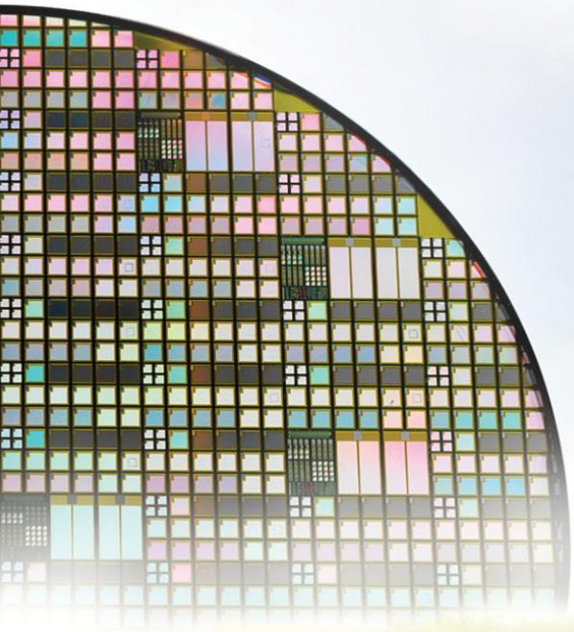
Littelfuse® Power Semiconductors



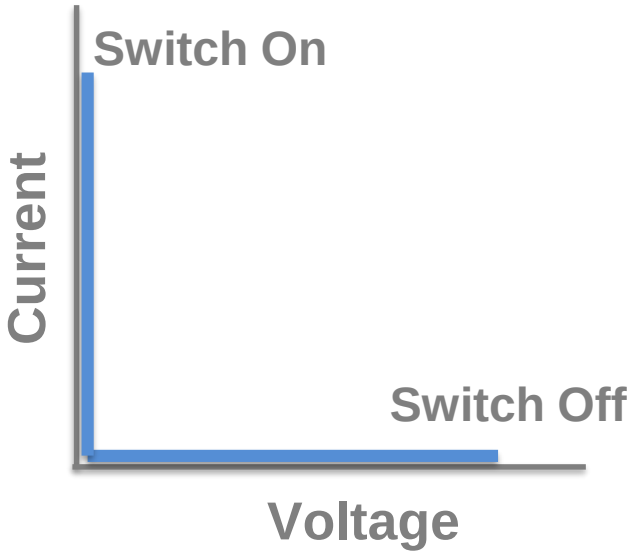
Rugged 1.2 KV SiC MOSFETs Fabricated in High-Volume 150mm CMOS Fab

Agenda

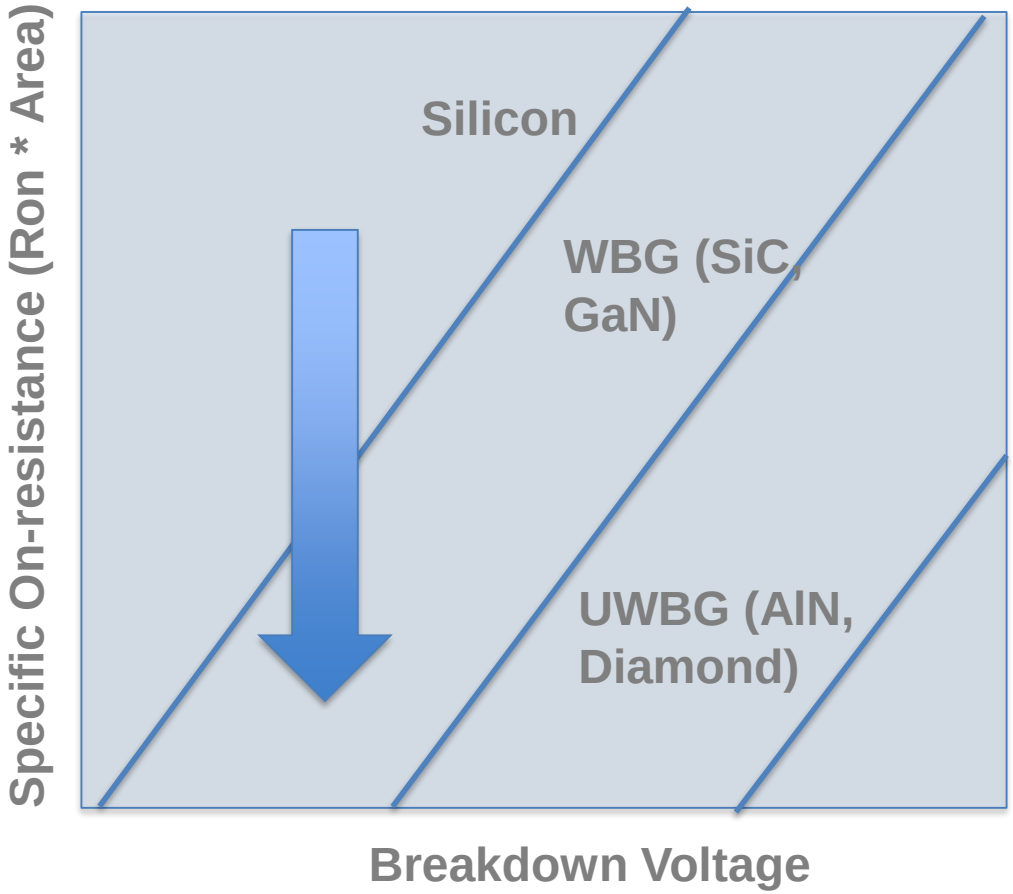
- Motivation for SiC Devices
- SiC MOSFET – Market Status
- High-Volume 150mm Process
- Performance / Ruggedness Validation
  - Static characteristics
  - Switching characteristics
  - Destructive testing
- Application Support

