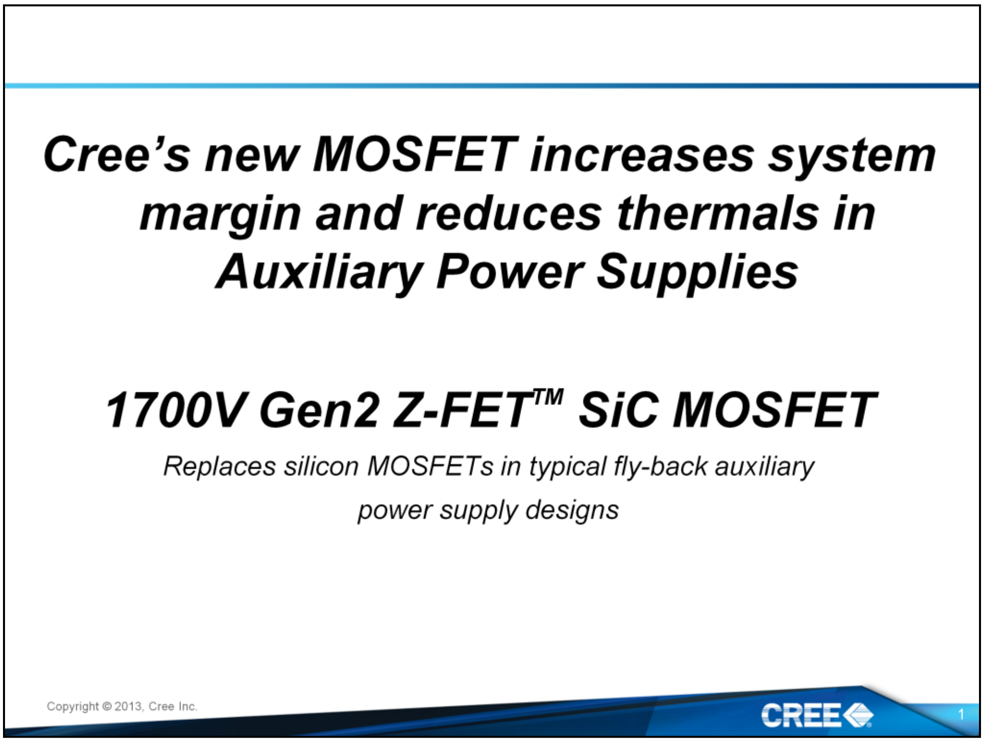

Welcome to the training module for the Cree second-generation C2M1000170D Silicon Carbide MOSFET. This new device features a 1700V blocking voltage and 1 Ohm On-Resistance, and provides substantial advantages over traditional silicon MOSFETS in auxiliary power supplies within inverter-based designs.

Three-phase applications, such as motor drives, uninterruptible power supplies and photovoltaic inverters, have a front end AC/DC or DC/DC converter to boost the DC link voltage up to 600V DC to 800V DC. Factoring in a design margin, the maximum DC link voltage is up to 1000V. To support such systems in practice, an auxiliary power supply is used to generate power for cooling fans, displays, control logic and system protection functions with the DC link voltage as its input.

This training module provides the details of how the new Cree Gen2 1700V SiC MOSFET can reduce system cost while improving the reliability of these critical power supplies. This module includes an example of a full reference design of a single-ended Flyback 60W Auxiliary Power Supply and presents measured results demonstrating the Cree Silicon Carbide advantages.

SiC MOSFET Beats Silicon in High Voltage Supplies

- **C2M1000170D replaces silicon devices and provides:**
  - Higher blocking voltage, >1700V
  - Lower switching and conduction losses
  - Higher peak current capability
  - Higher speed switching
  - Can be driven from common controllers

1Ω, 1700V SiC MOSFET Key Preliminary Specifications	
V_{DS}	1700V
I_D @ 25°C	4.9A
I_D @ 150°C	3.0A
R_{DSON}	1Ω
Packages	TO-247, (SMD TBD)

- **System benefits:**
  - Simpler, more rugged system design:
    - Higher blocking to protect against voltage spikes
    - May eliminate clamps and snubber circuits
  - Higher switching frequencies allow smaller, lighter, lower cost magnetic's
  - Lower operating temperature can reduce heat sink and/or fan size
  - ***Lower system cost***

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As the blocking voltage of silicon MOSFETs increases, so does the overall die size. Cree SiC MOSFETs are able to provide 1700V blocking voltage in a significantly smaller package. These devices are much more robust than the specified blocking voltage, with breakdown voltages much higher than 1700V. Additional material benefits of Silicon Carbide over Silicon include lower switching and conduction losses with higher speed and greater peak current. The Cree MOSFET is a simple DMOS device, making it a direct replacement for silicon that is easy to drive.

