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ZXLD1360 and Super Barrier Rectifier ideally suited for 700mA LED current in MR16 application

Introduction

MR16 solutions with LEDs are intended to replace halogen lamps with a more efficient solution. Often this is associated with problems in thermal management, both from the LED and the driver.

Since the LED mainly dissipates the heat through conduction rather than irradiation, the replacement system has to be carefully designed in terms of both shape and material, and in consideration of the LED derating curve. Also, the driving circuit has to manage increasing amounts of current, while the space is constrained by the limits of the base connector in an MR16 style LED lamp (GU5.3 standard).

MR16 systems typically operate from 12V AC or 12V DC, using conventional electromagnetic or electronic transformers, and the efficiency as well as the LED current is strongly affected by the power source used.

This design can be used for a system employing a single 3W LED in the lens section, and this can be arranged to suit the luminary designer's requirements.

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Figure 1- Combined strengths of ZXLD1360 and SBR2A40P1

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Description

The system diagram of the MR16 lamp solution with ZXLD1360 and SBR2A40P1 is shown in Figure 2, while Table 2 provides the bill of materials for this reference design.
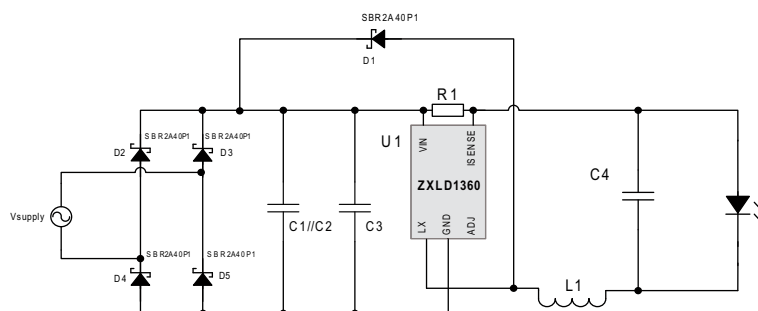

Figure 2 - MR16 circuit diagram

The ZXLD1360 is a hysteretic converter designed for LED current drive applications of up to 1A. The monolithic NMOSFET is sized appropriately to provide a cost-effective die size and is rated to 1A current. [1]

The main features of the ZXLD1360 are:

- Up to 1A output current

- Wide input voltage range: 7V to 30V

- Internal 30V 1A switch

- High efficiency (>90% possible)

- Up to 1MHz switching frequency

As the ZXLD1360 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 to support initial system evaluation and component selection and is available for download from www.diodes.com.

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 (200kΩ) 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.

The SBR2A40P1 belongs to the patented Super Barrier Rectifier (SBR) family, and has proven to be very stable at high temperature. It can be used both in the input bridge rectifier section and in the freewheeling section. [2]

The new SBR technology offers to combine the high performance of Schottky diodes while possessing the high reliability characteristics of p–n diodes. In particular the device combines low forward voltage, high switching speed and low leakage at high temperature. In an MR16 application the SBR technology

displays reduced a temperature coefficient when compared to Schottky parts, as is highlighted in table 1. This feature is fundamental since the diodes work predominantly in blocking phase in a MR16 application.

Table 1

	Typical Ir [mA]		
Part No.	**Ir @ 30V, 25°C**	**Ir @ 30V, 85°C**	**Ir @ 30V, 150°C**
SBR2A40P1	0.013	0.24	5.5
ZLLS2000	0.025	1.7	80

Also, the SBR for MR16 can be housed in a proprietary package, the PowerDI™123, that combines both space saving and high power density due to its excellent thermal performances, making the solution reliable at higher temperature. [2]

Bill of Material

Table 2 presents the BOM for the reference design.

