Defining Schottky Diodes based on Power Dissipation

As wireless devices grow more sophisticated and consumers demand longer battery lives, manufacturers need to save power wherever possible. One area where a large amount of power is consumed is in the LED backlight for LCD displays. To drive these LEDs a boost circuit is implemented to increase the battery voltage to a level large enough to overcome the forward voltage of the LEDs. Choosing the correct Schottky diode for this boost circuit can help reduce the overall power dissipation of the system. For this reason, defining Schottky diodes based on overall power dissipation rather than individual parameters of the device is a preferable approach. **Steven Shackell, ON Semiconductor, Phoenix, USA**

The main parameters on which new Schottky diodes were defined in the past were forward voltage and reverse leakage current. Two large contributors to these specifications are the Schottky barrier metal and the Schottky contact area. Since the parameters share a dependence on the same variables, there is a trade-off between the two. As the forward voltage is reduced, the reverse leakage current is increased, and vice versa. As the industry has driven to lower and lower forward voltages, the reverse leakage currents have been steadily increasing. It has now reached a point where additional reductions in forward voltage result in larger increases to the reverse leakage current, resulting in higher overall power dissipation.

Nevertheless, it is still common to think that the forward voltage is the main contributor to the power dissipation and reverse leakage current is of less importance; this is not necessarily true anymore. For example, if the output voltage of the boost converter (see Figure 1) is much larger than the input voltage the resulting duty cycle will be very large. The larger the duty cycle of the boost converter the longer the Schottky diode is reverse biased. In addition to the larger duty cycle, the output current of the boost converter could range from 10 to 40 mA. This is usually the case for the boost converter used in the LED backlight application for a wireless device. Table 1 compares a boost optimized Schottky diode from ON Semiconductor (Device 1) with another popular low forward voltage Schottky diode (Device 2). Although the forward voltage of Device 2 is 24 % lower, the power dissipation is 39 % higher.

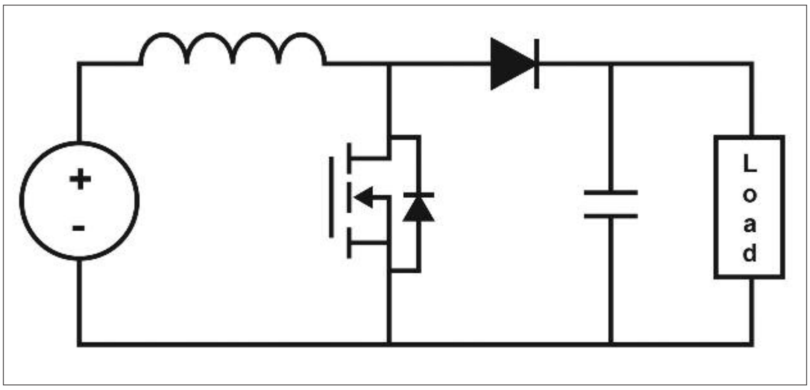

Figure 1: Schematic of boost converter

Calculating the power dissipation

In the above table the power dissipation (PD) is calculated by the equations 1 and 2:

$$D = \frac{V_{out} + VF - V_{in}}{V_{out} - V_F} \qquad (1)$$

$$P_D = D \times V_{out} \times I_R + (1 - D) \times V_F \times I_F \qquad (2)$$

where D = Duty Cycle of Boost Converter, P_D = Schottky Diode Power Dissipation, V_{out} = Output Voltage of Boost Converter, V_{in} = Input Voltage of Boost Converter, I_F = Average Forward Current through Schottky Diode, V_F = Forward Voltage of Schottky Diode at I_F, I_R = Reverse Leakage Current of Schottky Diode at V_{out}.

The first step in calculating the power dissipation is to calculate the duty cycle. The values of Device 2 in Table 1 will be used to do this. In wireless devices the input voltage/battery voltage can be as low as 2.5 V. The output voltage depends on the configuration of the LEDs. A common configuration is one string of 10 LEDs. For white LEDs the forward voltage is around 3.3 V. For this configuration the output voltage will be

Device	V_F @ 10 mA	V_F @ 100 mA	I_R @ 30V	P_D @ I_F = 10 mA	P_D @ I_F = 100 mA
1	270 mV	366 mV	19.2 µA	0.75 mW	3.54 mW
2	199 mV	277 mV	95.7 µA	2.80 mW	4.92 mW

