

How Silicon Carbide Is Improving Switched Power Converter Designs

When it comes to designing power converters, wide bandgap (WBG) technologies such as silicon carbide (SiC) are now a realistic option during component selection. The introduction of 650 V SiC MOSFETs has made them more attractive for applications where they would not have previously been considered.

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Their superior robustness in efficient hard-switching topologies makes them ideal for implementing the Power Factor Correction (PFC) stage of power solutions reaching into the kilowatt range. And, thanks to the higher switching frequencies supported, smaller magnetic components become an option, delivering a welcome reduction in volume to many designs.

No such thing as a free lunch

While the benefits are many, their attainment is not achieved by merely dropping a SiC MOSFET into the gap left by removing a silicon equivalent. Engineers need to take time to understand their characteristics to gain full advantage of the change while also understanding their different limitations and failure modes. The forward voltage of the body diode in a CoolSiC™ device is four times greater than that of a silicon MOSFET. As a result, an LLC converter could see a 0.5% drop in efficiency at light loads. High efficiencies in PFC topologies are also attained by boosting through the channel rather than the body diode.

On-resistance on par with silicon at operating temperature

One key comparison parameter is the on-resistance, $R_{DS(on)}$. Silicon MOSFETs look better than SiC on paper but, thanks to their lower multiplication factor (κ), an 84 mΩ CoolSiC™ device achieves the same $R_{DS(on)}$ as a 57 mΩ CoolMOS™ device at 100°C (Figure 1). CoolSiC also offers a higher breakdown voltage, $V_{(BR)DSS}$, than silicon MOSFETs, which is useful in applications that start-up in low-temperature environments.

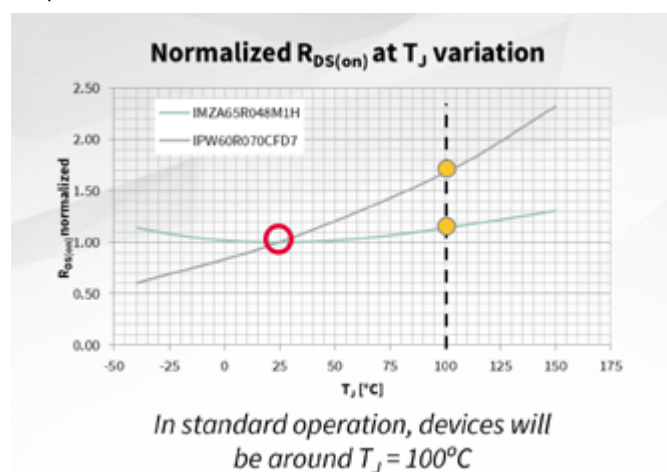


Figure 1: The influence of temperature on $R_{DS(on)}$ is lower for CoolSiC™ than CoolMOS™, resulting in a similar on-resistance at typical operational temperature.

The EiceDRIVER™ family remains the ideal companion to CoolSiC™ MOSFETs. However, to attain the low $R_{DS(on)}$ defined in the data-sheet, a gate voltage (V_{GS}) of 18 V, rather than the typical 12 V for silicon MOSFETs, is needed. If a new gate driver is being chosen, it is worthwhile selecting one with a 13 V undervoltage lockout to ensure safe operation under abnormal conditions of the target application. A further benefit of SiC is the limited impact temperature has on the transfer characteristic between 25 °C and 150 °C (Figure 2).

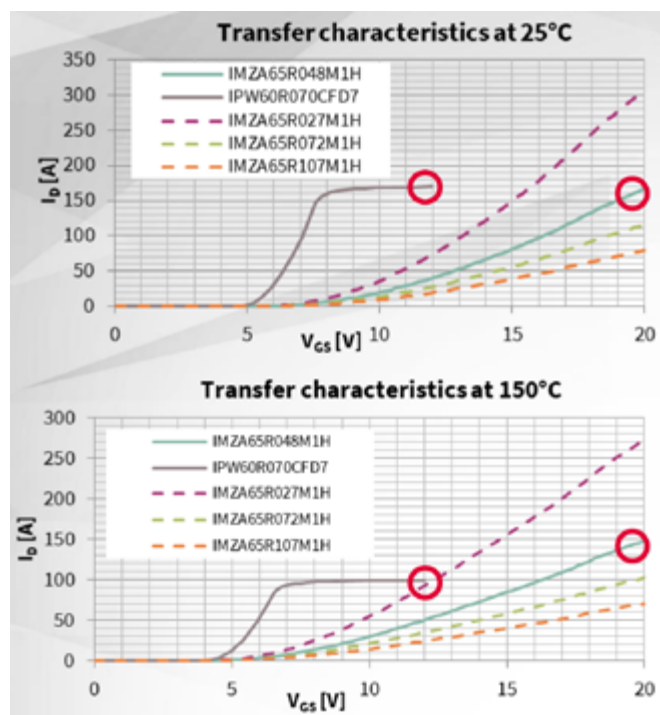


Figure 2: The transfer characteristics at 25°C (left) and 150°C (right) show a significantly lower impact for SiC devices than silicon MOSFETs.

