The SiC revolution – reliable, efficient, & cost effective

Silicon Carbide (SiC) devices have seen a substantial rise in popularity

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Over the past few years, Silicon Carbide (SiC) devices have seen a substantial rise in popularity. This has been fueled by an increased focus on saving energy, reducing the size of devices, and improving the long term reliability of the final products. Traditional silicon-based devices are reaching the physical and material limits of what is possible. The new SiC-based devices allow us to push those limits aside and reach for the higher voltages, lower conduction and switching losses, and high efficiency and reliability that we need to design and produce the revolutionary energy-smart devices of the future.

Infineon SiC solutions such as the CoolSiC™ family of products are an essential part of this rapidly expanding energy-smart SiC revolution. Within this family of Infineon's CoolSiC™ devices are the Schottky diodes, which target applications in server and PC power, telecom equipment power, and PV inverters. The latest development in the CoolSiC™ Schottky diode family, the sixth generation or G6, is the end result of many iterative steps over the past 17 years. Starting in 2001, Infineon released the first generation CoolSiC™ Schottky barrier diode. This was followed up in 2004 with the second generation diode which had a merged pn junction and high surge current capability. In 2009, the third generation introduced diffusion soldering which results in lower thermal resistance from junction to case (R_{thJC}). 2012 saw the introduction of thin-wafer technology, and in 2017, the sixth generation adds on a new layout, a new cell structure, and a new proprietary Schottky metal system. The latest features provide substantially increased reliability, quality and efficiency over all load conditions, and increases the power density as well.

Specifications
Output power: 800 W
Input voltage: 90 - 265 V AC
Switching frequency: 65 kHz and 130 kHz
Output voltage: 380 V DC
Efficiency: ~98.1 percent at 230 V AC

Figure 1: 800 W 65 kHz and 130 kHz Platinum rated server power factor correction evaluation board

Improving PFC efficiency

Application engineers, powers supply designers and academics who work with high-efficiency and high-density powers supplies have to focus on many different aspects

	Efficiency at V_{in} = 115 V AC and f_{sw} = 65 kHz			Efficiency at V_{in} = 230 V AC and f_{sw} = 65 kHz		
P_{out}	IDH06G65C6	IDH06G65C5	Efficiency	IDH06G65C6	IDH06G65C5	Efficiency
20%	95.93%	95.87%	+0.06%	97.15%	97.07%	+0.08%
40%	96.49%	96.46%	+0.03%	97.85%	97.80%	+0.05%
60%	96.38%	96.32%	+0.06%	98.07%	98.01%	+0.06%
80%	96.05%	95.98%	+0.07%	98.11%	98.06%	+0.05%
100%	95.57%	95.54%	+0.03%	98.10%	98.05%	+0.05%

Table 1: Measured efficiency of the 800 W PFC board at 65 kHz

	Efficiency at V_{in} = 115 V AC and f_{sw} = 130 kHz			Efficiency at V_{in} = 230 V AC and f_{sw} = 130 kHz		
P_{out}	IDH06G65C6	IDH06G65C5	Efficiency	IDH06G65C6	IDH06G65C5	Efficiency
20%	95.42%	95.35%	+0.07%	96.95%	96.91%	+0.04%
40%	96.28%	96.22%	+0.06%	97.74%	97.69%	+0.05%
60%	96.35%	96.30%	+0.05%	98.00%	97.95%	+0.05%
80%	96.14%	96.09%	+0.05%	98.09%	98.04%	+0.05%
100%	95.79%	95.75%	+0.04%	98.12%	98.08%	+0.04%

Table 2: Measured efficiency of the 800 W PFC board at 130 kHz

of the power supply design. The boost stage, or PFC stage, of the AC-DC converter is one place where the CoolSiC™ Schottky diode 650 V G6 can really show its strengths in supporting highly efficient, compact power supply designs.

One of the interesting features of the CoolSiC™ Schottky diode 650 V G6 is its best-in-class low forward voltage. This allows designers to realize efficiency improvements over a wide range of loads and provides some interesting results in the power factor correction.

Infineon did some real world testing on a PFC test board that illustrates this quite effectively. The board used in the test was an 800 W 65 kHz and 130 kHz Platinum rated server power factor correction evaluation board (EVAL_800W_130PFC_C7). A comparison in the measured efficiency between a CoolSiC™ Schottky diode 650 V G5 (IDH06G65C5) and a CoolSiC™ Schottky diode 650 V G6 (IDH06G65C6) can be seen in **Table 1** and **Table 2**.

What do these results really mean though? This test board shows an average 0.05 percent improvement in efficiency of the G6 diode over the G5 diode. This translates into a 1 percent improvement in power losses.

Taking it to the next step

There is more than can be done here beyond simply using the next generation SiC-based diode. A simple adjustment in the current rating of the boost diode produces some additional interesting changes in the measured efficiency of the power supply. Again a real-world test was performed using the same 800 W 65 kHz and 130 kHz Platinum rated server power factor correction evaluation board with a 6 A diode and a 10 A CoolSiC™ Schottky diode 650 V G6 diode. The combined results are shown in **Figure 2**.

The result shows something quite interesting. The increased current rating results in an efficiency improvement, which is linked to lower conduction losses. Replacing the 6 A boost diode with a 10 A boost diode shows an efficiency improvement of up to 0.2 percent at maximum output power. It is important to note though that the 6 A diode behaves better under light loads due to lower capacitive charge (Q_c) which means lower switching losses.

