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Reduced component count and compact reference design for MR16 replacement lamps using multiple 1W LEDs

Silvestro Russo, October 2007

Introduction

MR16 lamps are one variety of Multifaceted Reflector (MR) lamps that usually employ a halogen filament capsule as the light source. They are used in many retail and consumer lighting applications where their size, configurability, spot-lighting capability and aesthetics provide utility and creativity. Low efficiency, heat generation and halogen capsule handling issues are among the disadvantages of the technology. They typically operate from 12V DC or 12V AC, using conventional electromagnetic transformers.

LEDs offer a more energy efficient and no radiated heat solution to replace some halogen lamp applications.

This reference design is intended to fit into the base connector space of an MR16 style LED lamp. The design has been optimized for part count and thermal performance. The design can be used with up to 3 1W LEDs in the Lens section. This can be arranged to suit the luminary designer's requirements.

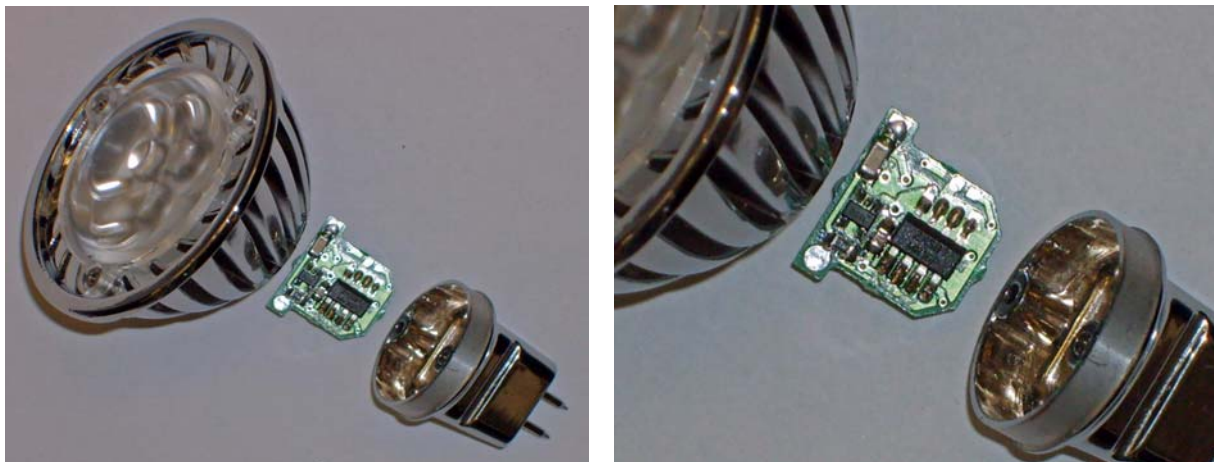


Figure 1 MR16 application with ZXLD1350

Data sheet

It is recommended that this design note is used with the data sheet for the ZXLD1350 see <http://www.zetex.com/3.0/pdf/ZXLD1350.pdf>

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Description

The system diagram of the MR16 lamp solution with ZXLD1350 and ZXSBMR16PT8 is shown in Figure 2, and Table 1 provides the bill of materials.

