High Performance SiC MOSFETs and Diodes Fabricated in High-Volume 6-Inch CMOS Fab

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Levi Gant

Littelfuse®

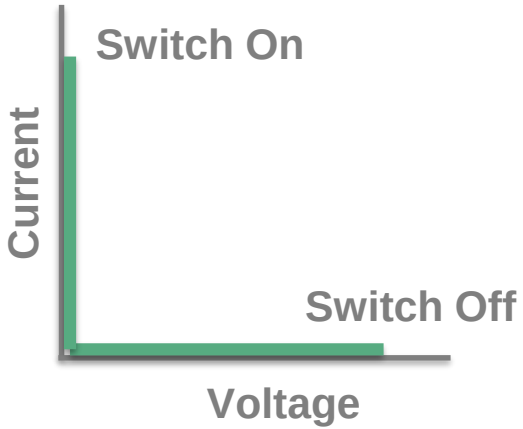
Expertise Applied | Answers Delivered

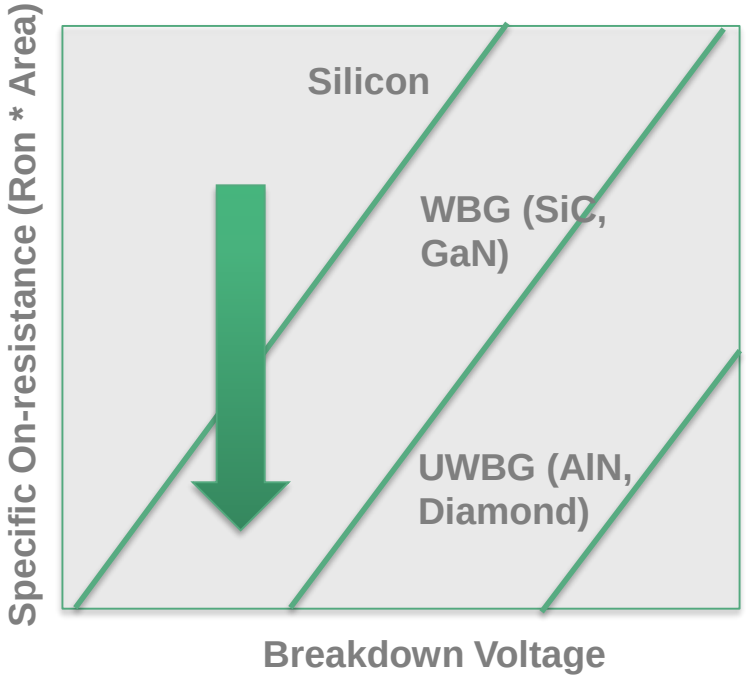
Outline

- Motivation for SiC Devices
- SiC MOSFET – Market Status
- High-Volume 150mm Process
- Performance / Ruggedness Validation
- Application Support

Device Perfection

- Ideal Switch
  - Zero leakage in off-state
  - Zero voltage in on-state
  - Zero switching loss





Lower Ron * Area, closer to ideal switch

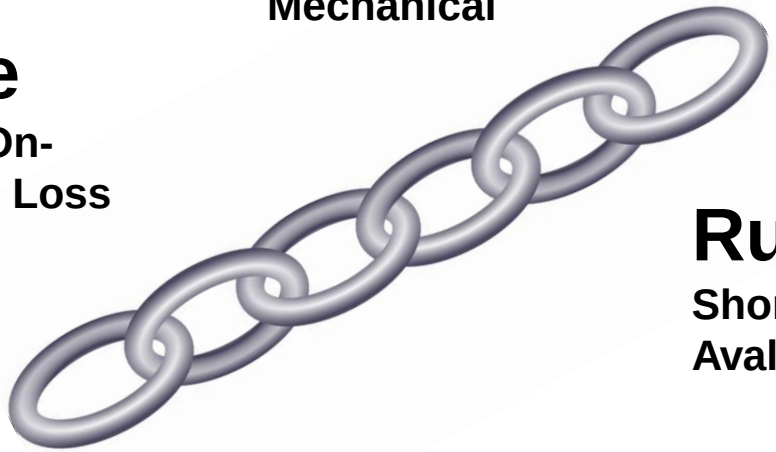
Reality: Ideal Switch Is Not Enough

Long-term Reliability

Voltage, Temperature, Moisture, Mechanical

Performance

Breakdown Voltage, On-resistance, Switching Loss



Ruggedness

Short-circuit, Avalanche, Surge, ESD

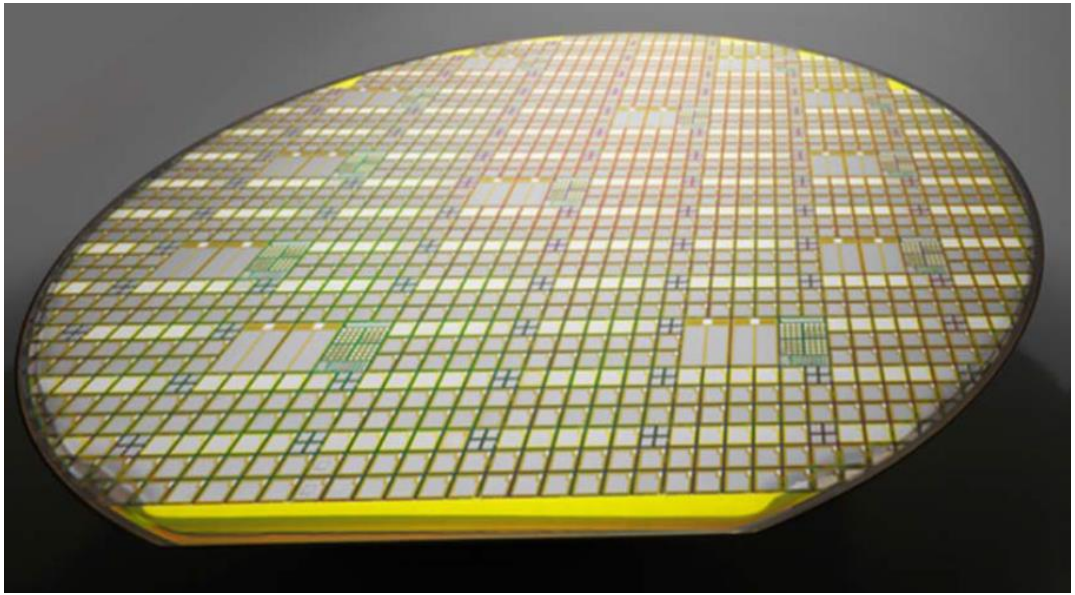
Cost

Manufacturability

Yield, Process Margin

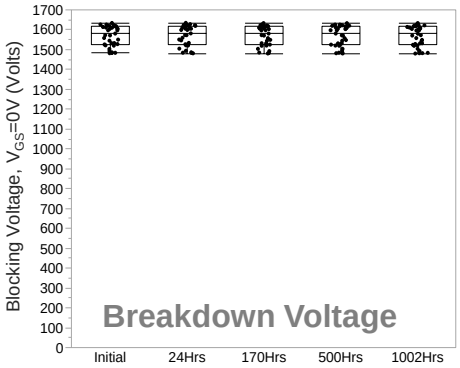
Manufacturing of SiC MOSFET in High-Volume 150mm CMOS Fab