Table 1: Boost optimized Schottky vs. low V_F Schottky

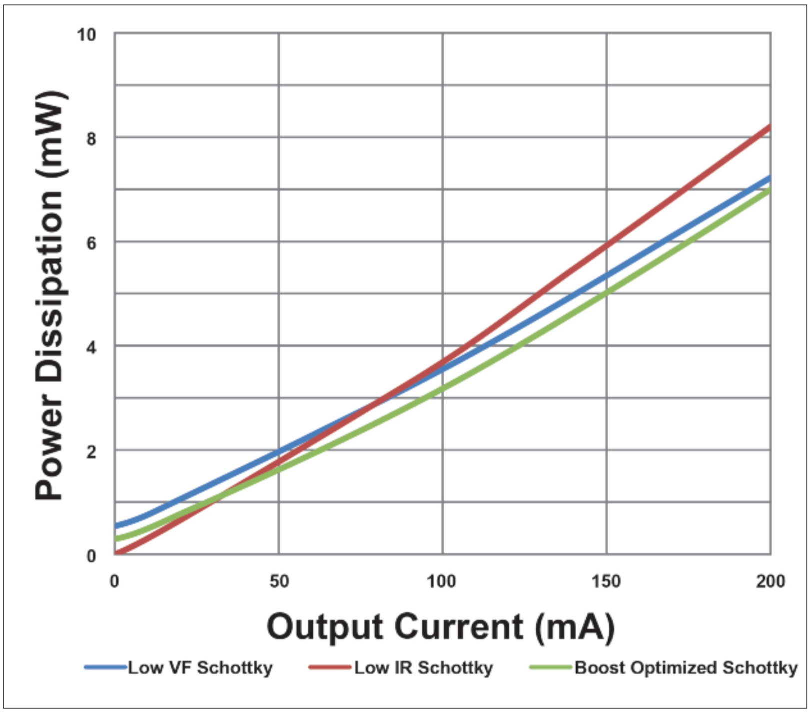

Figure 2: Power dissipation of different Schottky diodes

33 V. The forward voltage of Device 2 is 0.2 V at 10 mA. When these values are plugged into Equation 1 the resulting duty cycle is 92.5 %. This means that the Schottky diode will be reverse biased for 92.5 % of the time and forward biased for only 7.5 % of the time. Now let's take the values from Device 2 in Table 1 to calculate the power. When the device is reverse biased the voltage is 33 V and the leakage current will be around 100 µA. The resulting power when the device is reverse biased is 3.3 mW. Now looking at when the device is forward biased, the voltage will be 200 mV and the current will be 10 mA. This will give a forward biased power of 2 mW. When combining these values with the percentage of each bias, it is seen that the reverse bias contributes 3.05 mW and the forward bias contributes 0.15 mW. This example shows that in fact most of the power is generated from the leakage current.

The above example assumes the forward current is 10 mA. It is important to keep in mind that as the forward current increases the more the power dissipated in the forward biased condition will increase. However, the reverse biased power will remain the same. From this we can conclude that system designers need to consider the leakage current of Schottky diodes in low output current boost converters more than in high current boost converters to minimize total power dissipation.

Looking at the power dissipation over a range of output currents will further show the importance of choosing a boost optimized Schottky diode. Figure 2 plots the power dissipations of three equally sized devices: a Low V_F Schottky, a low I_R Schottky and a boost optimized Schottky. As described above the low leakage device has the better power dissipation at lower output currents, but as the current increases the power dissipation rises more rapidly.

When looking at the low forward voltage Schottky diode, the influence of the high leakage is apparent at the low output currents. However, the power dissipation slope is less steep and the power dissipation becomes less than the low leakage device at higher output currents. The boost optimized Schottky diode combines the best-of-both of the previous devices. It has much better performance than the low forward voltage device at low currents and continues this trend to the higher currents. It is not superior to the low leakage device at low currents but the power savings are significant at higher currents. Additionally, the boost optimized Schottky diode takes the large current spikes from the inductor of the boost converter into account; the low leakage device does not perform well with these current spikes.

Low leakage devices will normally have a lower forward repetitive peak current rating, or I_{FRM}, than a boost optimized Schottky diode or low forward voltage Schottky diode. With a low leakage device the forward voltage tends to rise very quickly at currents above the rated DC current. In return, the device cannot handle the large current spikes as well as the other Schottky diodes.

Conclusion

The importance of defining Schottky diodes based on power dissipation rather than individual device characteristics is now even more important as the trade-off between forward voltage and reverse leakage is becoming larger. ON Semiconductor's approach is an example of developing Schottky diodes based on power dissipation that will allow system designers to maximize battery lifetime in portable applications.