AN-1005: High Temperature Performance of Diodes
Applications Department, APD Semiconductor, San Jose CA

Introduction:
With the growing demand for portability today, power supply designers are forced to develop external power supplies that are smaller, lighter and more efficient than ever before. This growing trend is leading designers to look for new solutions on how to produce effective designs that can fit in the palm of your hand and not burn it at the same time. With aesthetics driving smaller casing to fit these power supplies into, dissipating heat has become an overwhelming issue in advanced designs. Simply put, the smaller the power supply, the higher the temperature it will operate at. The large amount of heat that is produced not only creates a problem with the UL 1012 safety standard, but it also severely lowers the lifetime reliability of the power supply itself. The main source of reliability problems in power supplies can be attributed to the failure of the output rectifiers. More so, the essential factor on how reliable and efficient the power supply will run in these smaller casing will depend on how well the output rectifiers perform under these high temperature conditions. Hence, the purpose of this paper.

The Schottky Diode and PN Junction Diode:
Traditionally, Schottky barrier diode and PN junction diodes (eg FREDs) have been the only two choices a designer would have to choose from in designing a power supply. Both have their strengths and weaknesses at high temperature.

The Schottky barrier diode has a low forward voltage drop (Vf), but it is extremely sensitive to temperature because of its high leakage characteristics over its operating range. The low energy barrier metal design makes it easily susceptible to thermal runaway when a nominal amount of heat is applied. Thermal runaway occurs when the reverse power exceeds the diode’s capability to dissipate heat at the same rate it is generated. The Schottky diode will continuously heat up until the metal barrier is destroyed causing the diode to fail short. For an International Rectifier (IR) 20CTQ150 Schottky diode, the typical leakage value at 150°C is 10mA. Figure 1 shows the results of a typical High Temperature Reverse Bias Test (HTRB) done on an International Rectifier 20CTQ150 Schottky diode.

With 80% of the rated voltage applied in blocking mode, the 20CTQ150 Schottky diode is only capable of operating at an ambient temperature of 134°C before it enters into thermal runaway. When mounted on a large heat sink, the maximum ambient temperature the 20CTQ150 Schottky diode could withstand is 159°C before thermal runaway begins. Because of this thermal instability in the Schottky diode, many power supply designers are forced to use multiple Schottky diodes in parallel to reduce the amount of heat in each diode, and therefore offsetting the chances the diode will go into thermal runaway. Of course, this design pushes up the overall cost of the power supply.

With the Schottky diode not being able to operate at high temperature, designers are often forced to look at
the other alternative, the PN junction diode, typically FRED devices. The PN junction diode has comparatively lower leakage at higher temperature than the Schottky diode, but the forward voltage is considerably higher. Figure 2 shows the typical value for forward voltage drop at Ta=125°C for a ST Microelectronics BYW51-200 Fast Recovery Epitaxial Diode, at rated forward current.

![Figure 2. Forward Voltage Vs. Temperature of the ST BYW51-200 (FRED)](image)

Figure 2. Forward Voltage Vs. Temperature of the ST BYW51-200 (FRED)

The high forward voltage translates to a higher power loss in the diode, thus creating a larger amount of heat within the diode. This also lowers the overall efficiency of the power supply. So, by exchanging the reduced chances of thermal runaway cause by using Schottky diodes by replacing it with PN junction diodes, the designer reduces the overall efficiency of the system. For power supply designers, efficiency is a very undesirable trade-off for thermal stability.

Introducing the Super Barrier Rectifier™ (SBR)

The Super Barrier Rectifier™ (SBR) from APD Semiconductor is a technological break-through that combines the low forward voltage characteristics of a Schottky diode, the low leakage profile and stability of a PN junction diode and fast yet soft switching characteristics that eliminate ringing yet switch as fast as Schottky devices. The SBR was specifically designed and engineered for today’s high power, high temperature environment.

Figure 3 shows a reverse leakage comparison graph at 150°C of the IR 20CTQ150 Schottky diode with the APD SBR20150.

![Figure 3. Typical Reverse Leakage at 150°C of SBR20150 and the Schottky 20CTQ150](image)

At 150°C, the 20CTQ150 Schottky diode has typical leakage of 10mA at the rated voltage of 150V. At the same temperature, the APD SBR20150 diode has a typical leakage of 0.095mA at the rated voltage of 150V. The reverse leakage for the APD SBR20150 diode is more than 100 times lower than a Schottky diode under the same conditions. This comparison translates to a superior device capable of handling extremely high temperature without the worry of thermal runaway. Figure 4a shows a thermal runaway comparison graph between the 20CTQ150 Schottky, the ST BYW51-200 FRED and the SBR20150, without a heat sink.
In addition to the low leakage characteristics over the entire operating temperature range, robust thermal stability, the SBR20150 diode has Schottky-like forward conduction loss. Figure 5 shows a comparison graph of the SBR20150 forward voltage against the ST Microelectronics BYW51-200 Fast Recovery Diode at 125°C.

At 125°C, the BYW51-200 Fast Recovery Diode has a typical forward voltage (Vf) of 0.77 volts at the rated current of 10A. Under the same conditions, the SBR20150 has a typical forward voltage of 0.67 volts at the same, rated, current. The difference in forward voltage is 100mV, which translate to approximately 1 watt of power saved at the rated current. This represents an efficiency improvement of over 13%. As shown of the graph, this efficiency improvement gets better as temperature increases.

Summary

The Super Barrier Rectifier™ (SBR) from APD Semiconductor is the only advanced rectifier in the market today to combine the low forward loss of a Schottky diode with the thermal stability that is far superior to even a PN junction diode. These advantages over existing technologies translate to a more efficient, more reliable, and cooler running application. This makes the SBR™ perfectly suited for today’s high power, high temperature environment.