- Compatible material, similar process steps
- Handling challenges: semi-transparent wafer
- High temperature implantation – different species
- High temperature activation

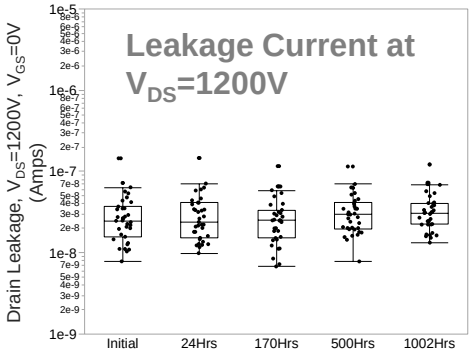


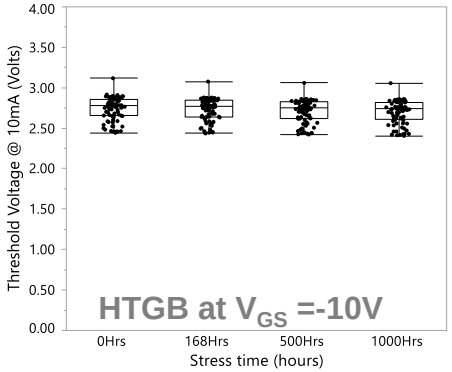
Concurrent manufacturing of Si and SiC – reuse established CMOS processes – minimize special tools.

Long-Term Reliability at 175 °C

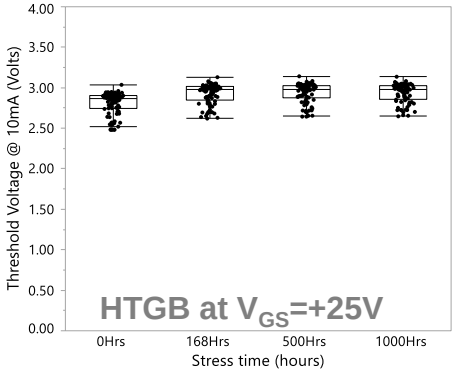


Passed High Temperature Reverse Bias at 175C, V_{GS}=0V, V_{DS}=960V.



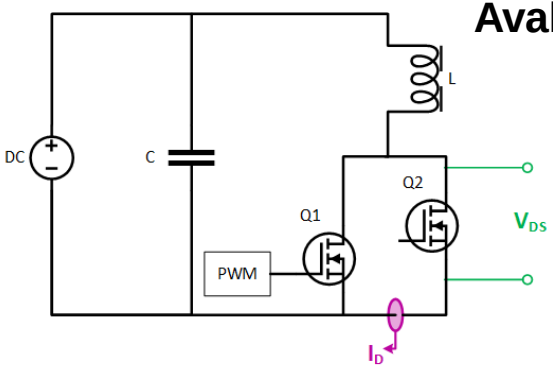


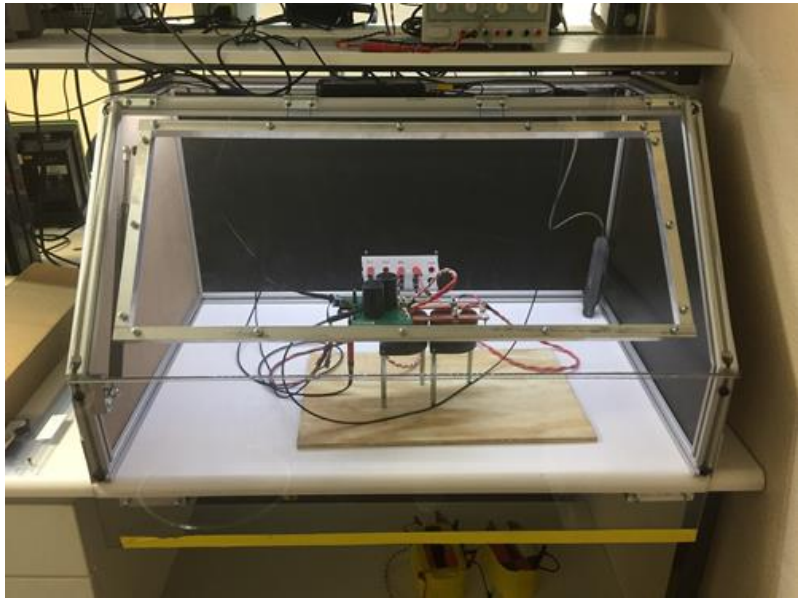
Passed High Temperature Gate Bias at 175C, V_{GS}=-10V and at V_{GS}=+25V.

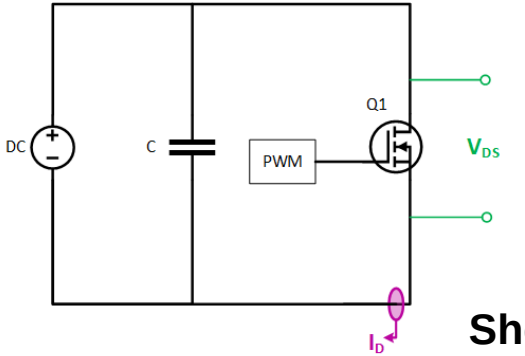


Device Ruggedness

Avalanche Test Circuit



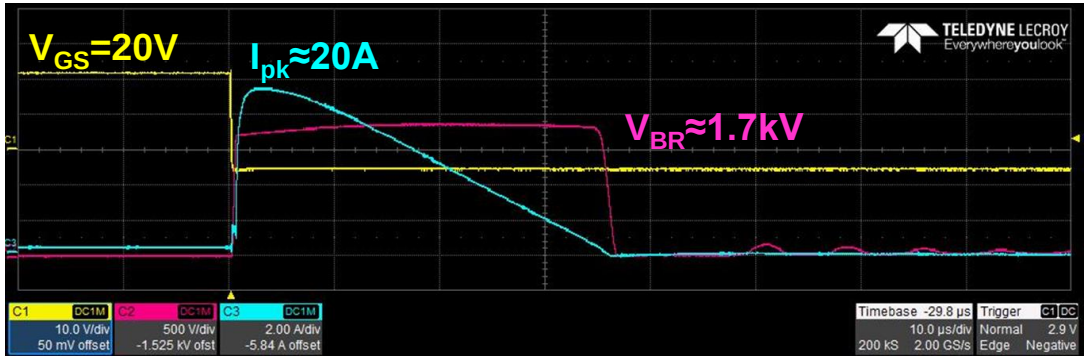




Short-circuit Test Circuit

Device Ruggedness (Cont.)

