Wolfspeed™

Advanced SiC Devices and Modules Address System Challenges

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A CREE COMPANY

900 V – 1700 V PRE-RELEASED & COMMERCIAL MOSFETs HAVE PROVEN SYSTEM IMPACT

DOE VTO Program: 88 kW Automotive Inverter with New 900 V SiC MOSFET Technology

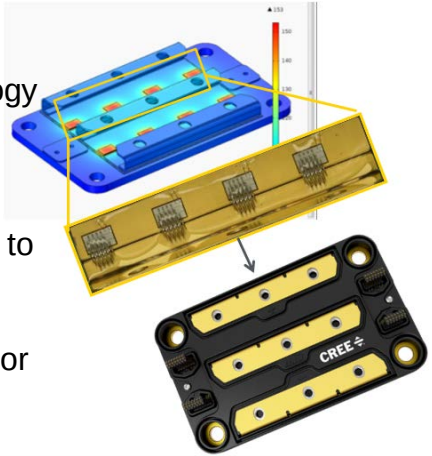
- SiC MOSFET:
  - Optimize and qualify 900V, 10mΩ SiC MOSFET with specific R_{DSON} of 2.2 mΩ·cm^2
- 100k volume inverter unit cost:
  - < $5/kW
- Inverter specific power:
  - > 22.5 kW/kg
- Inverter power density:
  - >21.5 kW/L

TO-247-4

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

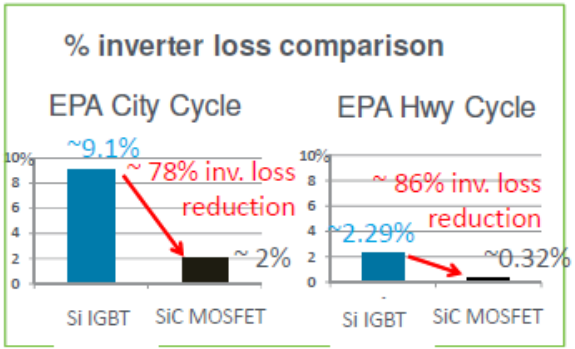
Technical Approach

- Use proven module technology and inverter design
- > 8,000 SiC MOSFETs fabricated
- > 1,000 SiC MOSFETs used to assemble >70, 900V / 350A, Half- bridge power modules
- Benchmarked performance for EV
- Assessing reliability



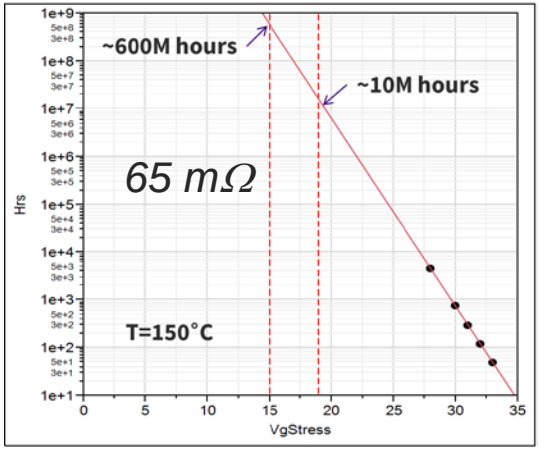
Results

- Ford Focus EV 90kW IPM
- In EPA drive cycle, measured data fror new 900V SiC pow modules reduced simulated inverter losses ~79% relative to Si based inverter



