DN78
ZXSC310 with reverse polarity protection
Ray Liu - Applications Engineer, Zetex Semiconductors

Description

The schematic diagram shown in Figure 1 is a typical example of the ZXSC310 used in a LED flashlight application. The input voltage can either be one or two alkaline cells. If the battery is put in the flashlight the wrong way, the reverse polarity can damage the ZXSC310 and switching transistor, Q1. Implementing a mechanical reverse protection method can be expensive, and not always reliable. This paper describes methods of electronic reverse protection, without efficiency loss, for the ZXSC series ICs and related LED flashlight application circuits.

Circuit problems caused by the reverse polarity battery

If a negative voltage appears at the input terminal of Figure 1 then reverse current will flow from the ground pin of the ZXSC310 to the VCC terminal and back to the battery. This current is high and will damage the ZXSC310. Some of this reverse current will also flow through the VDRIVE terminal of the ZXSC310 and into Q1 base-collector completing the circuit to the battery.

The reverse current through base-collector of Q1 turns the transistor on in the reverse direction and causes high current to flow from ground, through emitter-collector to the battery, resulting in battery drainage and possible damage to the switching transistor, Q1.

A common method of reverse polarity protection

A common method of reverse protection is to add a Schottky diode in series with the battery positive. The problem with this method of reverse protection is that there is a loss of efficiency due to the forward voltage drop of the diode, typically 5% to 10% depending upon input voltage, reducing the usable battery life. The proposed method of reverse protection for the ZXSC series IC’s gives full protection with no loss of efficiency.
Reverse protection without efficiency loss

By adding current limiting resistor and Schottky diode, the reverse current flow can be eliminated without a loss of efficiency.

Flashlight circuit with bootstrap

For the bootstrap circuit in Figure 2, the current through the ZXSC310 is blocked by the reversed biased Schottky diode, D1.

The current from V_{DRIVE}, which turns on Q1 in the reverse direction, is diverted via D2 back to the battery so that Q1 does not turn on. R2 is a current limiting resistor to control this V_{DRIVE} current. This value is typically set to 100\,\Omega to 500\,\Omega to minimize battery current drain without affecting the normal operation of the circuit.

![Figure 2](image_url)

<table>
<thead>
<tr>
<th>Ref</th>
<th>Value</th>
<th>Part number</th>
<th>Manufacturer</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td></td>
<td>ZXSC310E5</td>
<td>Zetex</td>
<td>LED driver in SOT23-5</td>
</tr>
<tr>
<td>Q1</td>
<td></td>
<td>ZXTN25012EFL</td>
<td>Zetex</td>
<td>Low sat. NPN in SOT23</td>
</tr>
<tr>
<td>D1</td>
<td>750,mA</td>
<td>BAT750</td>
<td>Zetex</td>
<td>750mA Schottky in SOT23</td>
</tr>
<tr>
<td>D2(1)</td>
<td>200,mA</td>
<td>BAT54</td>
<td>Zetex</td>
<td>200mA Schottky in SOT23</td>
</tr>
<tr>
<td>L1</td>
<td>68,\mu\text{H}</td>
<td>Generic</td>
<td>Generic</td>
<td>I_{SAT}&gt;0.4A, R&lt;0.8,\Omega</td>
</tr>
<tr>
<td>R1</td>
<td>270,\Omega</td>
<td>Generic</td>
<td>Generic</td>
<td>0805 size</td>
</tr>
<tr>
<td>R2(1)</td>
<td>100,\Omega</td>
<td>Generic</td>
<td>Generic</td>
<td>0805 size</td>
</tr>
<tr>
<td>C1</td>
<td>10,\mu\text{F}/6.3V</td>
<td>Generic</td>
<td>Generic</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>22,\mu\text{F}/6.3V</td>
<td>Generic</td>
<td>Generic</td>
<td></td>
</tr>
</tbody>
</table>

Table 1  Bill of materials

NOTES:
(1) Add for reverse protection
Typical operating characteristics
(For typical application circuit where $T_{\text{amb}} = 25^\circ\text{C}$ unless otherwise stated)

Figure 3  Performance graphs
Other circuit examples using reverse polarity protection

Flashlight circuit without bootstrap

The circuit shown in Figure 4 is for an LED flashlight application without bootstrap. As described previously, reverse current can flow from the GND terminal to $V_{CC}$ and back to the battery. To block this current path an extra diode, D2b, is added. It is recommended that a Schottky diode be used for this application to maximize the start-up input voltage from $V_{CC(MAX)}$ to $V_{CC(MIN)} + D2b V_F$, 3V to 1V. The Schottky diode, D2a, and resistor, R2, work in the same way as described in the bootstrap circuit in Figure 2. A dual Schottky diode, BAT54S, is recommended for D2 in order to achieve low component count.

![Figure 4 LED flashlight application without bootstrap](image-url)
Other circuit examples using reverse polarity protection

Flashlight circuit without bootstrap

Figure 5 is a step down converter with reverse polarity protection. The main application for this circuit is a four alkaline cell flashlight driving a high powered LED. Again the protection circuit operates as described above. A dual Schottky diode, BAT54S, is recommended for D2 in order to achieve low component count.
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Zetex sales offices

Europe
Zetex GmbH
Kustermann-park
Balanstraße 59
D-81541 München
Germany
Telephone: (49) 89 45 49 49 0
Fax: (49) 89 45 49 49 49

Americas
Zetex Inc
700 Veterans Memorial Highway
Hauppauge, NY 11788
USA
Telephone: (1) 631 360 2222
Fax: (1) 631 360 8222
europe.sales@zetex.com

Asia Pacific
Zetex (Asia Ltd)
3791-04 Metroplaza Tower 1
Hing Fong Road, Kwai Fong
Hong Kong
Telephone: (852) 26100 611
Fax: (852) 24250 494
asia.sales@zetex.com

Corporate Headquarters
Zetex Semiconductors plc
Zetex Technology Park, Chadderton
Oldham, OLG 9LL
United Kingdom
Telephone: (44) 161 622 4444
Fax: (44) 161 622 4446
hq@zetex.com

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