The SiC diode can be switched rapidly and efficiently, allowing shrinkage of an auxiliary power supply and higher frequency operation than with an equivalent silicon device. Additionally, the SiC device will run much cooler than an equivalent silicon device, which provides the designer with an option to reduce heat sink size, fan size, and other aspects of thermal design.

All of these advantages of the SiC MOSFET will reduce in lower system cost.

Key Advantages of Cree C2M1000170D vs. Silicon

SiC MOSFET reduces conduction and switching losses with higher V_{BR}

Parameter	Cree Z-FET 1700V/1Ω C2M1000170D SiC MOSFET	1500V/5Ω Silicon MOSFET	1500V/9Ω Silicon MOSFET	1700V/4A Si Emitter Switched Bipolar Transistor (ESBT)
Qual $V_{(BR)DSS}$	1700V	1500V	1500V	1700V (also 1500V version)
I_D @ T_C=25°C	4.9 A	4 A	2 A	4 A (8A for 1500V Version)
$R_{DS,ON}$ @ 150°C	2.1 Ω	9 Ω	20 Ω	V_{CS} ≤1.5V
C_{OSS}	14 pF	120 pF	60 pF	Not Specified
$T_{J,max}$	≥150°C	150°C	150°C	150°C
Gate Drive	≥15 V	≥10 V	≥10 V	≥10V

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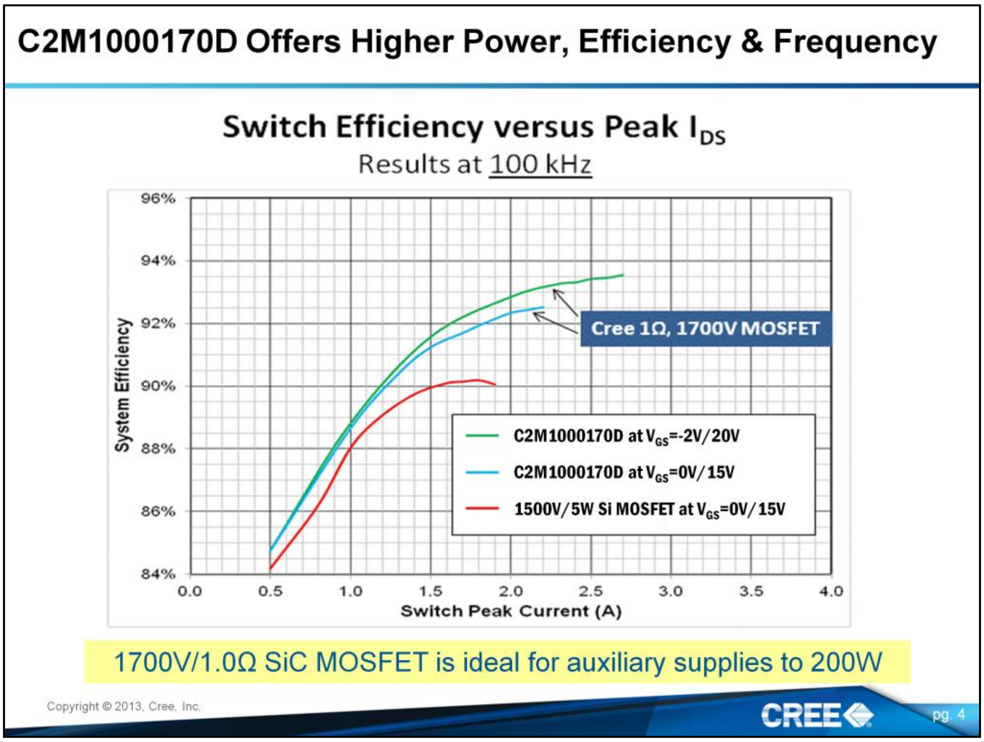
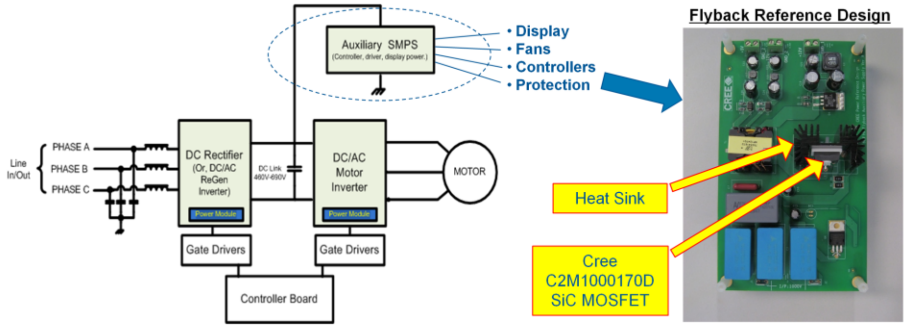
When compared to the primary competitors in the application space, the Cree C2M1000170D SiC MOSFET outperforms all of them. The Cree device is more robust and has better overall current-carrying capability. The lower output capacitance is linked to smaller die size of the SiC material, and is responsible for the reduced switching losses. The higher gate drive voltage is compatible with existing silicon drive circuits.