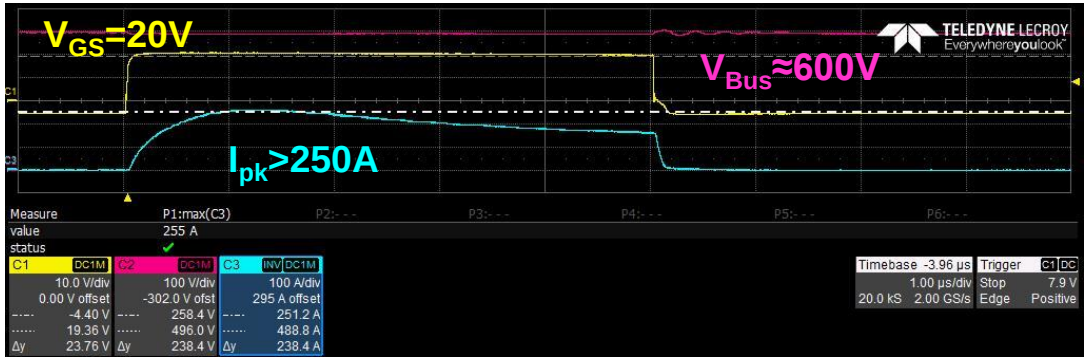
Avalanche Test Waveforms



Results indicate withstand:

- E_{AV} ≈ 1J

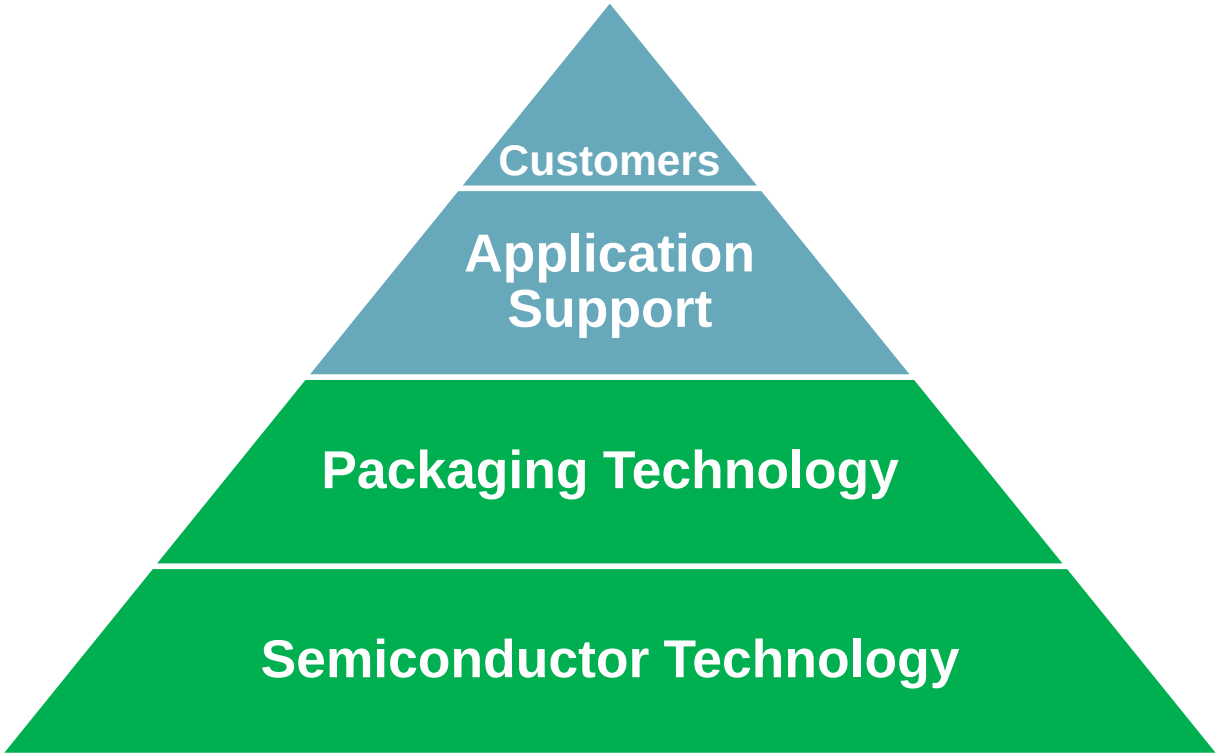
Short-circuit Test Waveforms



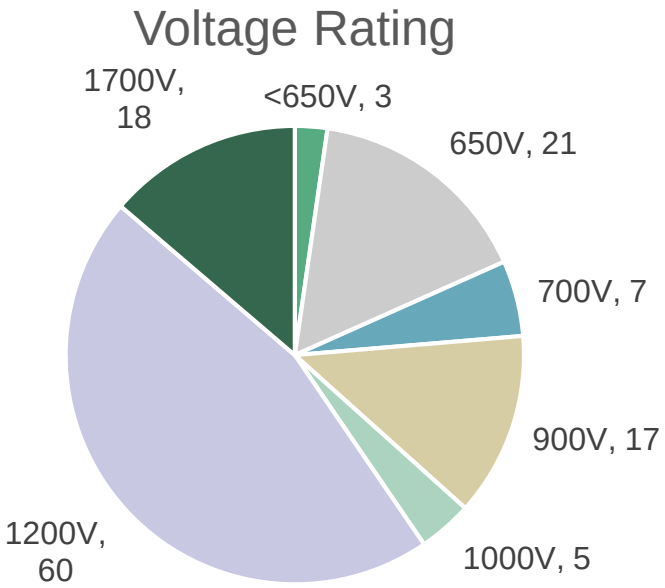
Results indicate device surviving:

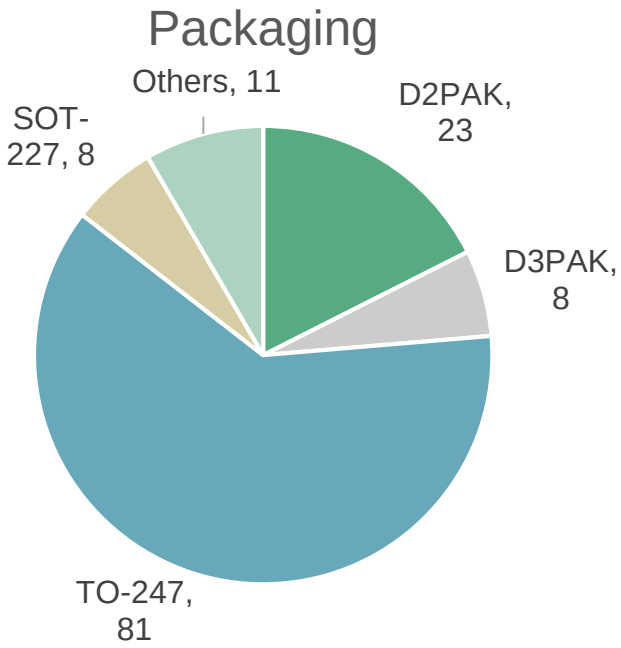
- V_{Bus} ≈ 600V
- T_{On} = 5µsec

Power Semiconductors – Need More than Just Semiconductors



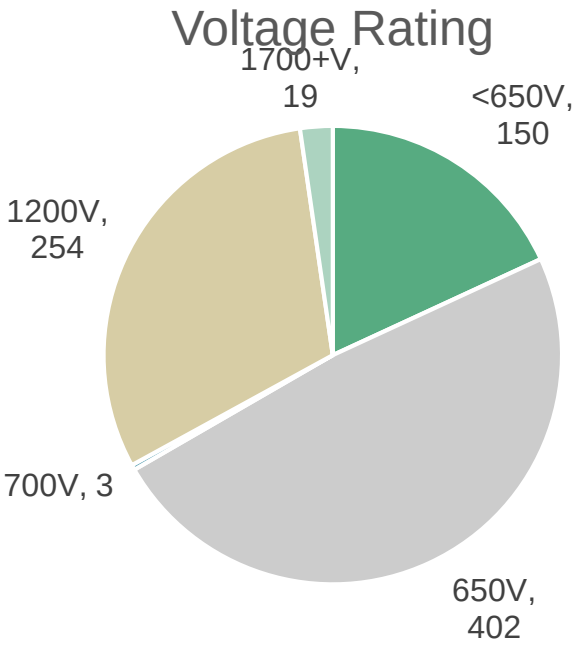
Commercially Available SiC MOSFETs

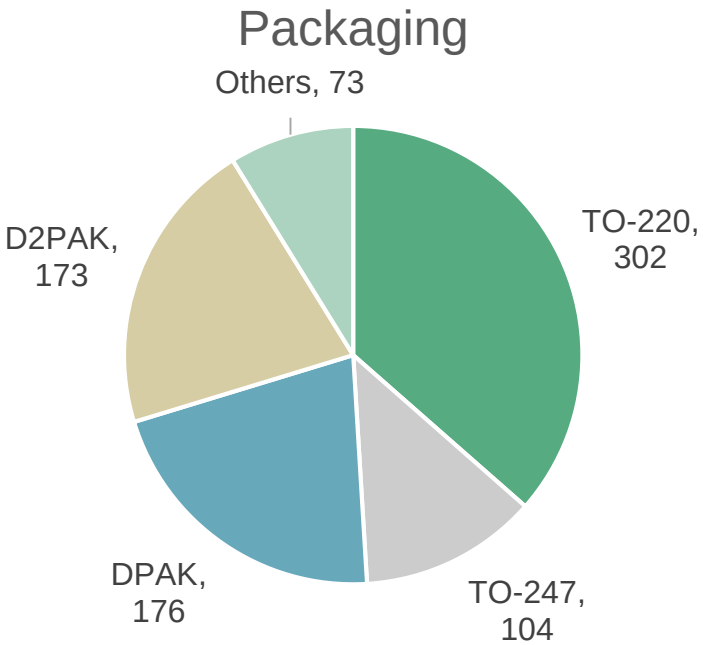




- On-resistance ratings ranging from 10 mOhms to 1.5 Ohms
- Through Hole = 68%; Surface Mount = 25%; Chasis Mount = 7%
- Charts based on DigiKey discrete SiC MOSFET availability (131 total). Obsolete devices included.

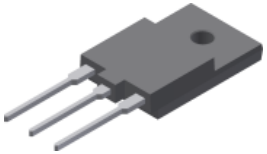
Commercially Available SiC Schottky Diodes

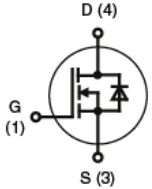




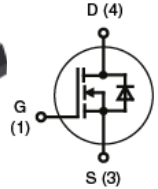
- Current Ratings ranginf from 50 mA to 216 A
- Surface Mount = 49%; Through Hole = 51%
- Charts based on DigiKey discrete SiC Schottky Diode availability (828 total).Obsolete devices included.

