AN1149

Super Barrier Rectifiers (SBR®) improve Daytime Running Lamp (DRL) efficiency

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Automotive lighting has been using LEDs for more than 10 years. Initially, one of the main driving forces behind adopting LEDs was the lumen per watt efficiency gains they offer over incandescent lamps. This meant that, to maximize the efficiency improvements, the focus was on lamps that are on most of the time. Other reasons include safety and, most recently, styling.

For example, the daytime running lamp or light (DRL) was introduced for the purposes of safety. These forward-facing lights remain illuminated, across all battery conditions, so that other road users can see the vehicle. The better efficiency of LEDs and their design flexibility allows automotive manufacturers to produce distinctively styled lighting - many cars are now instantly recognizable by their DRLs.

While LED technology offers vast improvements in performance, it is still important to consider an efficient power supply design. Buck-boost topology has been widely adopted for DRLs and Figure 1 shows a simplified circuit that typically employs a switching MOSFET (Q1) and, the focus for this document, a freewheeling or flywheel diode (D1) arrangement. Buck-boost topologies are normally implemented so that the correct drive of LEDs occurs across all input voltages – including cold cranking (9V or even down to 6V) and transients (>20V).

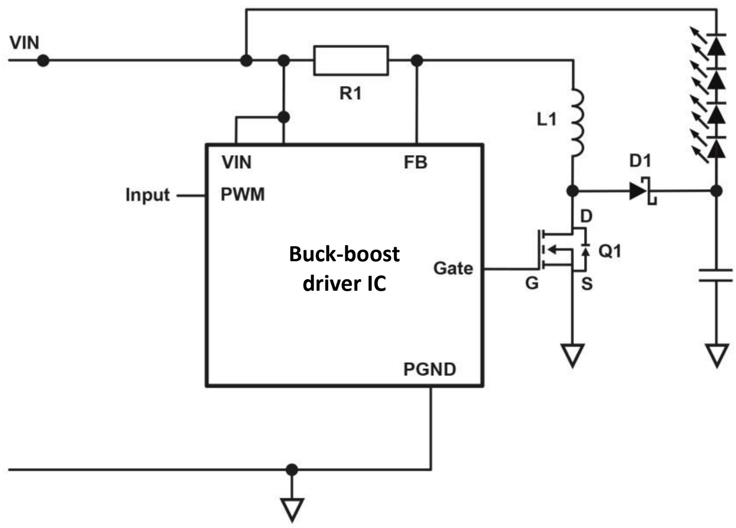

Figure 1. Simplified buck-boost DRL circuit

As this is a “boost” type of switching topology, the MOSFET and the freewheel diode peak currents will be much greater than the average LED current. This means careful choices must be made about the MOSFETs and freewheel diodes’ conduction and switching losses – especially at high temperatures.

This document demonstrates the performance improvements of using Super Barrier Rectifier (SBR®) technology in place of the typical Schottky diode technology in this automotive application.

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SBR Introduction

Super Barrier Rectifier (SBR) is a proprietary and patented Diodes Incorporated technology that utilizes a Metal Oxide Semiconductor (MOS) manufacturing process to create a superior alternative to the Schottky diode. Internally, the device is effectively a MOSFET with its gate (G) and source (S) terminals internally connected together effectively becoming the diode anode terminal and the drain (D) becoming the cathode terminal, see Figure 2.
SBR devices are represented by the same electronic schematic symbol as the Schottky diode (Figure 3).

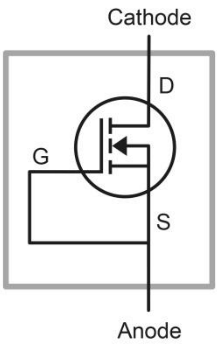

Figure 2. Simplistic representation of internal device and connections

Figure 3. SBR electronic schematic symbol

In every other way the device behaves as a diode and assures drop-in replacement compatibility. For example, a 10A, 100V Schottky can be replaced by the SBR equivalent device without concern for other components; however, immediate improvements in efficiency and reduced device case temperature can be realized.

Performance Evaluation

To demonstrate the performance improvements SBR brings over Schottky technology, we compare a leading competitor with the same rating, as shown in Table 1.