This chart compares the 100kHz switching performance of the Cree SiC MOSFET (green and blue lines) to the leading Si MOSFET (red line), over a wide range of peak currents. Note that as the peak current increases, the efficiencies of the devices become thermally limited. Each line terminates at the device's maximum junction temperature. Cree's SiC device provides more power, higher efficiency, and a longer useful life as compared to the silicon MOSFETs.

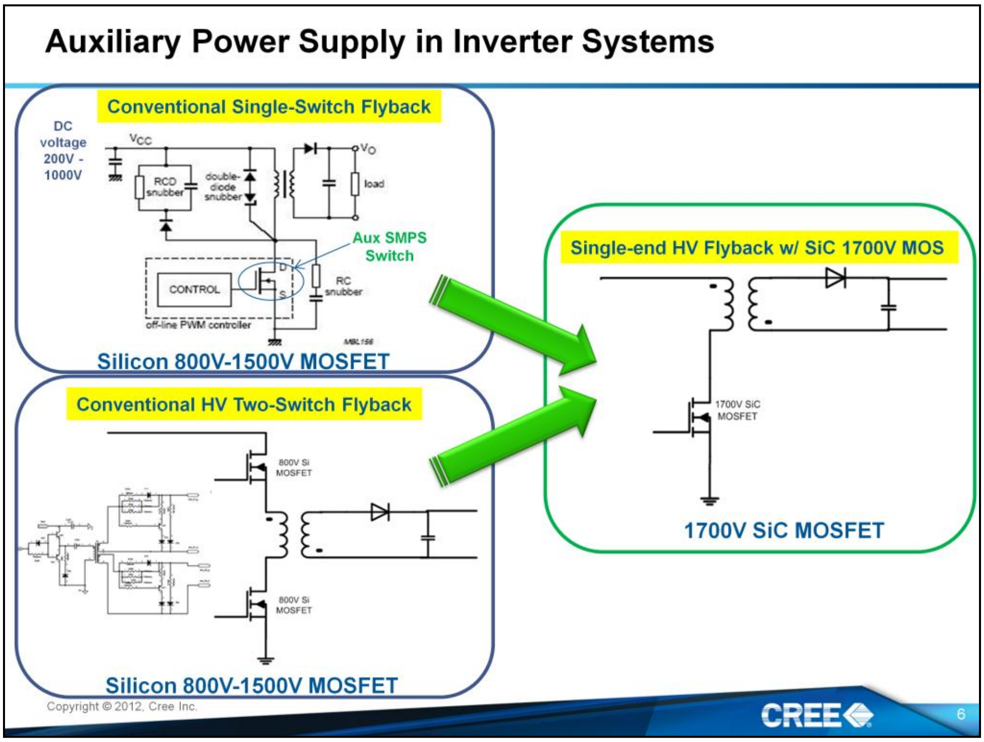
Auxiliary Power Supply in Inverter Systems