Possible Future Package Options

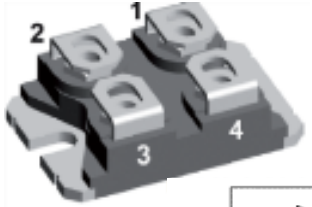


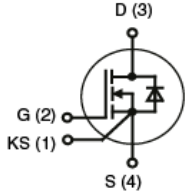


TO-3PF

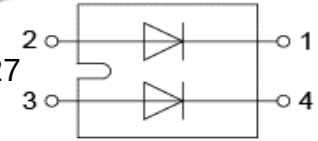


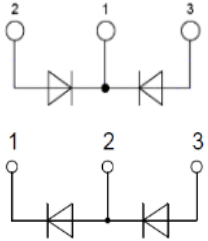
TO247 HV





SOT227

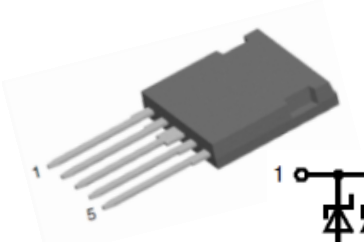


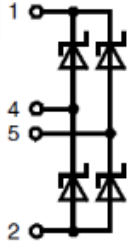


ISO247

Backside: Isolated

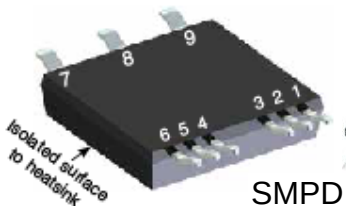
E72873

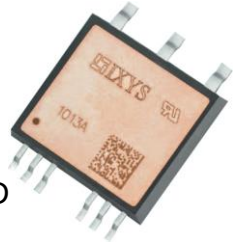




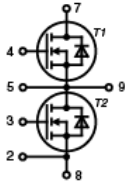
ISOPLUS i4

Full bridge

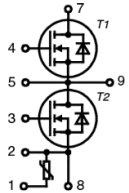




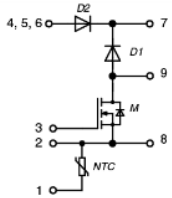
SMPD



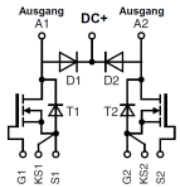
Half bridge



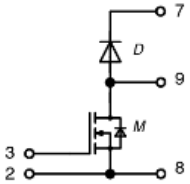
Half bridge + NTC/ RTD



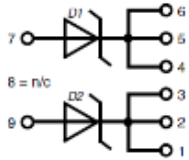
Boost + Bypass



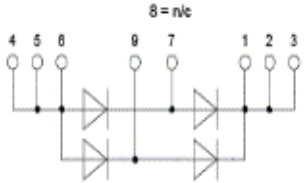
Dual boost



Boost

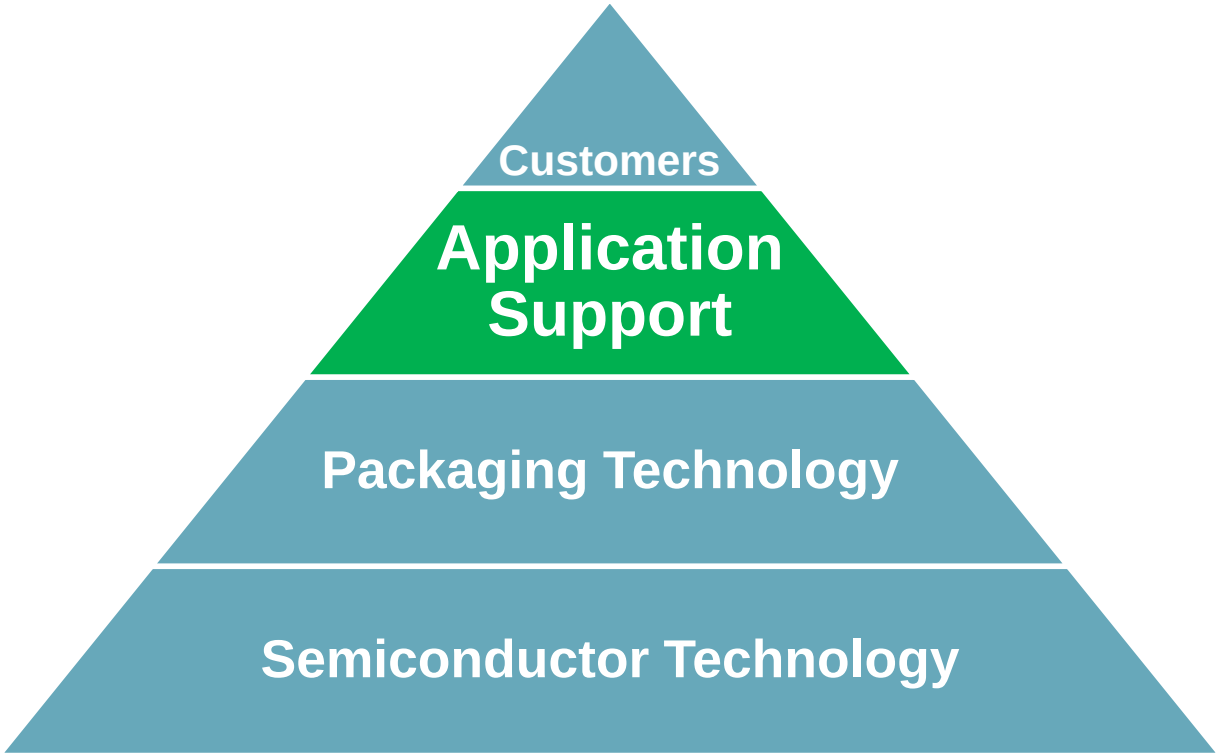


Dual



Full bridge

