AN65
Using the ZXSC310 to drive high power LEDs from 2 alkaline cell with hysteretic UVLO

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Introduction

This note describes how the ZXSC310 boost convertor can be used to drive high power LED's from batteries of less than 1V to greater than 6V .

The option of under voltage lockout (UVLO) to protect the batteries from deep discharge is also discussed. Two options are described one with hysteresis and a simpler one without.

The device is available in a SOT23-5 packag and requires only a few small external components in this application.

Rather than a classical supply philosophy, which would supply the full current to the LED until the battery was exhausted and then switch off suddenly, the ZXSC310 has been designed to allow a graceful fading of the intensity so that the user knows that it is time to replace the battery but can continue to use the torch (flashlight); albeit at gradually reducing intensity. (If a steady current is preferred the ZXSC400 can be used in circuits very similar to those to be described in this note.)

The following paragraphs describe some of the design considerations and trade-off's relevant to such an application.

Heatsinking

The High Power LED's can be driven at up to 5W and under such drives typically 4W will need to be extracted from the device without the junction temperature exceeding it's rated value. If maximum life is required then there should be a margin between the rated temperature and the actual temperature. If the device is expected to be used in an ambient temperature of say 30degC at 4W dissipation then the necessary thermal resistance form the junction to ambient needs to be no more than

(Tjmax-Tamb)/Pdiss thus:- (150-30)/4 K/W = 30K/W.

The LED data sheet for the Luxeon K2 defines the thermal resistance (junction to thermal bonding pad) as 9K/W, leaving a maximum of 21K/W from the mounting point to ambient to be guaranteed by the thermal design of the product. One square cm of FR4 pcb 1.6mm thick has a thermal resistance of about 50K/W from the top layer to the bottom layer, so it is clear that attention needs to be paid to the pcb mounting as well as the thermal path to the outside. Frequently ISM (insulated metal substrate) pcbs are used in all but the most cost constrained applications. If this is not possible then thermal vias can be used to conduct the heat to the bottom of the pcb from where it would need to be conducted to ambient and this is a requirement of the mechanical design of the product.

Sometimes, as in the designs presented below, 5W represents too much battery drain and a lower current is used which eases the thermal design. One K2 LED running at 500mA has a dissipation of about 1.5W so the maximum thermal resistance then becomes 70K/W - rather easier to implement.

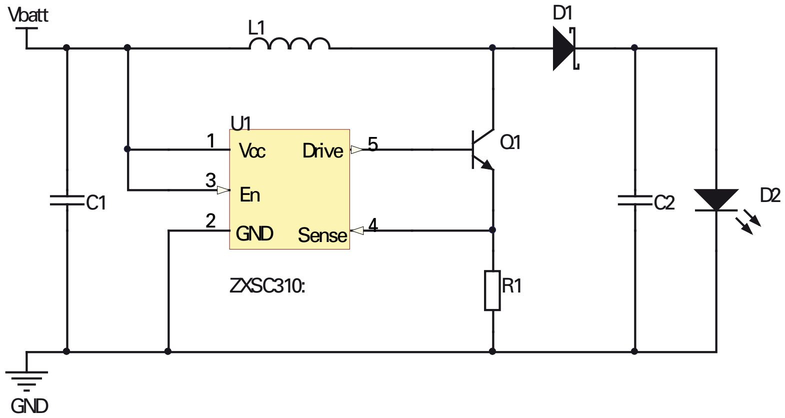

Figure 1 - Basic boost circuit

Choice of inductor

The inductor is usually the physically largest component in this type of design and there are trade-offs to be made in it's selection.

For the best efficiency (read battery life) the inductor needs to be operating within it's rating for saturation current and to have an acceptably low series resistance. It should also be physically small and inexpensive. These two pairs of attributes are usually mutually exclusive so a suitable compromise has to be reached and this is a function of the particular application.

Two examples are shown below.

- Driving a K2 at 350mA from 2 alkaline cells.
- Driving a K2 at 500mA from 2 alkaline cells.

The first graph shows how the LED current varies with battery voltage for a 350mA initial current.