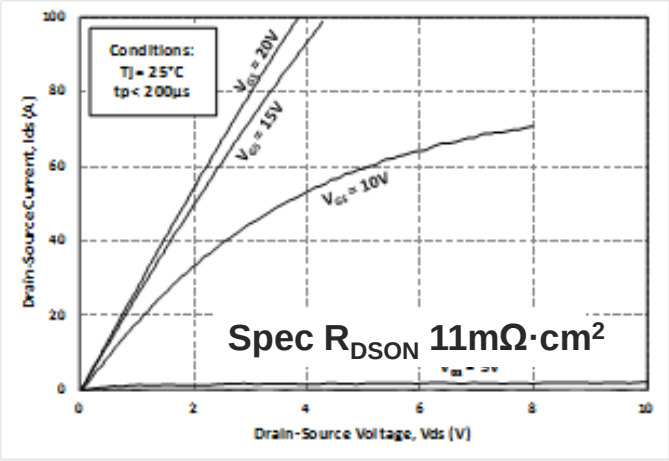
Internal Reliability Work on Gate Oxide

- Extrapolated VGS lifetime of ~600M hours at +15V (DC rec. op. point)
- Passed AEC-Q101 qualification of 3 lots x 77 parts with Ø fails in 1,000 hrs at VGS=15V, 150C



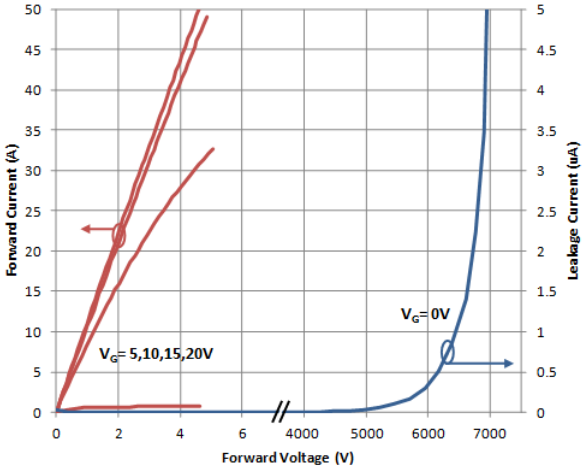
PRE-RELEASED 3.3kV & 6.5 kV GEN3 SiC MOSFETs ENABLE SYSTEM BOM REDUCTION & f_S INCREASE

3.3 kV SiC MOSFET



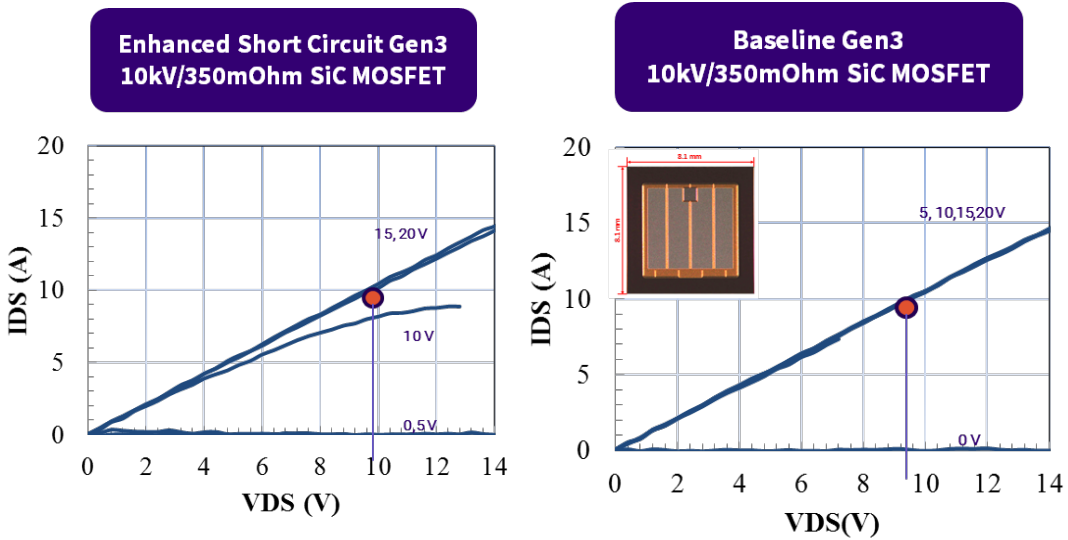
- Nominally a 40A SiC MOSFET
- $R_{DSONmax}$ at room temp ~41mΩ
- $R_{DSONmax}$ at 90˚C ~98mΩ
  - **all parameters subject to change without notice**