Table 2

Quantity	Part reference	Value	Description	Source
1	R1	0.15	Resistor, 1%, 0805	Various
5	D1, D2, D3, D4, D5	SBR2A40P1	SBR 40V, 2A - PowerDI™123	Diodes Inc.
1	C1	-	Not Fitted	-
1	C2	150µF/20V	Type D SMD Tantalum Cap	KEMET
1	C3	0.1µF/25V	SMD 0805 X7R	NIC Components
1	C4	1µF/25V	SMD 1206 X7R	NIC Components
1	L1	33µH	LPS6235-333MLB	Coilcraft
1	IC1	ZXLD1360	Zetex LED driver IC – SOT23-5	Diodes Inc.

Figure 3 and 4 show the circuit layout, highlighting its space saving features and compactness. In particular, both bottom layer and top layer are shown to display effective devices arrangement.
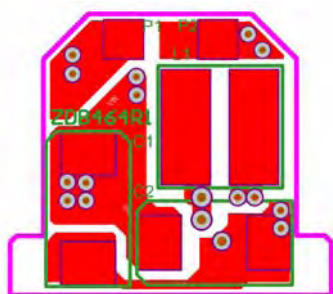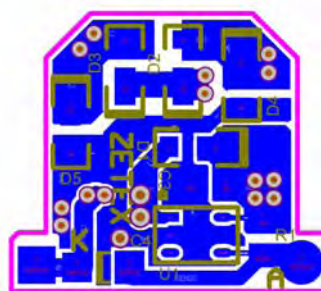

Figure 3 - PCB layout – Top Layer   **Figure 4 - PCB Layout – Bottom Layer**

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P1 and P2 on the top layer are the pads for the supply voltage connection, while K and A pads on the bottom layer connect the board to the LED cathode and anode respectively.
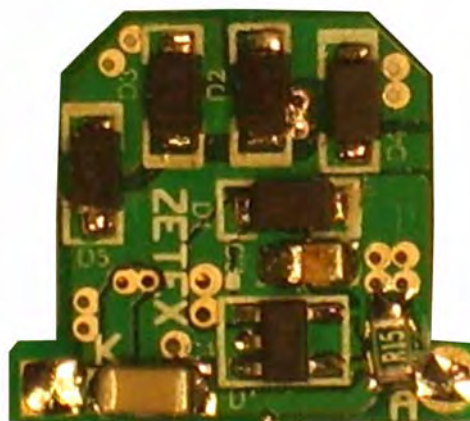

Figure 5 - Demo Board - Top Layer   **Figure 6 - Demo Board – Bottom Layer**

Choice of Inductor and Switching Circuit Layout

Inductor selection influences the performance of the system in terms of switching frequency and EMI emission. This section presents the critical choices and their implications.

A 33µH screened inductor was chosen to set the nominal frequency around 210kHz.

Radiated EMI is minimized using a screened inductor, keeping the critical track lengths to a minimum.

Ground areas have been maximized around critical areas, to allow a more efficient heat transfer.

Circuit Performance

Circuit performance has been evaluated taking into account two main parameters; the system efficiency and the LED current precision.

The reference current is set to a nominal 660mA but can be adjusted to any value up to 1A by changing the sense resistor R1 according to the formula:

Iref = 0.1/R1 [A]

Iref = 660mA,   for R1 = 0.15Ω,

In Table 3, the data shows the system supplied with a DC voltage ranging from 10V to 15V. The most important parameters are the system efficiency and the error between the rated LED current (660mA) and the actual LED current. In the DC case, the frequency ranges between 270kHz and 300kHz, depending on the input voltage.

Whatever the input voltage, the efficiency is higher than 77% and the LED current error lower than 2%.