Presented by: Sujit Banerjee, Kevin Matocha, Xuning Zhang, Gin Sheh, and Levi Gant
March 30, 2017 at the Applied Power Electronics Conference (APEC)

Ideal Device



- 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

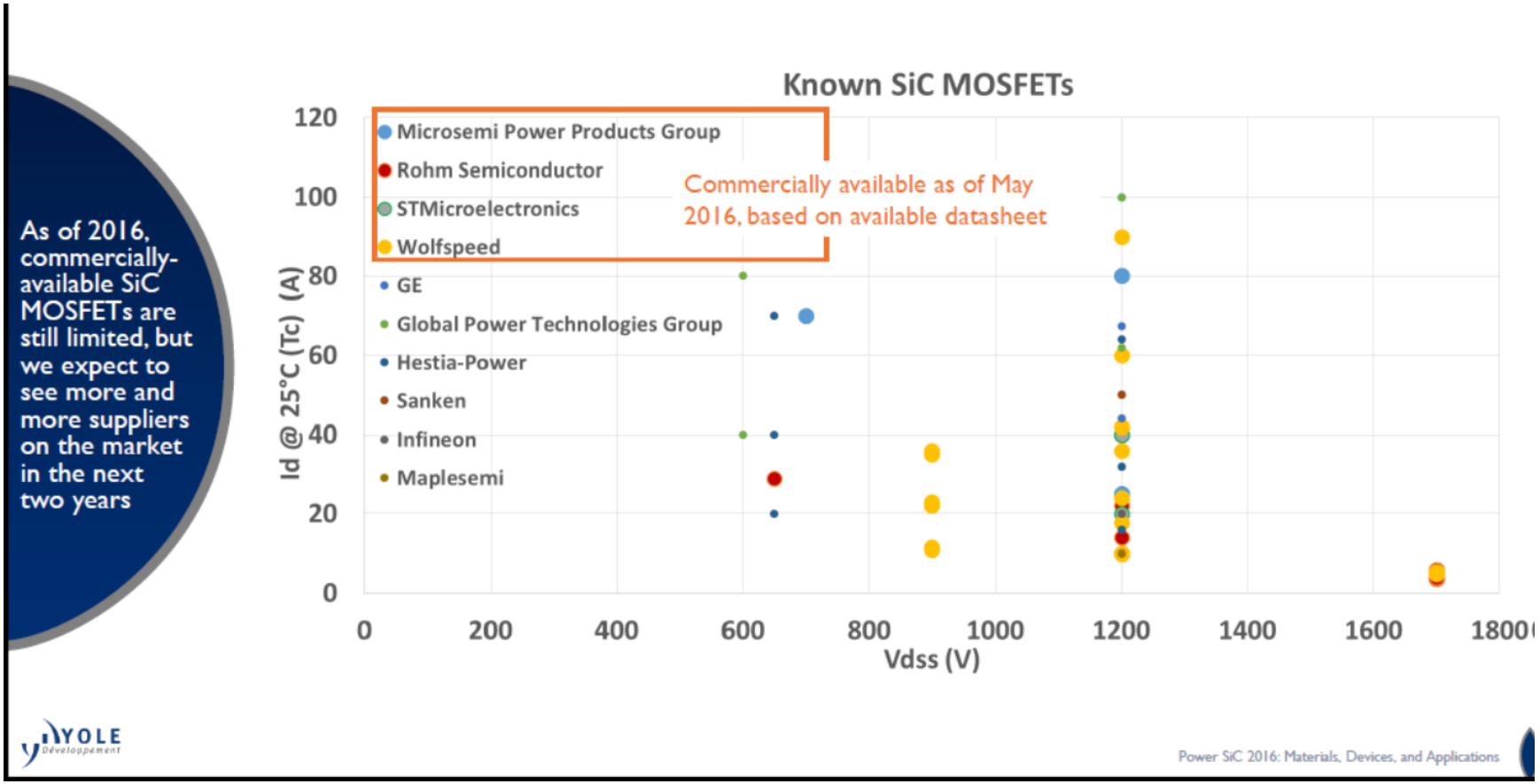
Short-circuit, Avalanche, Surge, ESD

Cost