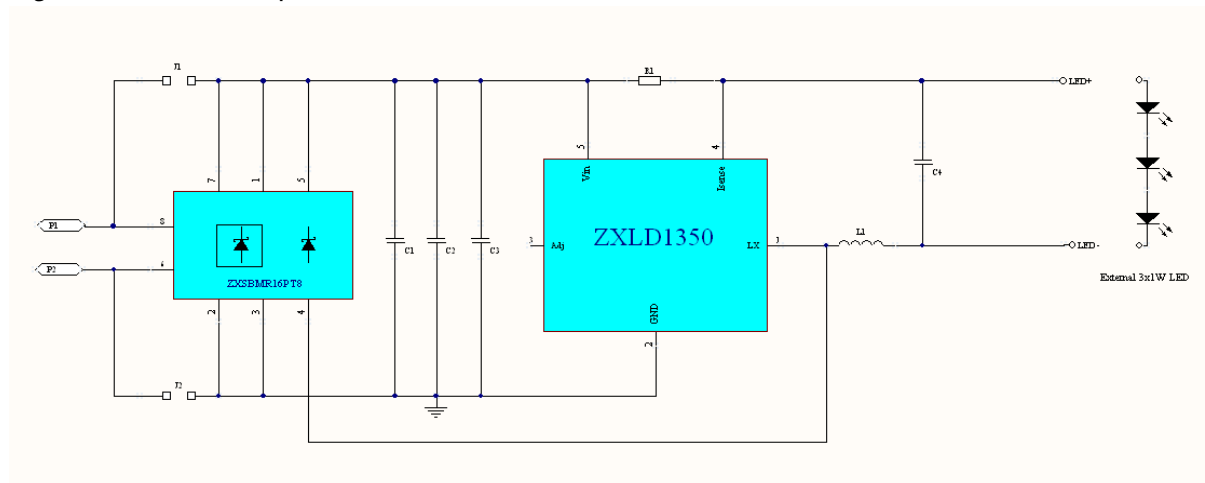


Figure 2 System diagram of ZXLD1350 MR16 Lamp Solution

The **ZXLD1350** is designed for LED current drive applications of up to 350mA. The monolithic NMOSFET is sized appropriately to provide a cost-effective die size and is rated to 400mA, which with the hysteretic mode of operation (the inductor current waveform will ramp +/- 15% about the nominal current set point) provides sufficient margin. The main features of the ZXLD1350 are:

- Up to 380mA output current
- Wide input voltage range: 7V to 30V
- Internal 30V 400mA NDMOS switch
- High efficiency (>90% possible)
- Up to 1MHz switching frequency

The **ZXSBMR16PT8** is a new space saving and thermally efficient device specifically designed for the critical requirements of MR16 applications. The device encompasses a full bridge and a freewheeling diode realized using extremely low leakage 1A, 40V Schottky diodes to allow a nominal 12V AC input operations. The Schottky bridge together with the embedded freewheeling diode enhance the system efficiency compared to the standard silicon diodes in a compact format. The reference design has solder tag pins to bypass the bridge rectifier should the final lamp design be used for purely DC operation.

As the ZXLD1350 has a hysteretic switching topology, the switching frequency is dependent on several factors - input voltage, target current and number of LEDs. An Excel based calculator is available for system initial evaluation and component choice.

See <http://www.zetex.com/3.0/otherdocs/zxld1350calc.xls>

System efficiency and LED current have been measured keeping the ADJ pin floating and the current in the device at its rated value. The input impedance of the ADJ pin is high (200K) and is susceptible to leakage currents from other sources. Anything that sinks current from this pin will reduce the output current. In order to avoid any kind of electromagnetic coupling a guard track around this pin is used.

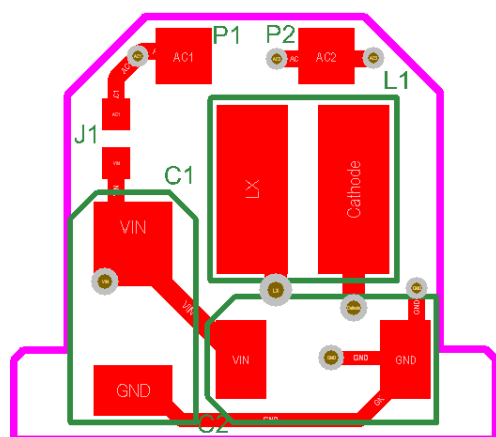
Quantity	Part reference	Value	Description	Source
1	R1	0.33Ω	Resistor, 1%, 0805	Various
2	C1, C2	150μF/20V	Type D SMD Tantalum Cap	Kemet
1	C3	0.1μF/25V	SMD 0805 X7R	NIC Components
1	C4	1μF/25V	SMD 1210 X7R	NIC Components
1	L1	100μH	MSS6132-104	Coilcraft
1	U1	ZXLD1350	LED driver IC	ZETEX
1	U2	ZXSBMR16PT8	Schottky bridge rectifier and freewheeling diode	ZETEX

Table 1 Bill of Material

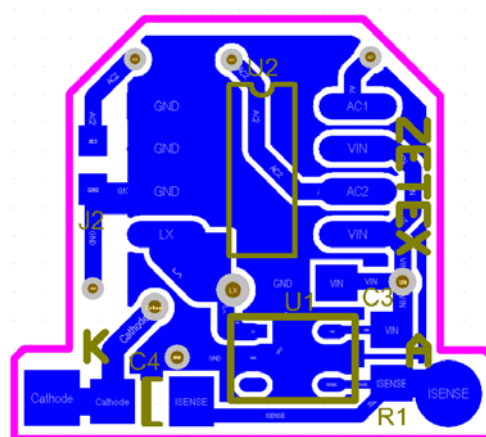
Referring to circuit schematic in Figure 2; the jumper connection could be used utilizing a zero ohm resistor, in order to enable the pure DC operations.