The balance between light and full load efficiency and the current rating of the boost diode means that the power supply design can be easily optimized according to the price and performance requirements.

Thermal performance

The high efficiency of the CoolSiC™ Schottky diode 650 V G6 and reduced power losses result in lower operating temperatures for the diode. Conduction losses are at the heart of the majority of the heat generation under

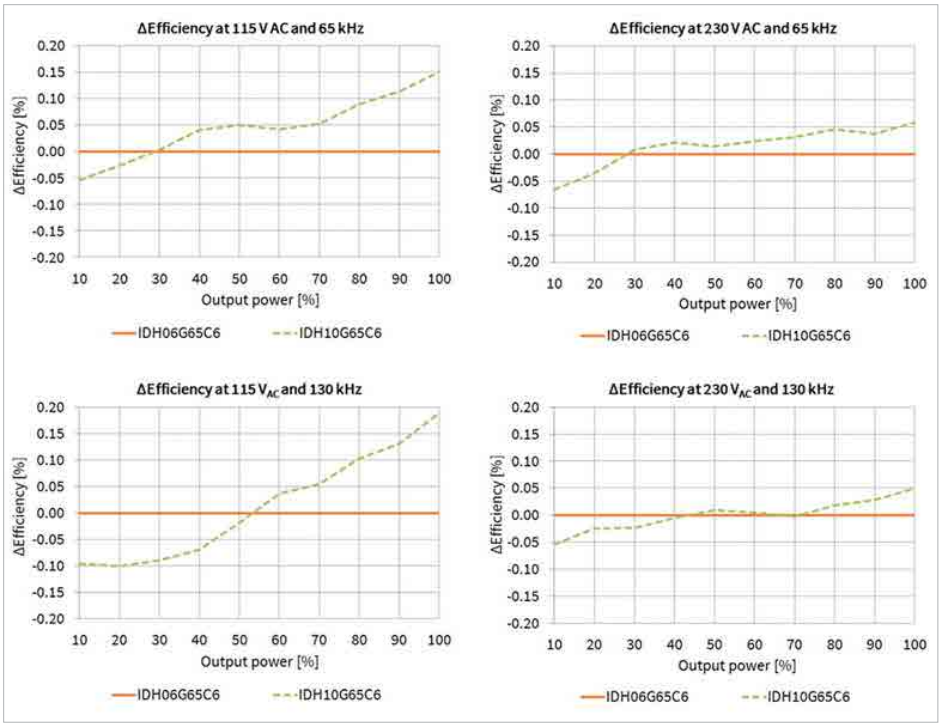

Figure 2: Measured efficiency of the 800 W PFC board - different current rating

full load conditions. The design improvements have introduced a lower forward voltage (V_f) in the new CoolSiC™ Schottky diode 650 V G6 diode which results in temperatures (measured and simulated) that are around 1 °C lower after 100 µs than the previous generation diode (CoolSiC™ Schottky diode 650 V G5).

Protecting the PFC circuit against surge events

When power supplies are used in harsh environments and you are using a SiC Schottky diode in your PFC design, it is very important to consider how the inevitable power surge events will be handled. The new SiC Schottky diodes have reduced conduction losses, but that improvement comes at a cost of lower surge current parameters in some areas. Restricting the forward current though the SiC diode is simple enough with the implementation of a bipolar bypass diode which will conduct only when the rectified voltage is higher than the output voltage. **Figure 3** shows a simplified example of how this can be done.

Conclusion

The CoolSiC™ Schottky diode 650 V G6 is a leading edge solution from Infineon. It takes full advantage of the clearly demonstrated benefits of SiC over silicon. Built around a proprietary innovative soldering process pioneered by Infineon, it includes features such as a compact design, thin-wafer technology, and a new Schottky metal system. The lower forward voltage of the CoolSiC™ Schottky diode 650 V G6 means that you see lower conduction losses, which in turn mean you see higher efficiency and lower junction temperatures. The result is a family of SiC products with a best-in-class figure of merit (Qc x VF), and improved efficiency over all load conditions.

Combining the advanced technological features and benefits of SiC with Infineon's proven quality and reliability, you can be sure that your power supply designs will maximize the system performance and take full advantage of all of the incredible potential of SiC devices.

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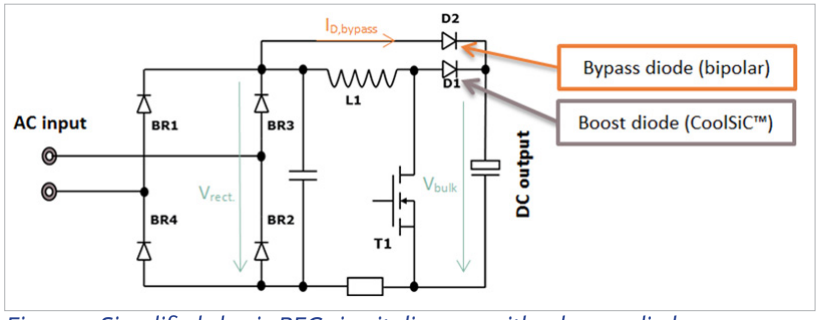

Figure 3: Simplified classic PFC circuit diagram with a bypass diode