Power Semiconductors – Need More than Just Semiconductors

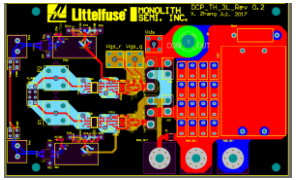


Extended Application Support

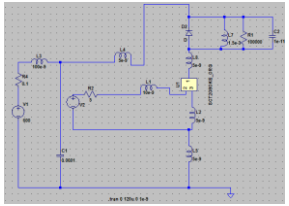
Operation Videos

Hardware

Design Files



Application Support Materials



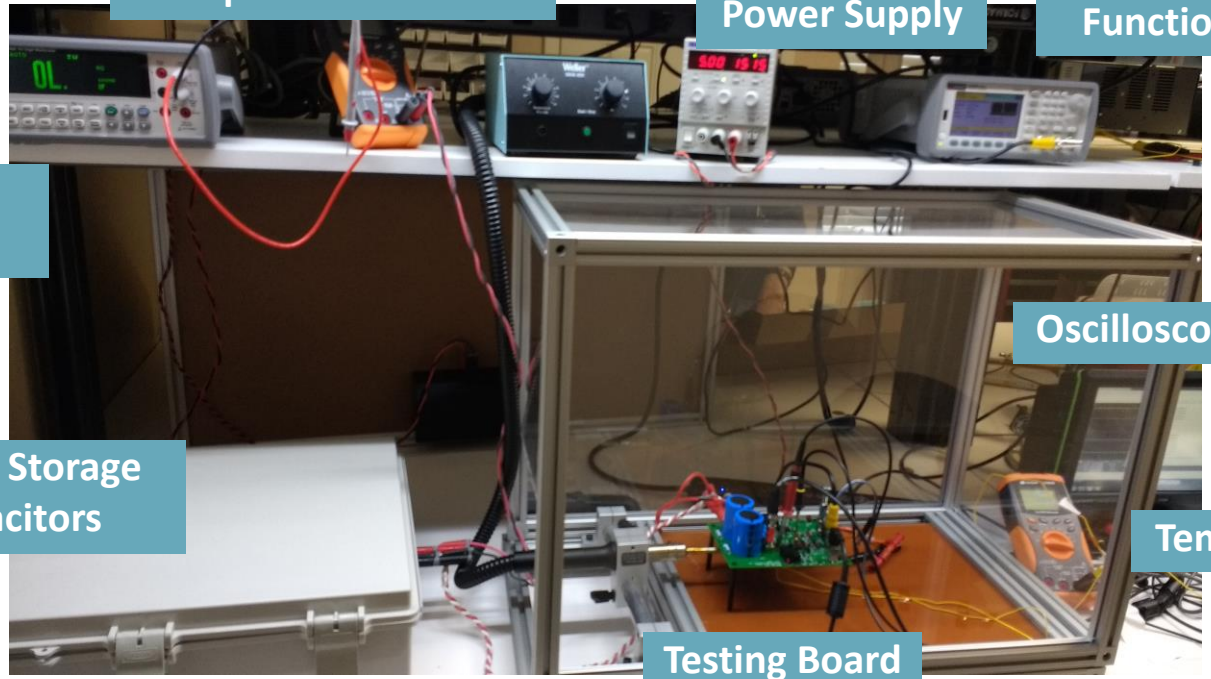
Simulation Model

App. Notes

DESIGN™

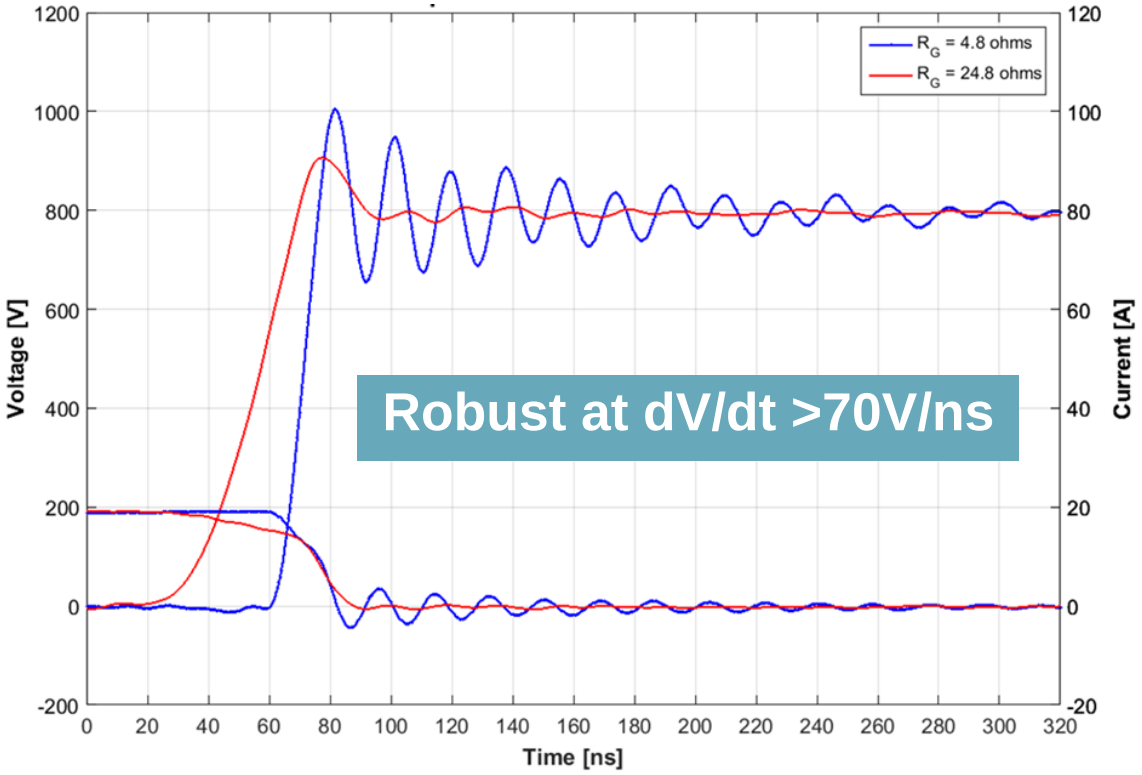
Design Tools

Dynamic Characterization (Cont.)



Dynamic Characterization

- Switching energy
  - External gate resistance
  - Current
  - Temperature
- Switching times
- Gate charge



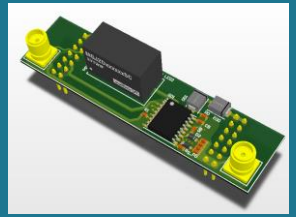
Robust at dV/dt >70V/ns

Application Support Hardware

Characterization

- Dynamic Characterization Platform (DCP)

Characterization



Driving Solutions

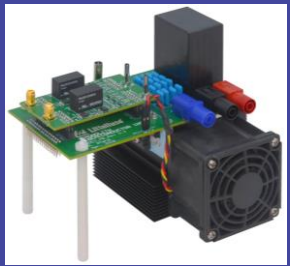
Driving Solutions

- Economic version gate driver (EGD)
- Standard version gate driver (SGD)

Reference Power Stage (GDEV)