	Diodes Inc. SBR10M100P5Q	**Competitor A 10A 100V rated**
Device Technology	SBR	Schottky Diode
Typical Forward voltage V_F(V) (I_F 1A @85˚C)	0.50	0.50
Typical Forward voltage V_F(V) (I_F 10A @85˚C)	0.70	0.72
Typical leakage current I_R(µA) @85°C	1.7	18
Typical leakage current I_R(µA) @125°C	15	300
E_{AS}(mJ)	400	20
I_{FSM}(A)(square,8.3ms/10ms)	220	200
Reverse Recovery Time t_{rr} (nS) (I_F=3A, di/dt=50A/µs, V_R=50V@85˚C)	28.3	33.2
Reverse Recovery Charge Q_{rr} (nC) (I_F=3A, di/dt=50A/µs, V_R=50V@85˚C)	9.4	14.1

Table 1. Forward and reverse characteristics of the devices

Using a buck-boost evaluation driver board (Figure 4), and running on a range of input voltages from 7V to 30V, each device is tested, at position D1, to drive a string of LEDs. Performance improvements are expected to be seen in the following areas:

1. Device case temperature
   a. SBR technology remains cooler due to lower internal losses.

2. Power efficiency
   a. Fast switching, low forward V_F, low reverse leakage current, low reverse recovery time and charge are all inherent with SBR technology and lead to improved efficiencies. These parameters remain more stable, compared with Schottky technology, at increased operational temperatures.

The efficiency of the driver board and case temperatures of each device were measured.

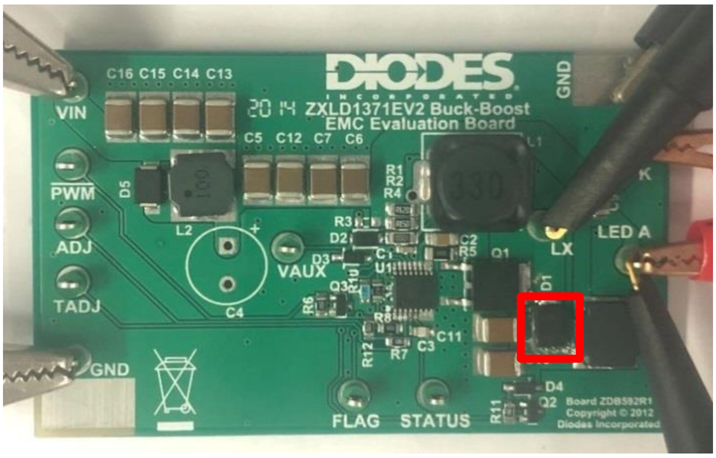

Figure 4. Each device tested in circuit at highlighted position D1

Ambient Temperature = 25°C

At 25°C both technologies provide high efficiency, with improvements of up to 3% for SBR reaching close to 92% overall, as shown in Figure 5.

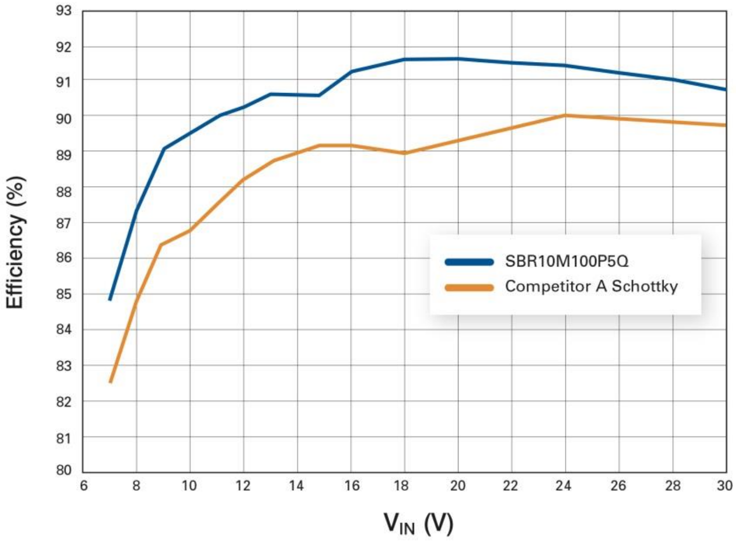

Figure 5. Buck-boost converter's efficiency with SBR vs. Schottky 25°C

Ambient Temperature = 85°C

At 85°C, however, significant efficiency drop-off of up to 6% can be seen with the Schottky device, as shown in Figure 6.