Manufacturability

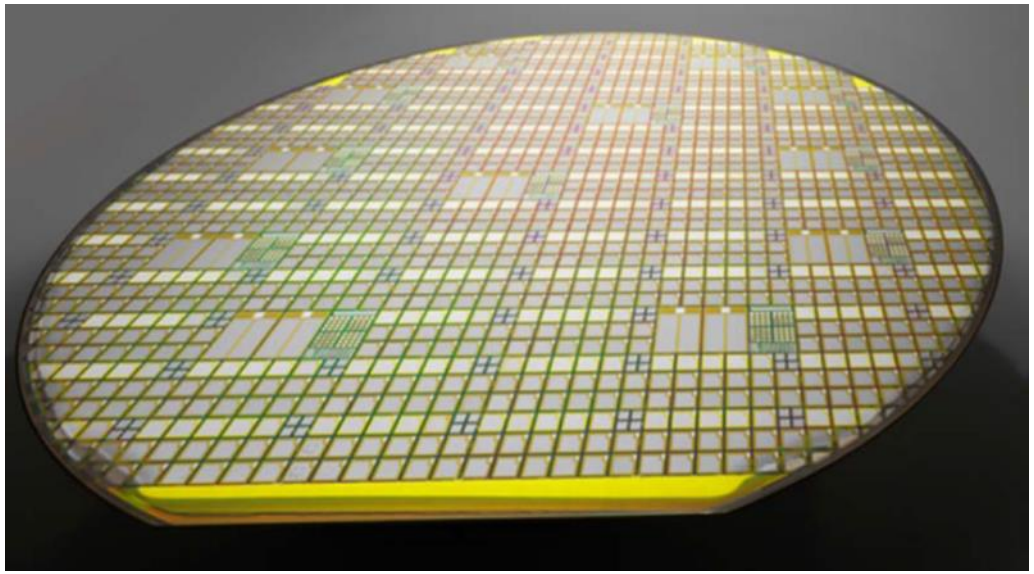
Yield, Process Margin

Commercially Available SiC MOSFETs



- Report from Yole Development, presented by Hong Lin at ECSCRM, 2016.
- Monolith Semi 1.2 kV MOSFETS will be commercially released in 2017.
- Graphic includes devices in sampling and development.