- Plug-in and play phase leg with full driving and thermal solutions

System Evaluation



Practical Applications

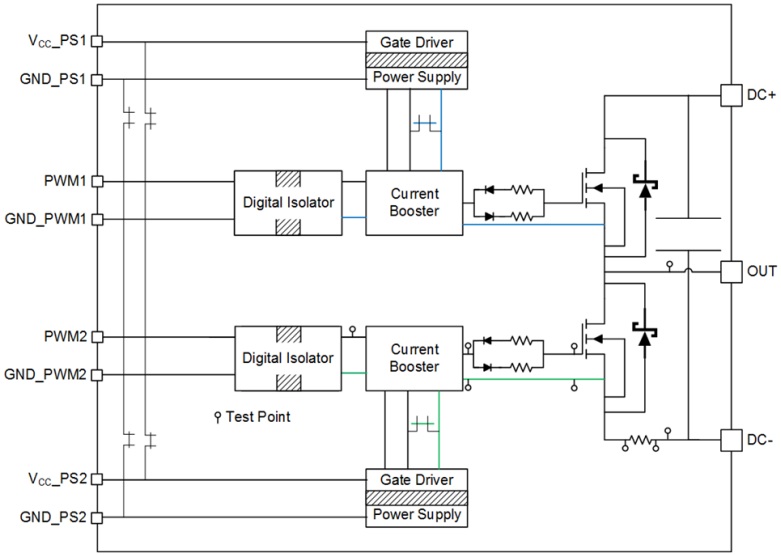
Demo Converters

- Different optimized design targets for different applications

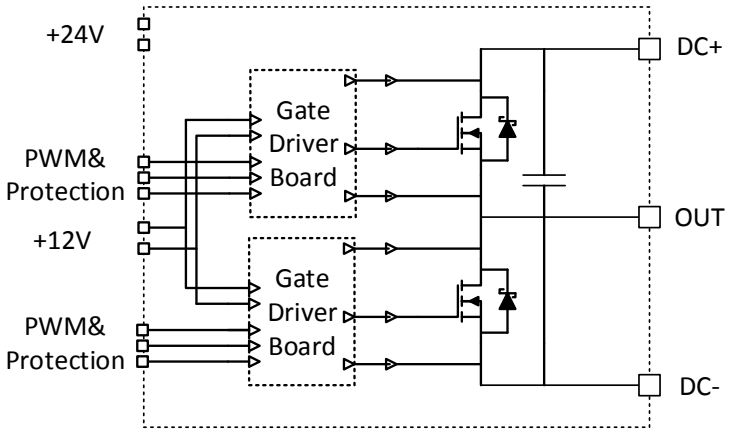
Littelfuse SiC Technical Support Center

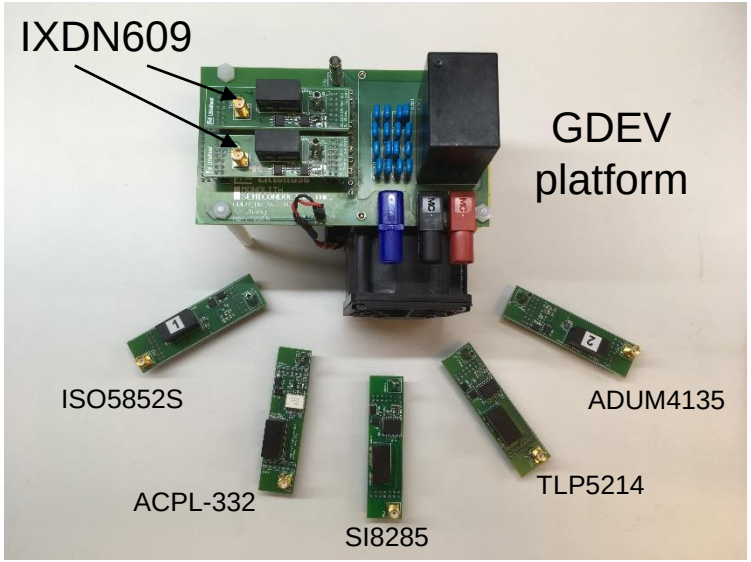
https://www.littelfuse.com/technical-resources/technical-centers/silicon-carbide.aspx

Dynamic Characterization Platform (DCP)



Gate Driver Evaluation Platform (GDEV)

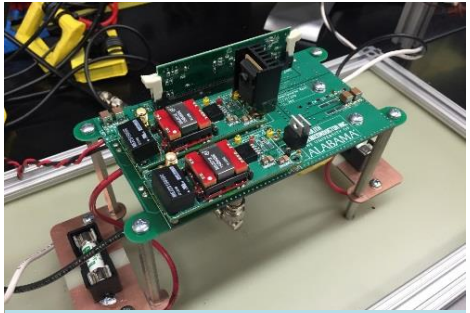




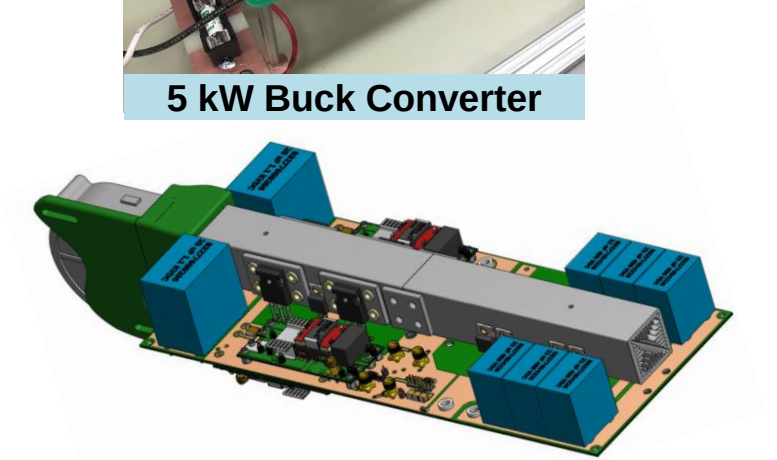
- High current gate driver with IXDN609/614 driver IC from Littelfuse for switching loss minimization
- Other drivers can also be evaluated per customer's request

Littelfuse Power Semiconductors

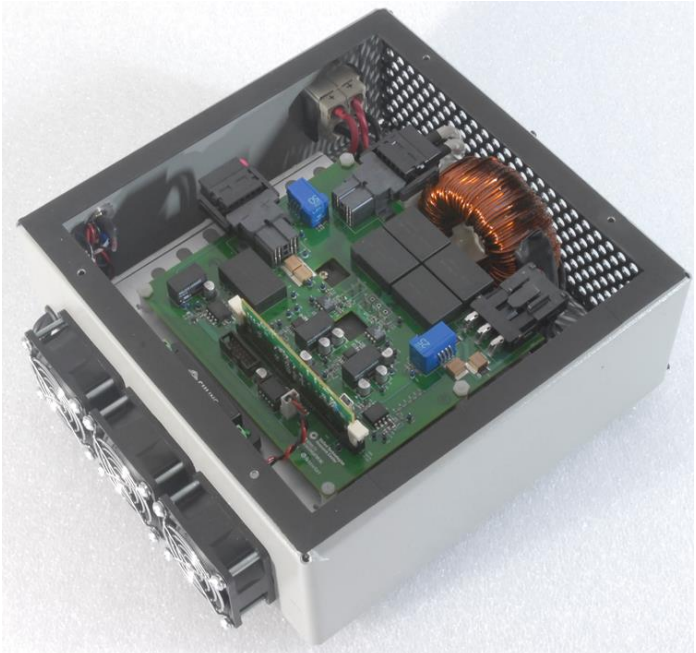
Converter demonstrations with Littelfuse SiC Devices



