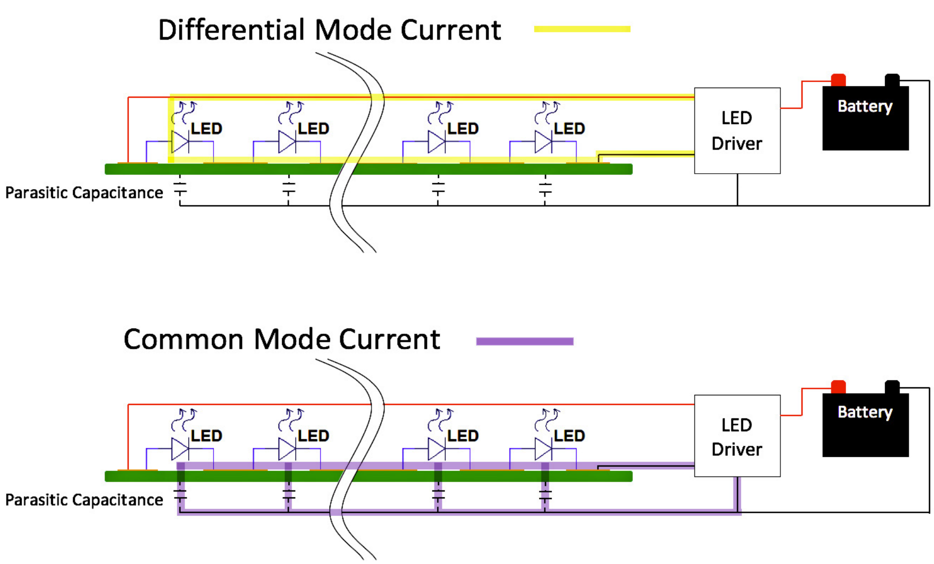

Figure 2. Differential mode (top) and common mode (bottom) currents.

2. Reverse Polarity

There are two methods of minimizing the effects of reverse polarity on an LED array. LEDs shall be driven using a forward bias for conducting current and emitting light. Lumileds LEDs are not designed to be driven in reverse bias, and typical

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LEDs may not have an integrated ESD protection. LEDs with integrated, unidirectional ESD protection, when operated in reverse direction, will have a current path and will be destroyed by overcurrent.

- Prevent negative potential from reaching LEDs
  - Use of Rectifier (Blocking) Diode (see Figure 5) or Blocking FET, in the input circuitry, prevents negative potential from being applied to, and potentially damaging, the LEDs
- Provide Circuitry to negate requirement for input polarity
  - Rectifier Bridge, etc.

Adding circuitry to negate polarity can be expensive and cause power losses, which may not be justified by the limited number of connect/disconnect cycles involved. Methods of driver design shall prevent application of a reverse voltage to the LED (i.e. Poka Yoke or keyed connectors).

3. ESD Guidelines

The likelihood of electrical stress in an LED application can be reduced by taking the following recommendations into account during the design of the application:

- Maintain proper spacing between signal traces and board edge in an MCPCB/IMS board and proper distance between signal traces and any grounded surface on the PCB (per IPC-2221B)
- Make use of guard traces/surfaces at edge of PCB, connected to ground, stitching together ground traces on top and bottom layer (see Figure 6)
- Consider grounding the heatsink, if practical
- Wherever floating electrical conductive materials are potentially exposed to an ESD impact, sensitive signal traces in close proximity need additional protection, for example, by adding large creepage distances or a guard ring. A guard ring (trace) is a barrier connected to a certain potential (e.g. ground), which can protect the sensitive trace signal from ESD event
- Add bypass capacitors and discharge protection capacitors whenever possible
- Use common ESD protection methods during manufacturing and installation of LED lamps (e.g. ankle-straps, wrist-straps, ESD safe shoes, conductive work mats, conductive flooring, ion generators, etc.)
- No unconnected metal on PCB to avoid spreading ESD event into the circuit
- Design the product and the process such that direct contact, with ESD sensitive component, is avoided during assembly
- Most Lumileds high power automotive LED packages feature an integrated TVS protection diode, providing ESD protection for handling the component to a certain level according to product specification. If a higher level of ESD protection for rough environments (e.g. according to ISO 10605) is needed, additional external unidirectional TVS devices are necessary, connected parallel to the LED
- Testing performed using Human Body Model (HBM) (see Figure 3)
- Damage can present itself as shown in Figure 4