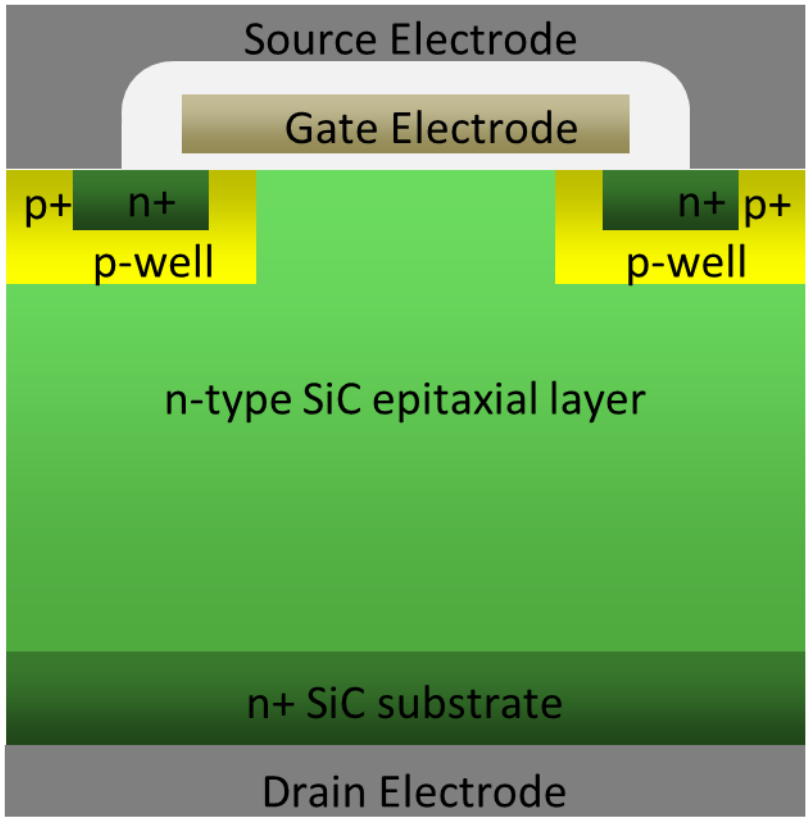
Manufacturing of SiC MOSFETs in High-Volume 150mm CMOS Fab



- 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.

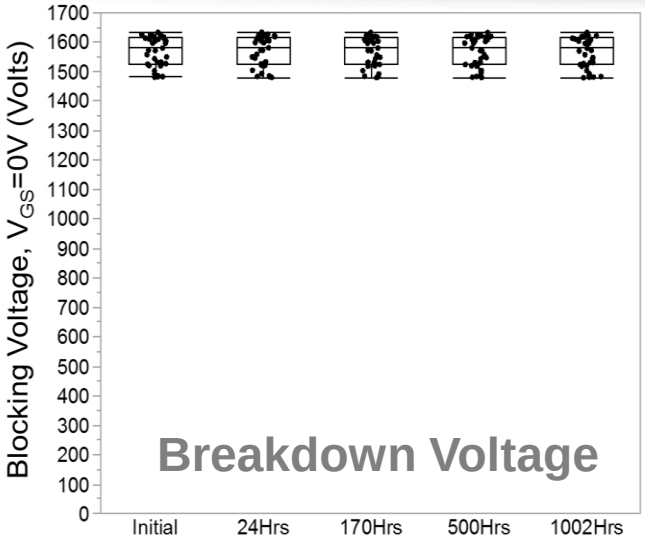
Design Specifications



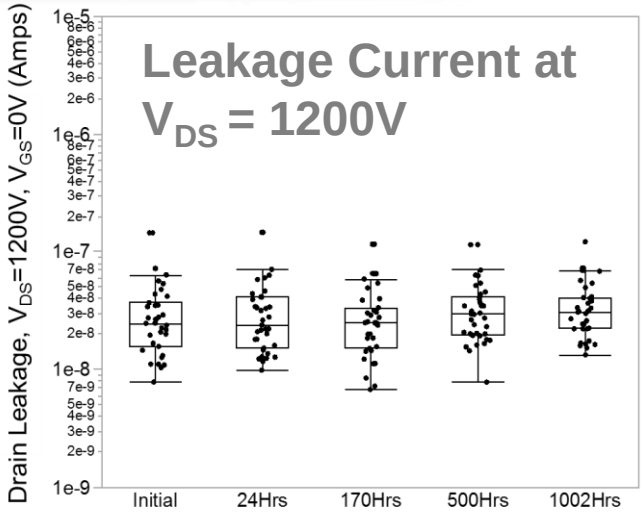
- Epitaxial layer: Epi doping variation
- Termination design: Dose variation, high field in molding compound
- JFET design: High oxide field
- Channel design: On-resistance vs. device ruggedness
- Source/contact design: Design rule