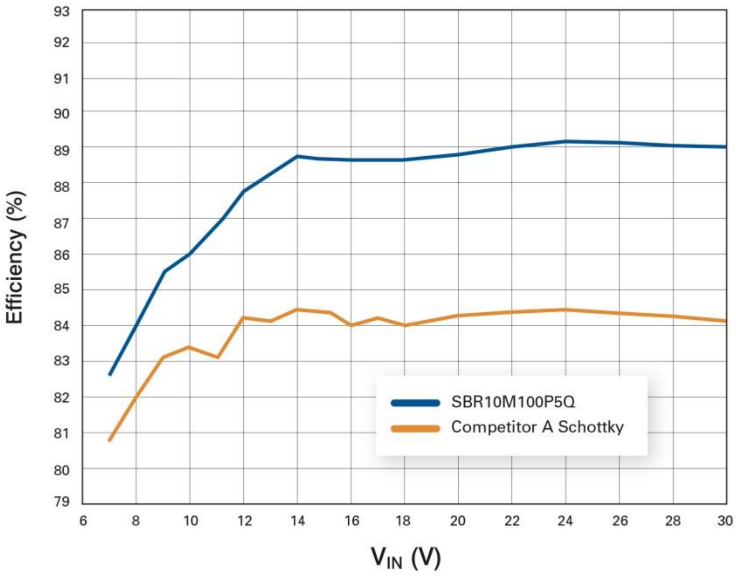

Figure 6. Buck-boost converter's efficiency with SBR vs. Schottky at 85°C

Device case temperatures

Despite the Schottky device having a large underside heatsink, the case temperature of the SBR consistently runs up to 5°C lower in temperature across a range of ambient temperatures, as can be seen in Figure 7.

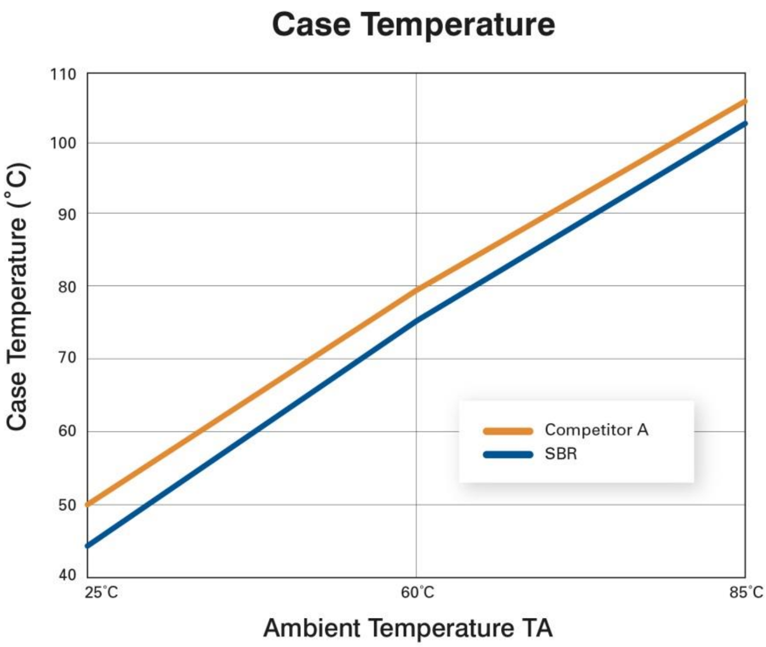

Figure 7. Case temperature vs. ambient temperature

Overall Efficiency

As the ambient temperature increases, the overall efficiency gap between the SBR and the Schottky device also increases, as can be seen in Figure 8. A combination of diode forward conduction losses, increased reverse leakage current and switching losses, in conjunction with the overall system losses, contribute to the differences seen as the ambient temperature rises.