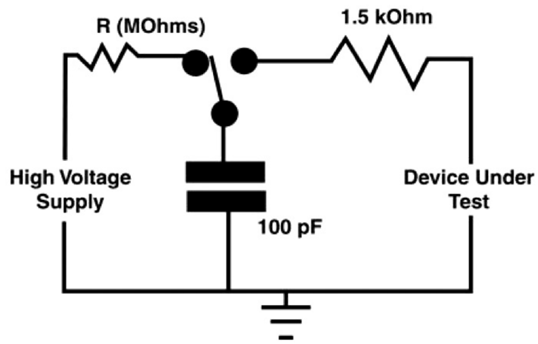

Figure 3. Typical Human Body Model (HBM) circuit.

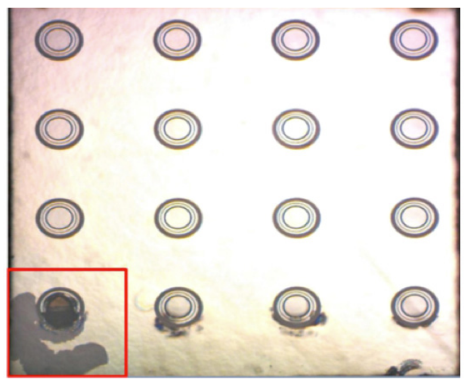

Figure 4. ESD damage on LED die.

4. Transients

When designing LED lamp electronics, careful consideration should also be given to the effects of transients. Transients can occur from surges within sources such as other electronics or automobile alternator (or other inductive system) operation.

There are two types of transients:

- Differential mode transients originating within the current path from the driver or the wire harness
  - Driver design shall not create transients and shall block input transients
  - Wire harnesses should be kept as short as is practical, and corresponding wires should be kept closely together
- Common mode transients coming from between passive/housing parts and the circuit
  - Sufficient isolation rules need to be applied to heatsinks, thermal interface materials (TIM), and distances to the PCB

Some transient tests include:

- Inductive coupling of noise on signal and power lines
- Capacitive coupling of noise on signal and power lines
- Immunity to magnetic fields
- Immunity to electric fields
- Load dump and Crank pulse immunity

To limit the effects of transients, a bi-directional Transient Voltage Suppressor (TVS) (see Figure 5) can be placed as part of the circuitry input of the LED driver between the input connection and the reverse bias protection. The TVS value should be chosen such that it is high enough that it does not conduct during normal operation (including overvoltage and jump start requirements), yet low enough that it will protect the circuitry against overvoltage transients.