Care has to be taken in this case, since the system is not reverse polarity protected.

In Figure 3 the circuit layout is shown, highlighting its space saving features and compactness. Both bottom layer and top layer are shown to display effective devices arrangement.



TOP COPPER AND SILKSCREEN



BOTTOM COPPER AND SILK SCREEN

Figure 3 Circuit layout

The main layout design suggestions are:

- All thin devices on one side
- Employ a star connection for ground tracks
- Use a ground ring protecting ADJ pin
- Check that:
 - Tracks connecting R1 to ZXLD1350 are as short as possible (being sense tracks)
 - The filter capacitor C3 is connected as close as possible to the V_{in} pin
 - The freewheeling current path is as short as possible to ensure system precision and efficiency

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Circuit board views

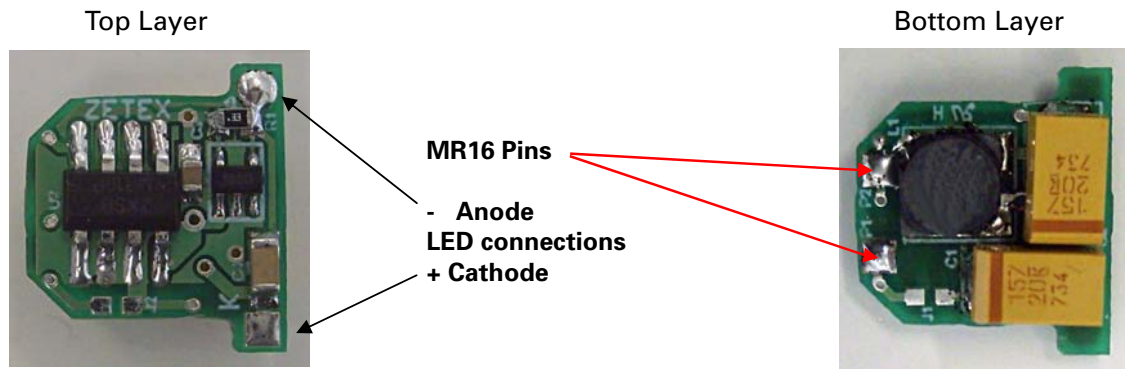


Figure 4 Circuit board views

Choice of Inductor and switching circuit layout

A 100 μ H screened inductor was chosen to set the nominal frequency around 250kHz. A screened inductor is chosen to minimize radiated EMI. The layout with any switching regulator is crucial to minimize radiated EMI. This reference design keeps the critical track lengths to a minimum. Ground areas have been maximized around critical areas.

Circuit performances

Circuit performances have been evaluated taking into account two main parameters, the system efficiency and the current precision.

The reference current is set to a nominal 300mA but can be adjusted to any value up to 350mA by changing the sense resistor R_{sense} according to the formula:

$$I_{ref} = 0.1/R1 \quad [A]$$

For $R1 = 0.33\Omega \quad \rightarrow \quad I_{ref} = 300mA$

In Table 2 the data related to the system supplied with a DC voltage ranges from 12V to 15V. For these tests the Schottky bridge was included. The most important parameters are the system efficiency and the error between the rated LED current (300mA) and the actual LED current. In the DC case the frequency ranges between 150kHz and 300kHz, depending on the input voltage. Whatever the input voltage, the efficiency is higher than 87% and the error lower than 2%.

Vin [V]	Iin[A]	Vout[V]	Iout[A]	Efficiency	Current Accuracy
12.000	0.275	9.80	0.296	87,9%	1.3%
13.000	0.252	9.78	0.294	87.7%	2.0%
14.000	0.232	9.76	0.294	87.6%	2.0%
15.000	0.220	9.75	0.294	87.4%	2.0%

Table 2 DC input voltage

Table 3 shows the data related to the system supplied with an AC electromagnetic transformer. Using a SMD tantalum capacitor will save space and avoid using a larger aluminum electrolytic capacitor. This will improve the reliability of the system and stabilize performance during its lifetime. There is a trade off between physical size, reliability, cost and average LED current. Typical output voltages from a nominal 12V AC transformer can be $\pm 10\%$. With 3 LEDs the voltage across these will be around 10V. If the input capacitor value is lower than 200 μ F, the AC input waveform is distorted (as can be seen in figure 8). When the rectified AC is not sufficiently

smoothed the ripple may drop below the combined LED forward voltage which stops the switching regulator and so reduces the average current in the LEDs. This will also reduce the average lumens output.