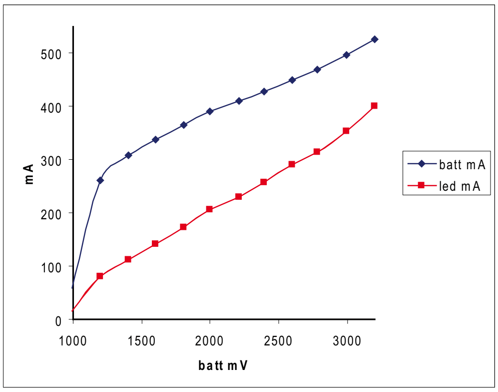

Figure 2 - Performance at a nominal 350mA drive

This characteristic applies with the following BoM

Table 1. Bill of materials for figure 1

Ref	Part No	Value	Package	Manufacturer	Web
U1	ZXSC310		sot23-5	Zetex	www.zetex.com
Q1	ZXTN25012		sot23	Zetex	www.zetex.com
D1	SBR2A40P1		di123	Diodes	www.diodes.com
R1		50mΩ	0805	generic	
D2	LXK2-xxx		proprietary	Lumileds	www.lumileds.com
C1		1µF 6.3V	0805	generic	
C2		1uF 25V	0805	generic	
L1	LPO2506OB-103	10uH	proprietary	CoilCraft	www.coilcraft.com

A photograph of this inductor is shown in Figure 3, as can be seen it is low profile and compact

.

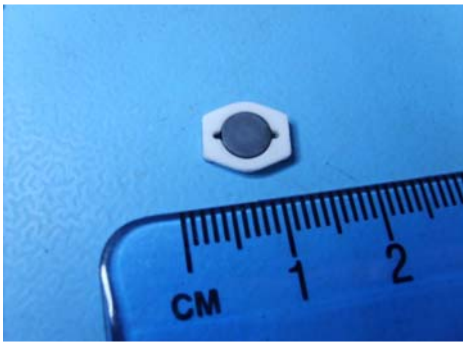

Figure 3 - The low profile inductor

Higher power circuits

For more LED current an inductor with lower resistance and higher saturation is preferred, the data shown in Figure 4 was obtained using a slightly larger inductor, pictured below the circuit diagram in Figure 5.

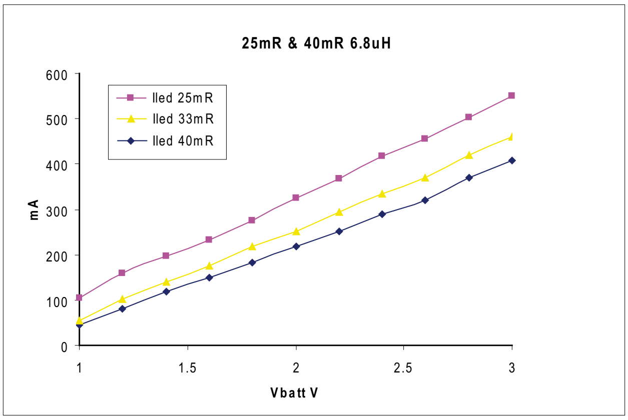

Figure 4 - Performance for a nominal 500mA drive

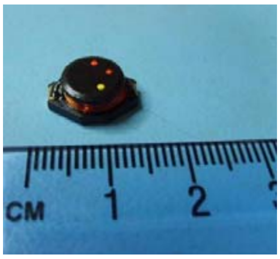

Figure 5 - The slightly larger inductor

In this case the BoM is:

Table 2 - BoM for a 500mA drive

Ref	Part No	Value	Package	Manufacturer	Web
U1	ZXSC310		sot23-5	Zetex	www.zetex.com
Q1	ZXTN25012		sot23	Zetex	www.zetex.com
D1	SBR2A40P1		di123	Diodes	www.diodes.com
R1		25/33/40mΩ	0805	generic	
D2	LXK2-xxx		proprietary	Lumileds	www.lumileds.com
C1		1μF 6.3V	0805	generic	
C2		1uF 25V	0805	generic	
L1	DO3316P-223	22uH	proprietary	CoilCraft	www.coilcraft.com

Shutdown

This circuit has no switch off functionality and there is therefore the risk that the cells could go into deep discharge which could lead to leakage. The addition of a few low cost components can get round this problem as shown in the circuit diagram below.