Motor Drive Auxiliary Power Supply Example



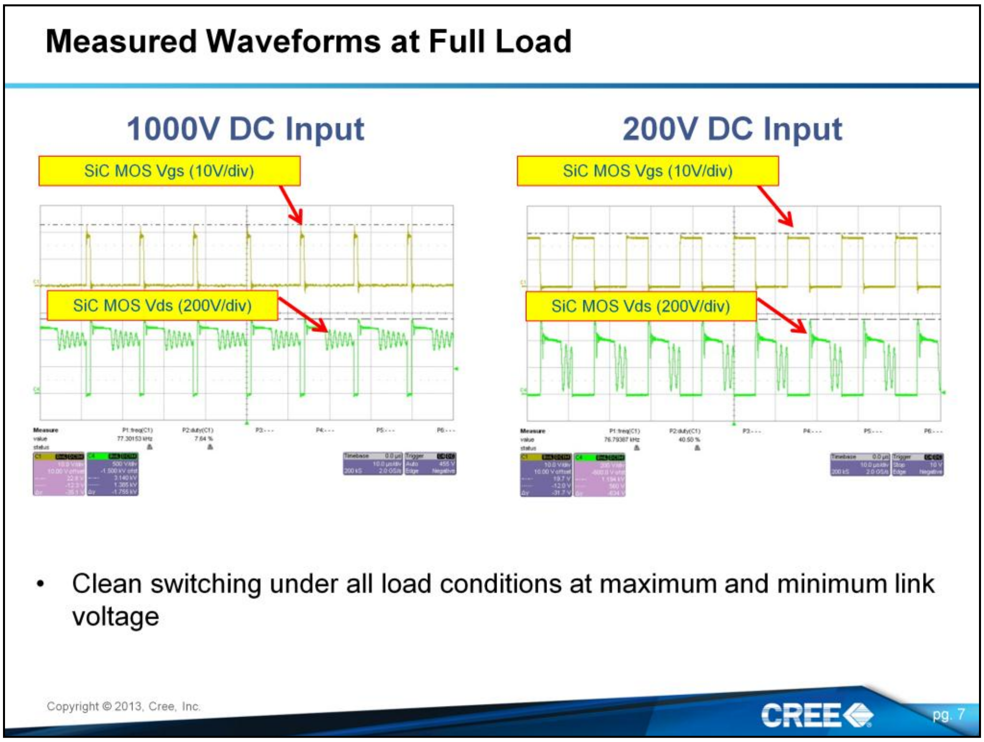
- Motor drives, PV Inverters, UPS's, other inverter based systems require auxiliary power for cooling fans, displays, control logic, system protection
- Three-phase E-meter power supply is an emerging application
- Required supply voltages often derived from the high voltage DC link of 460V to >1000V
- Comparison testing performed using flyback reference design

The featured application for the C2M1000170D is within auxiliary power supplies. Generally, motor drives, PV inverters, and UPS's require auxiliary power to drive cooling fans, displays, control logic, system protection, and other low-voltage systems. It is preferable to derive the necessary low-voltage supply from the high-voltage DC link. The Cree SiC MOSFET device has been placed in a flyback reference design to observe its performance within such an auxiliary supply.