6.5 kV SiC MOSFET

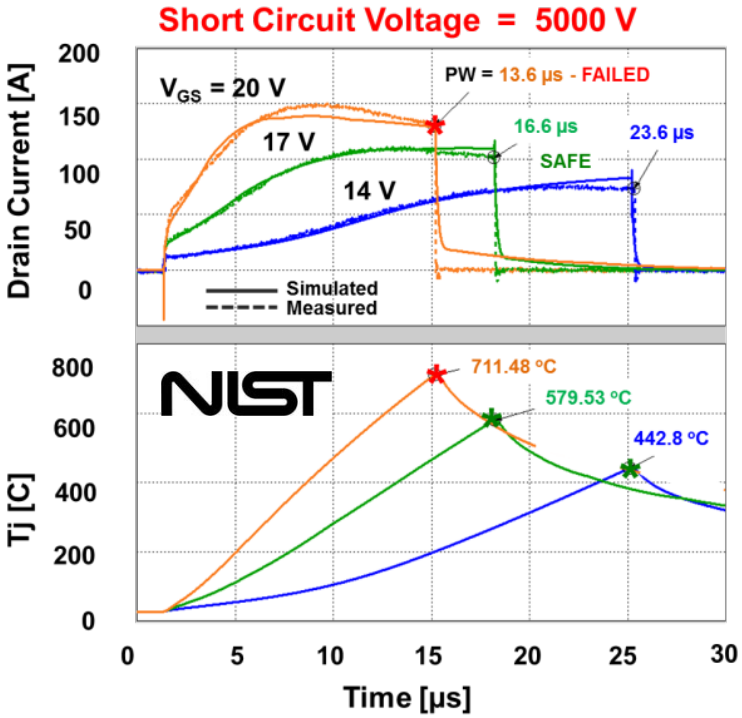


- Nominally a 20-30A SiC MOSFET
- $R_{DSONmax}$ at room temp ~100mΩ
- $R_{DSONmax}$ at 90˚C ~171mΩ
  - **all parameters subject to change without notice**

GEN 3 10 KV/350 mΩ SIC MOSFETS & SIMULATION/TEST OF ENHANCED SHORT CIRCUIT CAPABILITY



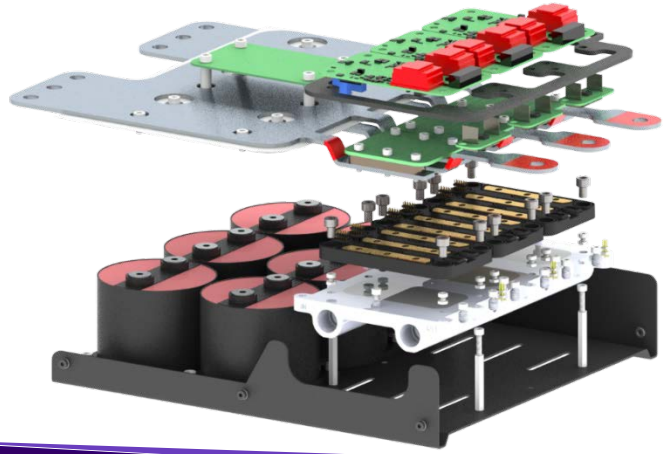
Enhanced Short-Circuit Capability



- **10 kV/350 mOhm SiC MOSFETs Capable of Sustaining Short Circuit Current > 13 µsec at 5 kV**
- **Courtesy of Al Hefner at NIST**

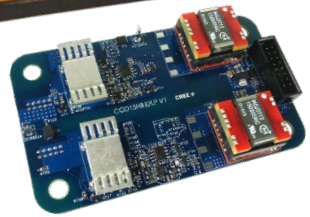
WBG INTEGRATION NEEDS CONSIDERATION OF MODULE PERFORMANCE, PROTECTIONS, & BUSSING CAPABILITY AT THE SYSTEM LEVEL

V_{DSmax}(V)	Chip R_{DSON} (mΩ)
900	10
1200	16
1700	20
3300	41
6500	100
10000	350