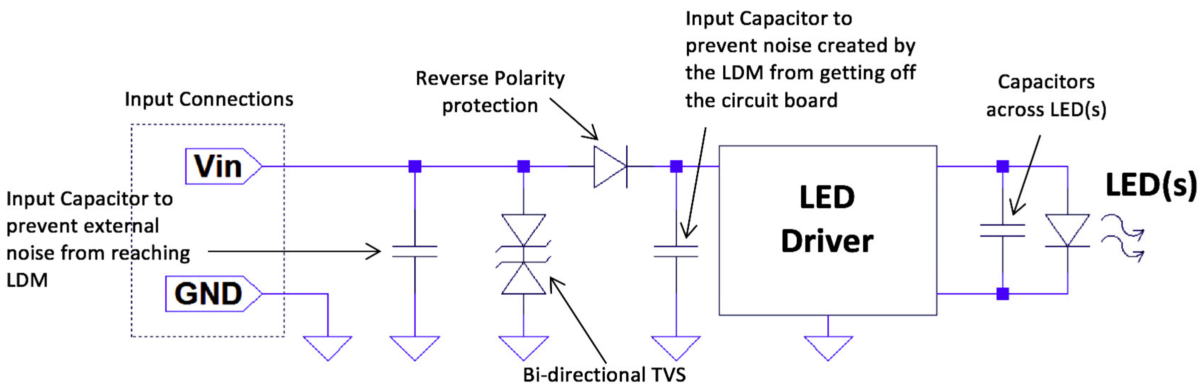

Figure 5. Typical input circuit.

5. Noise

Radiated and Conducted Immunity tests are required for all automobile components. Noise is considered to be any electrical signal in the system that is not desired. Radiated noise can enter on the wiring harnesses, or directly onto PCB traces; noise will be present. The objective is not to eliminate the noise, but rather to prevent any noise from affecting the LED operation.

A typical lamp includes LEDs, printed circuit board(s) (PCBs), heatsinks and other optical and thermal management components (i.e. reflectors, lenses, diffusers) and a power supply.

The key components that need to be addressed are the power supply, wire harness and the LED board.

- To minimize the effects of noise, small passive components can be added to the circuitry
- Low value capacitors (1nF – 0.1µF) should be located as close to PCB inputs as is practical
- Signal traces should be kept as short as practical
- Signal traces should not be placed on the edge of the PCB (consult PCB manufacturer guidelines and applicable customer specifications)
- Circuit common (ground) should be added where practical
  - Adding a ground layer in the PCB is a good way to enable common grounding
- Wider traces are recommended to provide more capacitance
- Low value capacitors (1nF – 0.1µF) should be located across LED strings as is practical
- Wire harnesses should be kept as short as is practical, corresponding wires should be kept close together, and wire loops should be avoided
- Use of metal shield/housing (where applicable) to protect sensitive components from radiated noise, and to limit onboard components radiation off the PCB
- Signal wires/traces should be kept away from power wires/traces
- LED Pad area should be kept to a minimum required for heatsinking to limit parasitic capacitance with a ground plane
- Avoid ground loops (common impedance) (see Figure 6)

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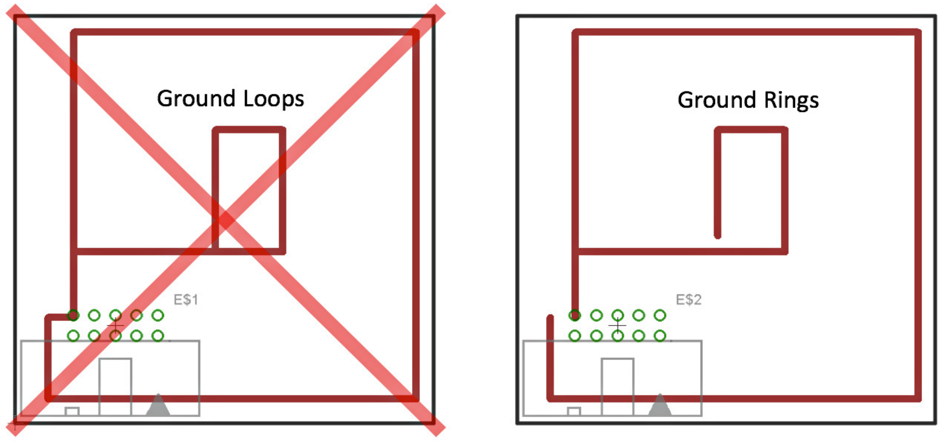

Figure 6. Ground loop vs. ground ring.

About Lumileds

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With a rich history of industry "firsts," Lumileds is uniquely positioned to deliver lighting advancements well into the future by maintaining an unwavering focus on quality, innovation and reliability.

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