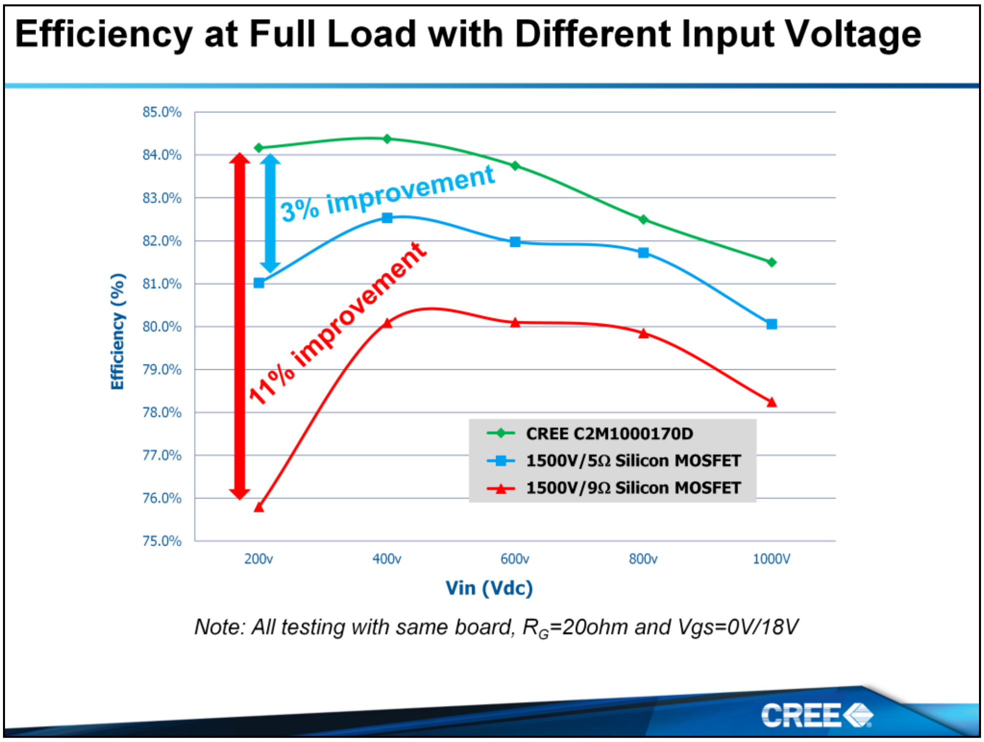


In these auxiliary power supply designs, a flyback topology is commonly used to buck link voltage to logic levels. A single switch flyback configuration is used with a DC link up to roughly 450V, while for systems with link voltages above 500V, a two-switch configuration is used. Silicon MOSFETs or specialized bipolar devices, such as IGBTs and ESBTs, are currently used for switching in both flyback designs. These silicon devices are limited by their die size to <1500V. They have weak avalanche performance requiring conservative design margins, and their poor switching efficiency limits switching frequency. It is the limited performance and blocking voltage of silicon that necessitates the two-switch configuration above 500V.

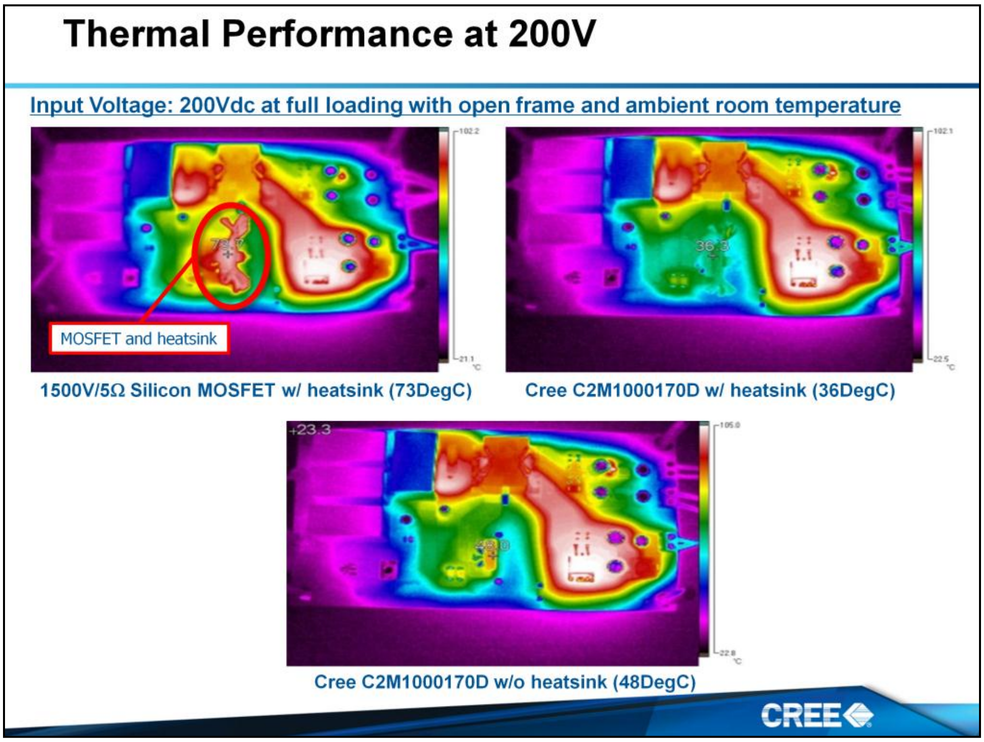
In both designs, a SiC single switch flyback topology replaces the existing silicon switches. The SiC switch provides additional ruggedness with a larger voltage design margin, greater efficiency, and higher frequency over the silicon switch. Additionally, replacing the two-switch silicon topology in the high-voltage flyback with a single-switch SiC design results in a simpler topology that is easier to drive and has a lower Bill-of-Materials cost.