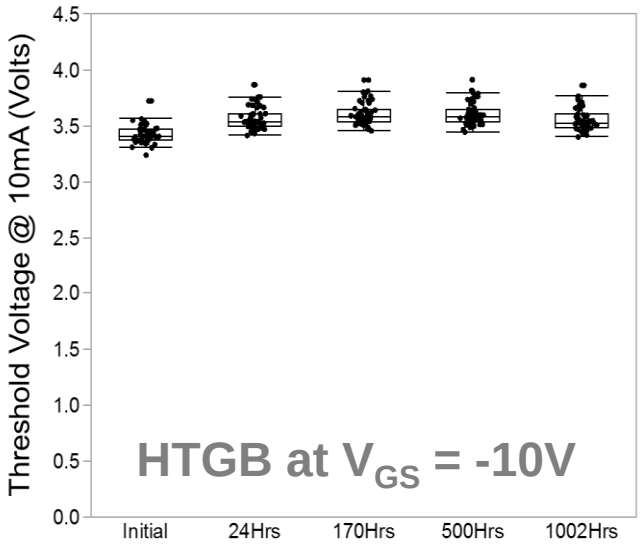
Designed for manufacturability and ruggedness

Long-Term Reliability at 175°C

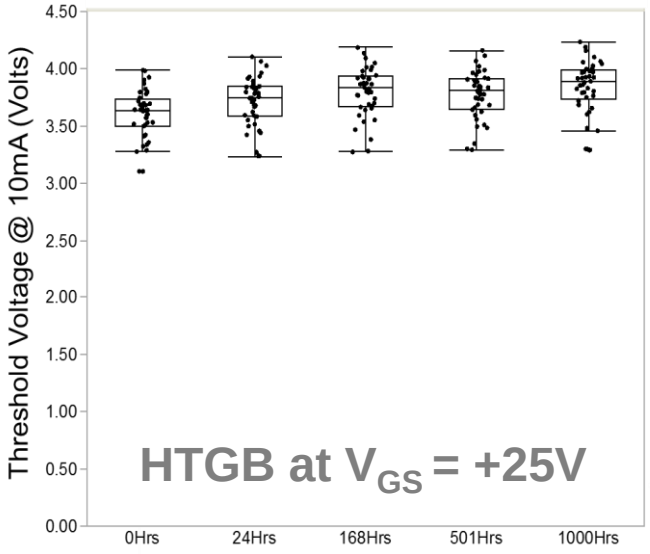


Passed High Temperature Reverse Bias at 175°C, V_{GS} = 0V, V_{DS} = 960V.