Avoiding negative gate voltages

Negative gate voltages can result in a long-term degradation of the SiC MOSFET that can result in latent failures. Thus design engineers should ensure that V_{GS} never drops below -2 V for more than 15 ns. Should this occur, a drift of the gate threshold voltage ($V_{GS(th)}$) can result that also increases $R_{DS(on)}$ over the lifetime of the application. Ultimately this leads to a drop in the hard-won system efficiency gains, the key reason for choosing SiC in many cases.

A high-value resistor is typically used with silicon MOSFETs to combat negative V_{GS} , thereby slowing di/dt and dv/dt . However, for SiC devices, the preferred approach is to insert a diode voltage clamp between gate and source. If the negative voltage is purely an inductive issue, selecting a CoolSiC™ device with a Kelvin source is highly recommended. This can result in E_{ON} losses three-times lower than a device without it (Figure 3).

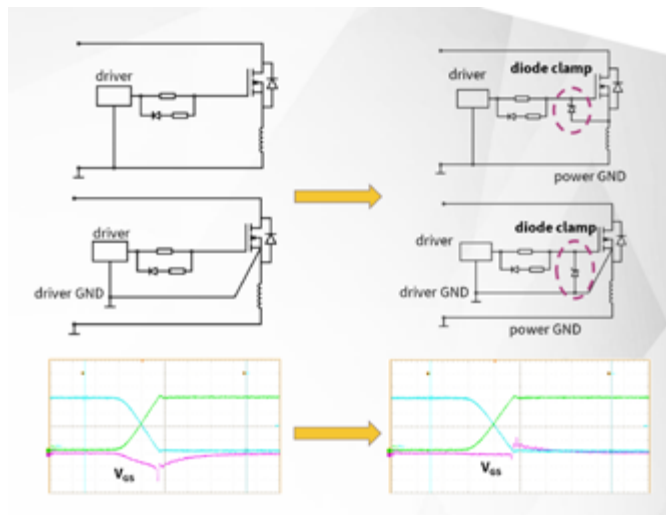


Figure 3: To avoid that the gate of a SiC MOSFET goes negative, a diode clamp, separate commons, and a Kelvin source should be considered.

Pushing beyond 99% efficiency

A further advantage of CoolSiC™ MOSFETs is their higher output capacitance, C_{OSS} , at drain-source voltages, V_{DS} , above around 50 V. This delivers reduced levels of overshoot without needing to implement a gate resistor. The Q_{OSS} behavior of SiC technology also benefits hard and resonant switching topologies as less discharging is required, something that impacts E_{on} losses in CCM totem-pole PFCs. Using 48 mΩ devices, efficiencies of over 99% for a 3.3 kW CCM totem-pole PFC can be attained (Figure 4) where the best possible efficiency using CoolMOS™ in a dual-boost PFC design peaks at 98.85%. And, despite the higher cost of the SiC MOSFETs, the SiC-based design is more cost-competitive.

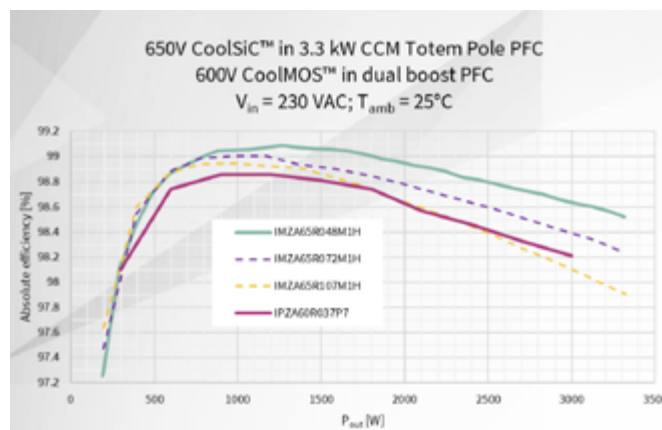


Figure 4: Even a 107 mΩ CoolSiC™ CCM totem-pole PFC comes close to 99% efficiency, mostly outperforming the best CoolMOS™ dual-boost PFC approach.

Summary

SiC MOSFETs offer a range of advantages over silicon alternatives that, coupled with its robustness in hard switching applications, make it worth considering in the most efficient power conversion applications. The 650 V CoolSiC™ family's introduction makes SiC MOSFET technology more economically viable for those pushing power conversion to its limits.

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