Table 3- DC input data

Vsupply [V]	Iin [A]	Pin [W]	Vout [V]	Iout [A]	Pout [W]	Efficiency [%]	Error [%]
10V	0.247A	2.47W	2.97V	0.647A	1.92W	77.9%	2%
11V	0.227A	2.50W	2.97V	0.650A	1.93W	77.3%	2%
12V	0.210A	2.52W	2.99V	0.655A	1.96W	77.7%	1%
13V	0.195A	2.54W	2.96V	0.660A	1.95W	77.1%	0%
14V	0.182A	2.55W	2.96V	0.665A	1.97W	77.3%	1%
15V	0.171A	2.57W	2.96V	0.669A	1.98W	77.2%	1%

Figure 7 highlights the main waveform in the circuit during AC operations when C2=150uF and Vsupply is 12VAC (waveform CH1 is the device VIN voltage and CH2 is its LX voltage).

Note that in the single LED application, the VIN voltage can have a bigger ripple compared to a 3 LEDs application. This is because in a standard buck configuration the only constraint is VIN > VLEDs, with VIN greater than the driver minimum voltage. The possibility of having a larger voltage ripple allows efficiency and accuracy to be maintained using a smaller input capacitor when compared to a 3 LEDs MR16 solution. [3]

In Table 4 the data related to the system supplied with a 12V AC voltage. System efficiency is better than 50% and the error between the rated LED current (660mA) and the actual LED current is usually lower than 1%.

Table 4 - DC Input data

C1 [uF]	Vin [V]	Iin [A]	Pin [W]	Vout [V]	Iout [A]	Pout [W]	Efficiency [%]	Error [%]
150	12	0.328	3.936	2.97	0.667	1.981	50.3%	1%

Furthermore, in the AC case the frequency ranges between 240kHz and 300kHz, performing a natural frequency dithering that simplifies the eventual EMC filter design.
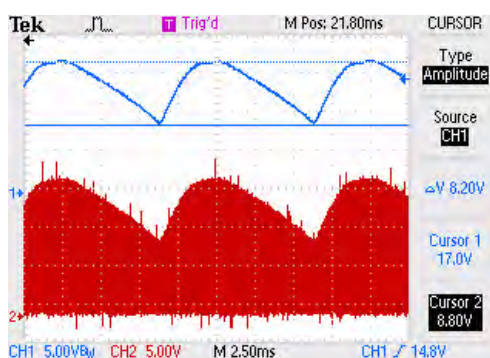
Figure 7 - Main waveforms

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Thermal Considerations

An important consideration in MR16 systems is the difference between the ambient temperature and the operating temperature of the driving circuit. The driving circuit temperature is determined by; the size of the MR16 connector, the proximity of this circuit with the LED thermal dissipation area, and the material used to manufacture the lamp. The temperature range seen by the driving circuit within the connector of an MR16 lamp is usually between 75˚C and 90˚C, even with a max ambient temperature of 40˚C. This condition makes the environment very hard for both the freewheeling diode and the bridge rectifier diodes, but is managed by SBR technology's key characteristics of high temperature stability and higher thermal runaway capability compared to a Schottky diode.

Table 5 shows the maximum operating temperature for MR16 replacement systems based on SBR and Schottky diodes.

Table 5 - System maximum operating temperature

System tested	Input Voltage	Output current	Maximum system temperature
MR16 with SBR2A40P1 SBR	12AC	660mA	105˚C
MR16 with ZLLS2000 Schottky diodes	12AC	656mA	80˚C

It is clear that the SBR2A40 outperforms the conventional Schottky diode in this application, being itself immune to the run away problem typical of Schottky diodes.

Conclusion

In conclusion SBR technology displays high temperature stability and higher thermal runaway capability compared to a low leakage Schottky diode. This characteristic, in conjunction with the excellent features of the PowerDI™123 package and the ZXLD1360 led driver, allow easy design of MR16 systems coping with the most demanding environmental conditions.

This reference design, in summary, provides all the elements to design a 700mA single LED MR16 system, capable of managing the most demanding specifications.

References

[1] ZXLD1360 datasheet   www.diodes.com

[2] SBR2A40P1 datasheet   www.diodes.com

[3] DN86 MR16 reference design   www.diodes.com

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