Waveforms collected at both the highest and lowest input voltages resemble typical waveforms for flyback designs, and are very similar to waveforms generated from silicon devices. Replacing existing silicon devices with the Cree SiC MOSFET is a relatively simple design change.



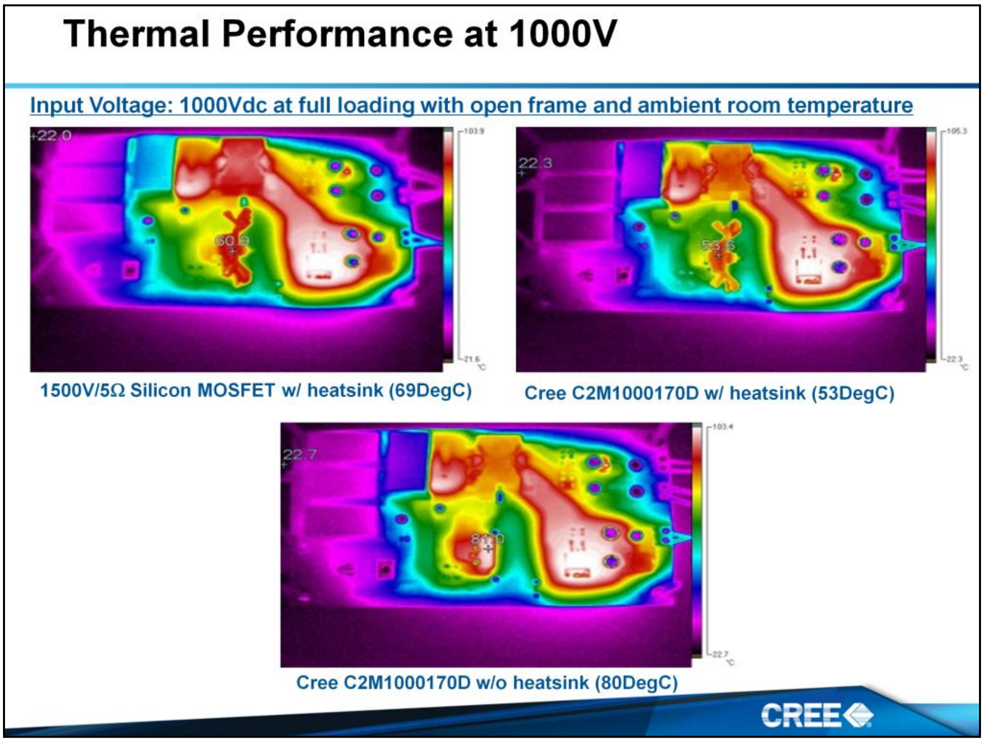
Shown here are actual test results comparing the Cree C2M1000170D SiC MOSFET to two leading silicon MOSFETs. All data was collected using the flyback reference design with the same gate resistance and input voltage for all three devices. Notice that a 3 to 11% improvement is gained at 200V by using the Cree SiC MOSFET, and the Cree MOSFET's increased efficiency continues up to and beyond 1000V. This efficiency increase provides a very significant improvement in thermal performance.