C1 [μF]	Vin [V]	Iin[A]	Vout[V]	Iout[A]	Efficiency	Current Accuracy
100	12.70	0.303	9.28	0.225	54%	25%
150	12.60	0.394	9.50	0.271	52%	10%
200	12.53	0.432	9.55	0.293	52%	2%
300	12.50	0.386	9.70	0.295	60%	2%

Table 3 AC input voltage

Figures 5 to 7 show the input voltage ripple and LX voltage varying the input capacitance value $C_{in} = C1 + C2 + C3$. The higher the input capacitance the higher to output current precision and the average lumens outputs. The case with $C_{in}=300\mu\text{F}$ has the best performance both as efficiency and current precision. Reducing the input capacitance the output current precision will decrease up to 25% with system efficiency always above 50%.



Figure 5 $C_{in}=300\mu\text{F}$

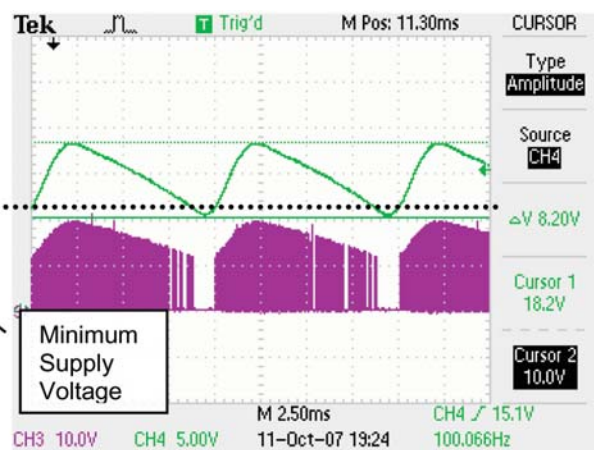


Figure 6 $C_{in}=200\mu\text{F}$

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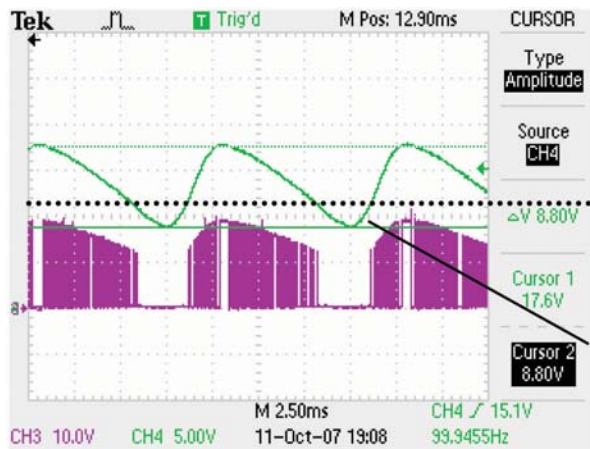


Figure 7 $C_{in}=150\mu F$

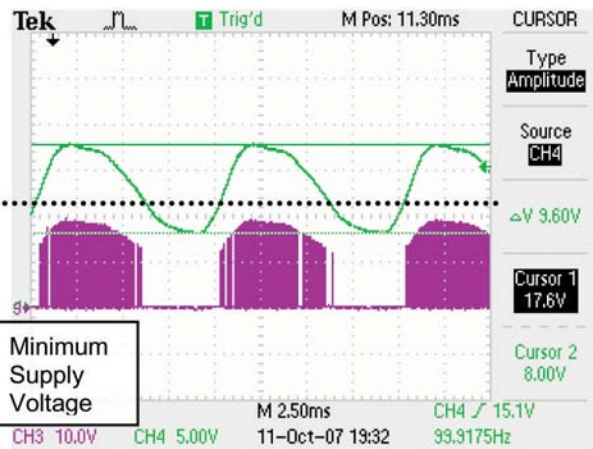


Figure 8 $C_{in}=100\mu F$

Figure 5 to 8: input ripple and LX voltage (Ch3 is the LX pin voltage and Ch4 is the input voltage)

Gerber plots and further assistance are available from your local Zetex contact or Distributor. You can contact your local sales office by email.

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Conclusion

A compact, reliable, efficient and minimum part count solution can be realized using the ZXLD1350, ZXSMBR16PT8, and associated passive components. The compact design in the connector housing keeps the temperature sensitive semiconductors as far from the heat generating LEDs as possible. A compromise between LED current and size of capacitance is necessary for the final solution which accounts for efficiency, accuracy, size, and component count.

This is the first design note in a series of reference designs MR16 variants solutions and options.

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