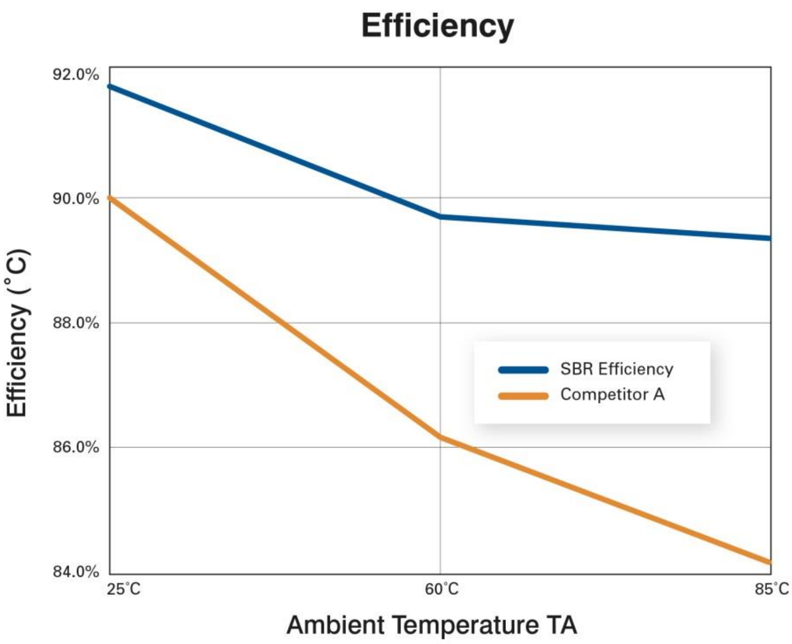

Figure 8. Efficiency vs. ambient temperature

Power saving

The overall result in improved efficiency is a saving in wasted power. Figure 9 shows that the improvement in efficiency returned a saving of up to 800mW.

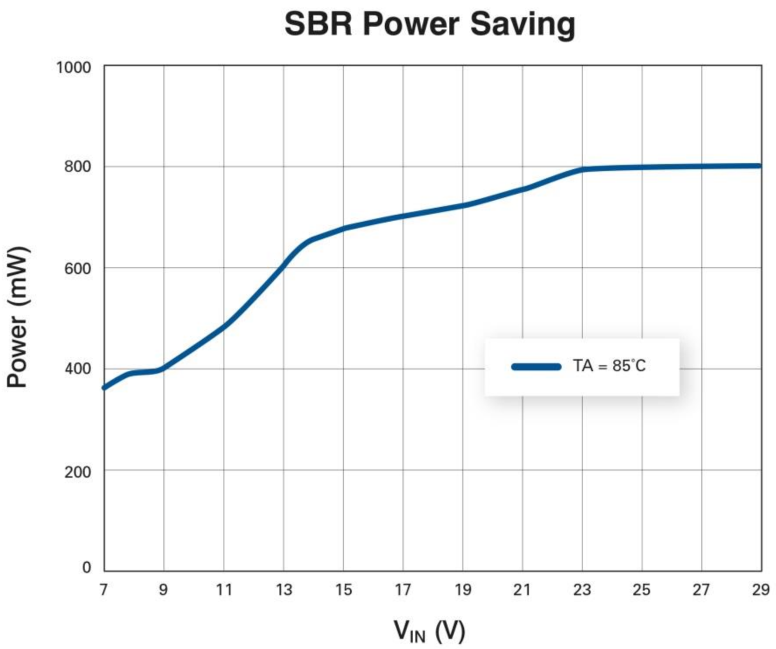

Figure 9. Power saving benefit of SBR vs. Schottky device at ambient temperature of 85°C

Conclusion

For some time Schottky technology has been selected for the freewheeling diode in typical buck-boost converters driving daytime running lamp LED lighting. The introduction of the SBR10M100P5Q, with its drop-in compatibility with Schottky diodes, means that circuit designers can now easily achieve lower losses due to faster switching times, lower forward voltage drop and lower reverse leakage current, leading to improvements in efficiency of up to 5%.

The lower operating temperatures, of up to 5°C, together with increased robustness for hotter ambient temperatures, give automotive customers extra confidence for long-term reliability and stability over Schottky diode technology. The reduced burden on thermal management systems also means further savings can be realized.