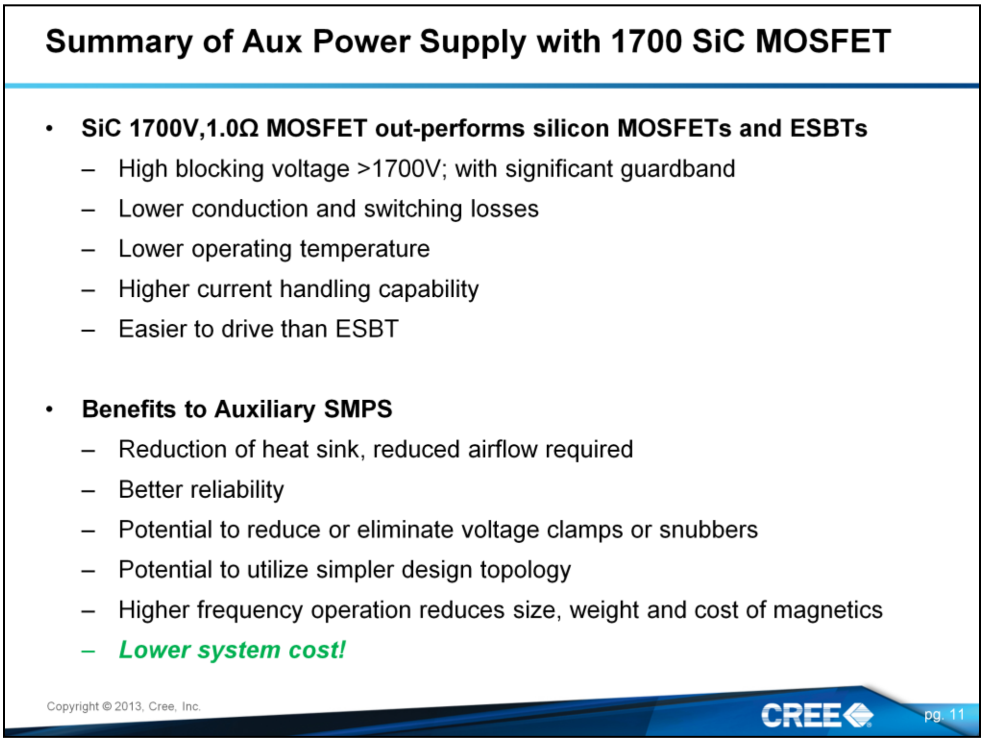
One of the greatest advantages of using the Cree SiC diode is thermal performance. These images are thermal maps of the backside of the board in the flyback reference design. Note that at 200V DC, 75kHz and equivalent operating conditions, the silicon MOSFET with heatsink is running at 73˚C, but the Cree SiC device with heatsink is running at only 36˚C – a 50% decrease in temperature. This translates directly to thermal advantage in design and system reliability.

In addition, the bottom image shows the Cree SiC MOSFET running without heatsink. Under these conditions, the silicon MOSFET would be driven to the thermal limit, but the Cree SiC MOSFET is running at only 48˚C (1/3 of the maximum junction temperature). Under these operating conditions, the heatsink is totally unnecessary for the 1700V 1-Ohm SiC MOSFET.

Switching losses are the source of heating at these conditions.



At 1000V DC, conduction losses are the primary source of heating versus switching losses. Regardless, under these conditions the Cree SiC MOSFET is still operating at 15-20 degrees lower than the silicon MOSFET. As before, under these operating parameters, the Cree device can safely operate without a heatsink. At 80˚C, it is only running at roughly 1/2 of the maximum junction temperature.



In summary, Cree's 1700V, 1-Ohm Silicon Carbide MOSFET outperforms comparable silicon devices. It provides a higher blocking voltage with a considerable guardband, lower conduction and switching losses, and higher current handling capability at lower operating temperatures. It is easier to design-in and drive than many incumbent silicon devices.

When installed in an auxiliary switched-mode power supply, the advantages of the SiC MOSFET become even more apparent. System designs could potentially utilize simpler topologies, with the reduction or even total elimination of voltage clamps or snubbers, combined with reduced heatsink and airflow requirements. The system will benefit from significantly increased reliability and higher operation frequency. All of these advantages combine to provide a lower system cost.

Cree has the global footprint & world-class distribution network to deliver SiC products wherever you need them.

Cree is the leader in Silicon Carbide power semiconductors.

Cree is one of world's fastest-growing power semiconductor manufacturers.

Cree has excellent capitalization.

Cree is vertically integrated—for an efficient supply chain and product traceability.

Cree has the technology roadmap for improved SiC production and cost reduction.