1. Introduction

The AL8860Q is a hysteresis mode DC-DC buck LED driver, designed for driving single or multiple series connected LEDs in automotive lamps. In some circumstances the LED string should become in fault status such as open-circuit, short-circuit, LED string anode shorted to GND, which may result in damage to the system and battery. For safety and reliability, the total solution in automotive LED lighting application must take these fault conditions in consideration. This application note describes the performance of AL8860Q when LED string is in fault status.

2. AL8860Q Operation

Figure 1 shows the reference design of AL8860Q. In normal operation, when a voltage is applied at +Vin, the AL8860Q internal NDMOS switch is turned on. Current starts to flow through sense resistors R1, R2, and the LED string. The current ramps up linearly, the ramp rate being determined by the input voltage +Vin and the inductor L1. This rising current produces a voltage ramp across R1 and R2. The internal circuit of the AL8860Q senses the voltage across R1 and R2 and applies a proportional voltage to the input of the internal comparator. When this voltage reaches an internally set upper threshold, the NDMOS switch is turned off. The inductor current continues to flow through R1, R2, L1, the LED string and the Schottky diode D1, and back to the supply rail, but it decays, with the rate of decay determined by the forward voltage drop of the LED string and the Schottky diode. This decaying current produces a falling voltage at R1 and R2, which is sensed by the AL8860Q. A voltage proportional to the sense voltage across R1 and R2 is applied at the input of the internal comparator. When this voltage falls to the internally set lower threshold, the NDMOS switch is turned on again. This switch-on-and-off cycle continues to provide the average LED current set by the sense resistor R1 and R2. Please refer to the datasheets for the threshold limits, AL8860Q internal circuits, electrical characteristics and parameters.

![Figure 1: Schematic diagram](image-url)
3. Open Circuit of LED string

The AL8860Q has by default open LED protection. Figure 2 shows the operation when LED string open circuit happens and then LED string is reconnected. If the LED string is open circuit, the AL8860Q will stop oscillating and the SW pin will fall to GND. No excessive voltages will be seen by the AL8860Q and no damages will be caused to the system. Once the LED string is reconnected, the AL8860Q will resume normal operation.

4. Short Circuit of LED string

If the LED string should become shorted together (the anode of the top LED becomes shorted to the cathode of the bottom LED), the AL8860Q will continue to switch and the current through the AL8860Q's internal switch will still be at the regulated current - so no excessive heat will be generated within the AL8860Q. However, the duty cycle at which it operates will change dramatically and the switching frequency will most likely decrease.

Figure 3 shows the operation when LED string short circuit happens. The on-time of the internal power MOSFET switch is significantly reduced because almost all of the input voltage is now developed across the inductor. The off-time is significantly increased because the reverse voltage across the inductor is now just the schottky diode voltage causing a much slower decay in inductor current.
5. LED anode shorted to GND consideration

LED drivers and power supplies can be remote mounted from the LED modules. The remote mounting distance is based on the voltage drop generated across the supply leads. The voltage drop will vary based on the operating current and the gauge wire used. Typically a maximum voltage drop of 1V across the output leads is acceptable. Table 1 shows the lead length based on the current and wire gauge that will generate a 1V drop.

<table>
<thead>
<tr>
<th>Wire Gauge</th>
<th>0.350</th>
<th>0.700</th>
<th>1.050</th>
<th>1.400</th>
<th>5.0</th>
</tr>
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<tbody>
<tr>
<td>18</td>
<td>447</td>
<td>224</td>
<td>149</td>
<td>112</td>
<td>31</td>
</tr>
<tr>
<td>16</td>
<td>711</td>
<td>356</td>
<td>237</td>
<td>178</td>
<td>50</td>
</tr>
<tr>
<td>14</td>
<td>1132</td>
<td>566</td>
<td>377</td>
<td>283</td>
<td>79</td>
</tr>
</tbody>
</table>

Table 1. Remote Mounting Distance Chart

When LED string is on a separate board away from the AL8860Q driver board, there may be chances that the anode terminal of the AL8860Q driver board is shorted to GND by misconnection. To avoid damage from this event, a fuse resistor can be added at the input. See Figure 4, if LED anode is shorted to GND, the input power supply will be connected to GND via fuse (F1) and sense resistor (R1, R2), and the current flowing through F1 is \( \frac{V_{in}}{R_{1//R_{2}}} \), which is high enough to blow out the fuse to cut off the current path.

6. Summary

It has been demonstrated how the AL8860Q reacts when fault status occurs. The AL8860Q is capable of providing robust protections against LED open, LED short and LED anode short to GND, ensuring safety and reliability in automotive applications.
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