900-1700V low-profile 62mm

PowerAmerica

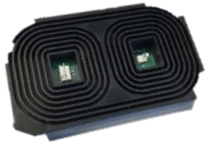


900-1700 V H-Bridge

3.3 kV Gate Driver & Transformer

3.3-6.5 kV Half-Bridge

10 kV XHV-6 Half-bridge

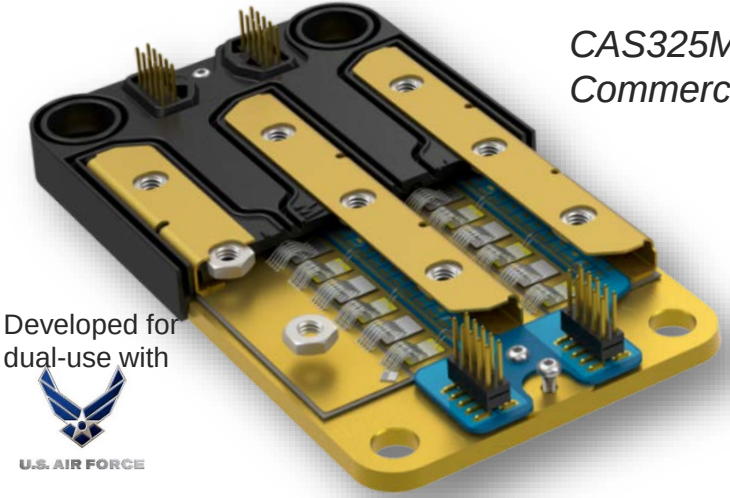


10-15 kV Gate Driver & Power Supply

NEXT GENERATION MODULES NEED TO GO BEYOND LOW INDUCTANCE AND HIGH TEMPERATURE

HT-3000 Series

CAS325M12HM2
Commercial Product



Developed for dual-use with

U.S. AIR FORCE

- Equalized impedances across die
- 5 nH V+/V- Loop inductance
- High Tj capability
- Form fitting gate driver, 3-Phase Eval Kit, Full LTSpice models, Application notes…

XHV-6 10-15 kV Pre-Released Module

Developed for dual-use with

Office of Naval Research ONR Science & Technology

- Equalization, Low L (~15 nH), and High T can map over…

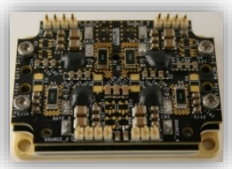
  …However modules need to balance simple, low inductance bussing & keep low inductance internally

  …as well as have integrated health protections to protect during fault situations
- Platform will drive cost/performance trade-off and dictate integration levels

WORKING DIRECTLY WITH SYSTEM DESIGNERS ENABLES FULL UTILIZATION OF WBG POTENTIAL

- Clean sheet thinking
  - Topologies need to be re-considered for WBG in general
  - Advanced packaging needs developing within these topologies to ease system integration issues
  - Re-imagine what is possible by combining SiC MOSFETS, integrated packaging, and optimized topologies
    - Consider the PHEV on-board charger and Little Box Challenge Work
- Packaging technology can be optimized across power levels
  - Advanced low power packaging (<50 A) needs advancement in the advanced cooling, e.g., half bridge with <1nH inductance >>500 kHz
  - Smart medium and higher power packaging (>50A) needs integrated gate control and protections such as over I/V/T. Integrated health monitoring for robust operation under faults and increase reliability

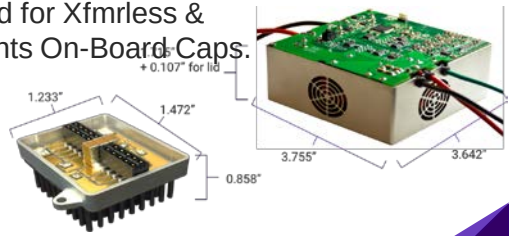
ARPA-e funded 6 kW SiC-based PHEV on-board charger



- Used Bridgeless Boost on Frontend to Eliminate Rectifier Drop & f_S Increase to Shrink Filter Size

GLBC – Used HERIC Topology & Commercial 900 V, 65 mΩ.

– Custom FB Module for HERIC Common Source to *Eliminate Common-Mode*, Optimized for Xfmrless & Implements On-Board Caps.



Leading the Pack™

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