Here the shutdown capability of the ZXSC310 is used to switch the unit off before the cell voltage falls below the specified value. There is then only a very small current drawn from the battery. This circuit will exhibit some temperature dependence as the Vf's of the diodes are temperature dependent, so it may not be suitable for applications requiring constant performance over a wide temperature range .

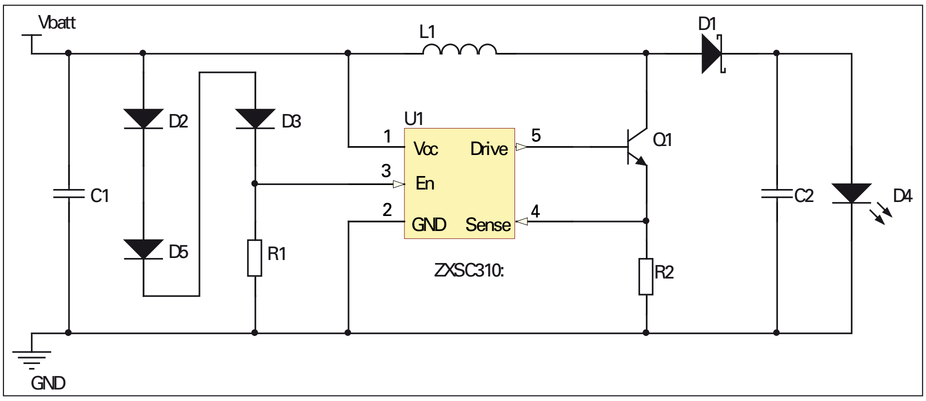

Figure 6 - A circuit for simple UVLO

For this design the BoM is:

Table 3 - BoM for the Simple UVLO circuit

Ref	Part No	Value	Package	Manufacturer	Web
U1	ZXSC310		sot23-5	Zetex	www.zetex.com
Q1	ZXTN25012		sot23	Zetex	www.zetex.com
D1	SBR2A40P1		di123	Diodes	www.diodes.com
D2,D3,D5	1N4148WT		sod523	Diodes	www.diodes.com
R1		see text	0805	generic	
R2		50mΩ	0805	generic	
D4	LXK2-xxx		proprietary	Lumileds	www.lumileds.com
C1		1µF 6.3V	0805	generic	
C2		1µF 25V	0805	generic	
L1	LPO2506OB-103	10µH	proprietary	CoilCraft	www.coilcraft.com

The performance of this circuit is shown in Figure 7 for different combinations of diodes and resistors.

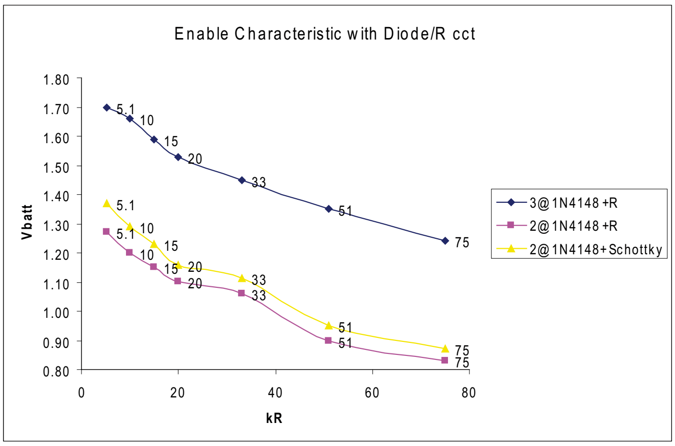

Figure 7 - Selection of components for the required UVLO value

As an example 3 1N4148 diodes and a 62k resistor would give a shutdown at about 1.3V. Resistance values above 75k are too high to give reliable shutdown .

Switch off with hysteresis

The circuit above can be improved by the addition of a few more components to give some hysteresis. This avoids the possible scenario where the device switches off reducing the drain on the battery whose voltage then rises and switches the LED's back on again. The circuit shown in Figure 8 uses 2 transistors in a type of Schmitt circuit to avoid this possibility. The actual switching levels do depend on the transistors chosen. A dual transistor would save a little space but the switching levels may have to be adjusted. The performance of the example circuit is shown in Figure 9.