5 kW Buck Converter



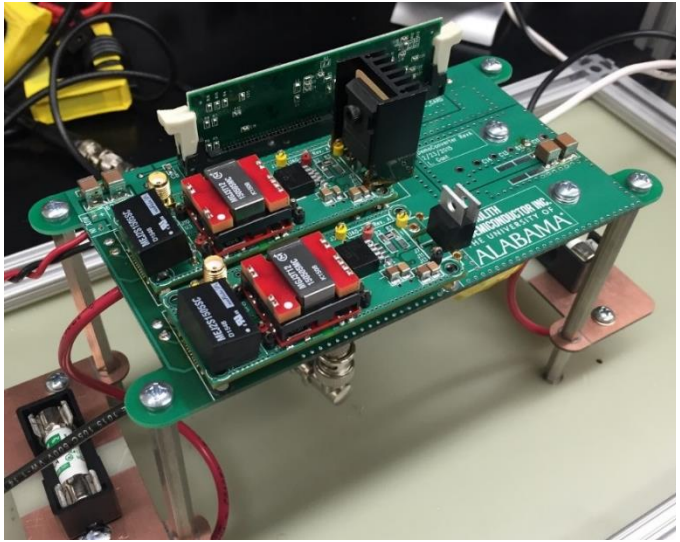
10 kW Phase-shift Full-bridge Converter



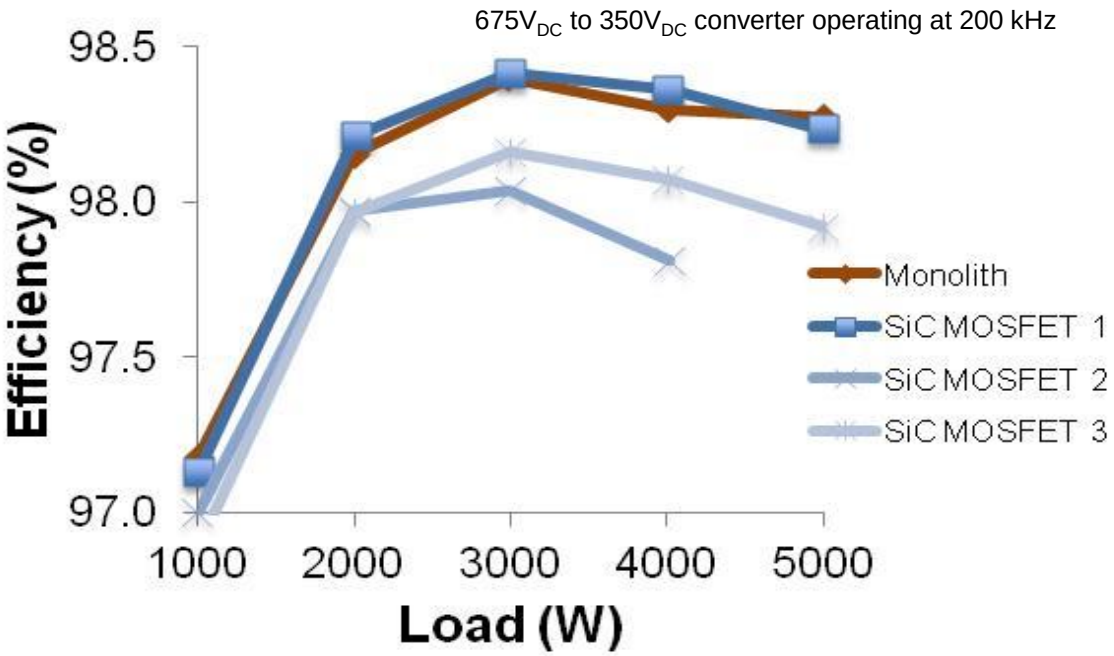
20 KW Boost Converter

Littelfuse® Power Semiconductors

Buck Converter demonstration: 5kW @ 200 kHz



1200V, 80 mΩ MOSFET
1200V, 10A SBD

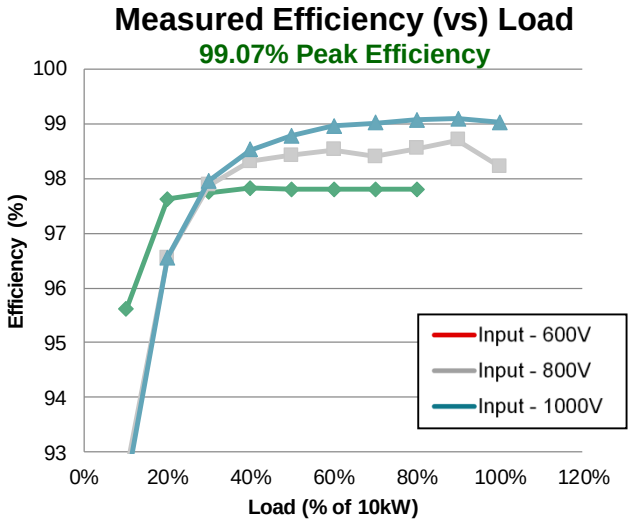


PV Inverter demonstration: 3-Ph, 3-L 10 kW; >99% Efficiency

Total Size: 350mmx 200mm x 100mm

1200V, 80 mΩ MOSFET x 6

- Collaboration with TI
- Littelfuse SiC MOSFET
- TI driver and controller
- 50 kHz operation
- > 99% efficiency
- >1.4 kW / liter power density



New approach to SiC power semiconductors

Littelfuse®
Expertise Applied | Answers Delivered

MONOLITH SEMICONDUCTOR INC.

- Industry-leading customer support
- Global manufacturing and supply chain excellence
- Diverse technology portfolio to enrich systems-level engagements
- Extensive industrial and automotive experience

- Deep power semiconductor and applications expertise
- High performance and quality SiC MOSFET and diode technology
- Manufacturing in automotive-qualified 150mm CMOS fab

New approach to SiC power semiconductors

Littelfuse®
Expertise Applied | Answers Delivered

IXYS

MONOLITH SEMICONDUCTOR INC.

- Extensive packaging knowledge, expertise, and resources
- Complementary technologies that fill in gaps
- Respected name in power semiconductor industry

Thank You!

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Questions?