This circuit will have less temperature dependence than the previous one.

The ZXTD09N50DE6 is a dual in SOT23-6 which gives very similar performance to the 2 ZXTN2040F's and offers space saving at a slightly higher price.

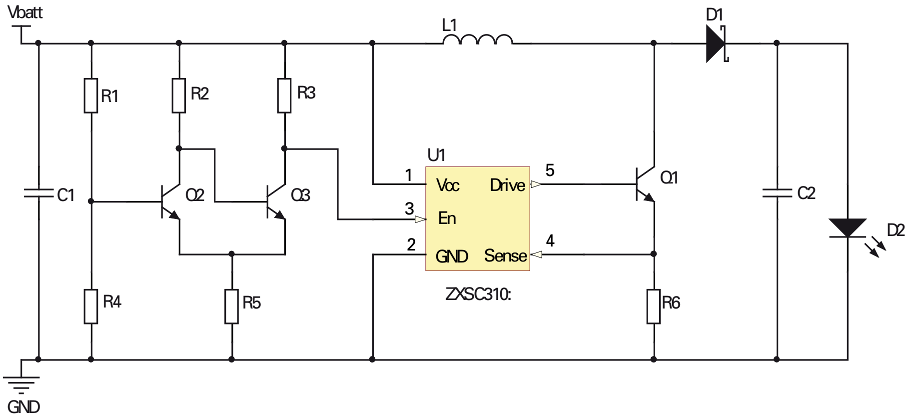

Figure 8. UVLO with hysteresis.

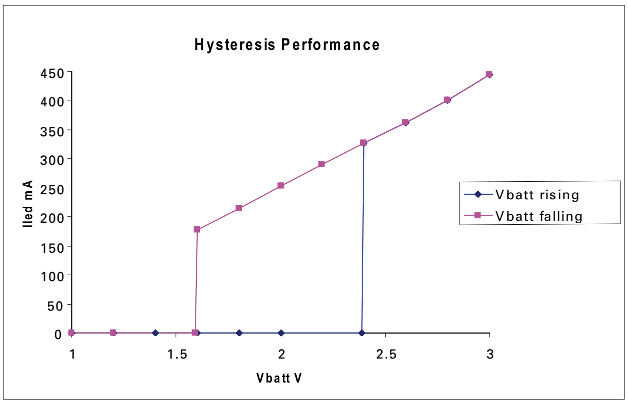

Figure 9 - Hysteretic UVLO Performance.

Table 4 - BOM for hysteretic UVLO

Ref	Part No	Value	Package	Manufacturer	Web
U1	ZXSC310		sot23-5	Zetex	www.zetex.com
Q1	ZXTN25012		sot23	Zetex	www.zetex.com
Q2,Q3	ZXTN2040F		sot23	Zetex	www.zetex.com
D1	SBR2A40P1		di123	Diodes	www.diodes.com
R1		16kΩ	0805	generic	
R2, R3, R4		10kΩ	0805	generic	
R5		1k2Ω	0805	generic	
R6		50mΩ	0805	generic	
D4	LXK2-xxx		proprietary	Lumileds	www.lumileds.com
C1		1µF 6.3V	0805	generic	
C2		1µF 25V	0805	generic	
L1	LPO2506OB-103	10µH	proprietary	CoilCraft	www.coilcraft.com

There is a sample schematic which will run with the free downloadable Zetex Simulator available at www.zetex.com and this is a good way of testing the effects of different component values.

Choice of switching transistor

The switching transistor Q1 needs high current gain and low Vcesat for the circuit to work properly. The Zetex ZXTN25012 has been developed with this application in mind and whilst other types could be used they would not give the same efficiency and would run hotter.

Conclusion

We have shown how, with the addition of a few small components, the ZXSC310 can drive high power LED's from 2 alkaline cells. Additionally 2 methods of adding UVLO to the designs have been described.

The same principles can be applied to the ZXSC400 which has feedback capability to maintain the LED current more constant as the battery becomes discharged.

Please see the full data sheets (and other Application and Design Notes) at www.zetex.com.

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