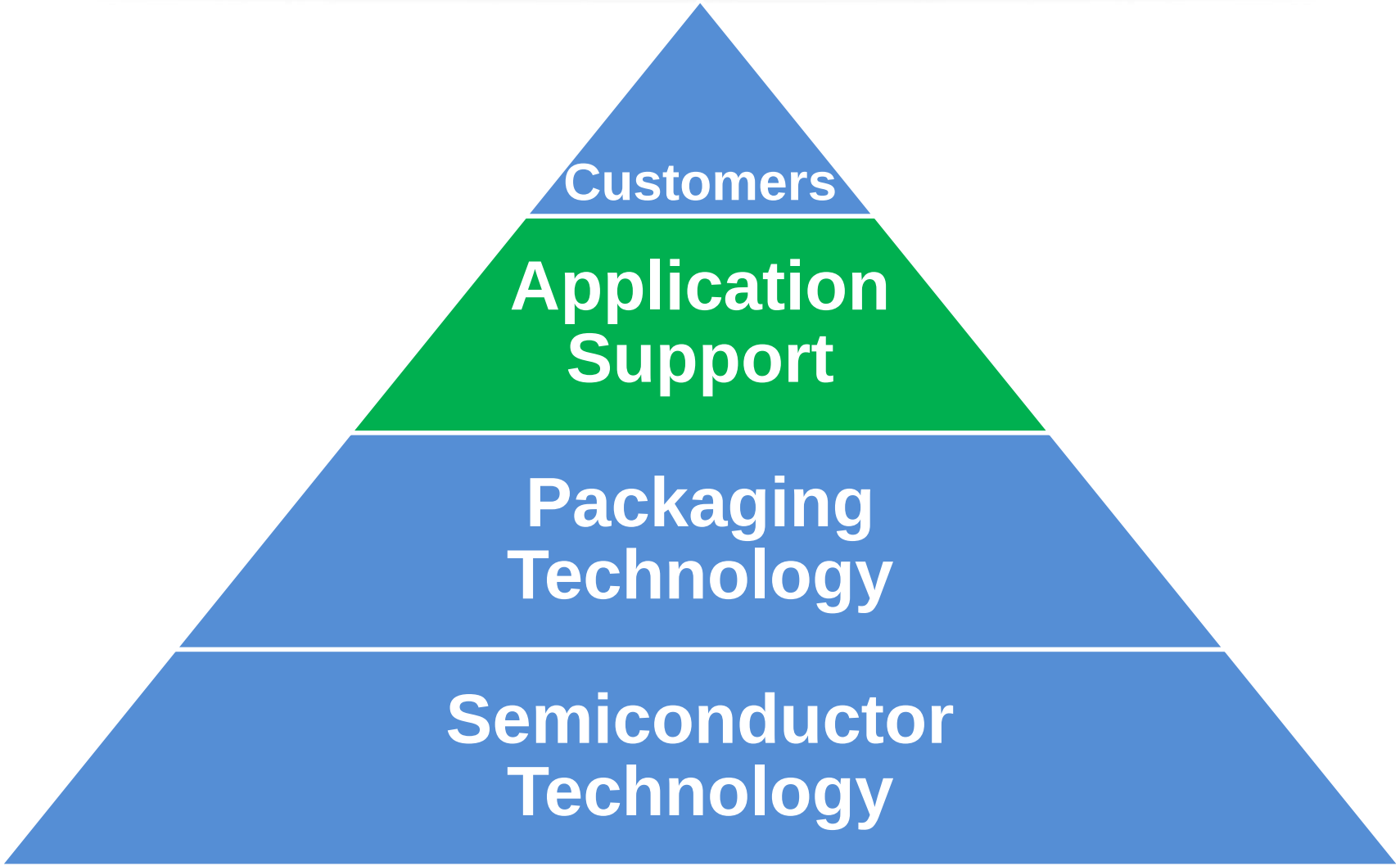




Passed High Temperature Gate Bias at 175°C, V_{GS} = -10V and at V_{GS} = +25V.



Power Semiconductors – Need More than Just Semiconductors



Making the Connection Between Devices and Applications

Device Team

Apps Team

MONOLITH SEMICONDUCTOR INC.

Silicon Carbide Power MOSFET

MSA12N080A

1200 Volt N-Channel, Enhancement-Mode SiC MOSFET

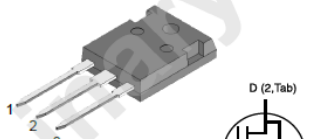
Product Summary		
V_{DS}	1200	V
Maximum $R_{DS(on)}$	100	mΩ
I_D ($T_C \leq 100$ °C)	28	A

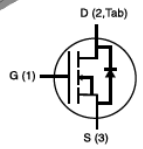
Features:
- Optimized for high-frequency, high-efficiency applications
- Extremely low gate charge and ouput capacitance
- Low gate resistance for high-frequency switching
- Normally-off operation at all temperatures
- Ultra-low on-resistance

Applications:
- High-frequency applications
- Solar Inverters
- Switch Mode Power Supplies
- UPS
- Motor Drives

High Voltage DC/DC Converters

TO-247-3L





MAXIMUM RATINGS

Parameter	Symbol	Conditions	MSA12N080A (TO-247)	Unit
Continuous Drain Current	I_D	V_{GS} = 20 V, T_C = 25 °C	40	A
		V_{GS} = 20 V, T_C = 100 °C	28	
Pulsed Drain Current[1]	$I_{D(pulse)}$	T_C = 25 °C	80	A
Power Dissipation	P_D	T_C = 25 °C, T_J = 175 °C	200	W
Operating Junction Temperature	T_J		-40 to +175	°C
Gate-Source Voltage	$V_{GS,MAX}$	Absolute maximum values	-10 to +25	V
	$V_{GS,OP}$	Recommended values	-5 to +20	
Storage Temperature	T_{stg}		-40 to +150	°C
Lead Temperature for Soldering	T_{sold}		260	°C
Mounting Torque	M_d	M3 or 6-32 screw	0.6	Nm
			5.3	in-lb

note 1: Pulse width limited by $T_{J,max}$

THERMAL CHARACTERISTICS

Parameter	Symbol	MSA12N080A (TO-247)	Unit
Maximum Thermal Resistance, junction-to-case	$R_{th,JC,max}$	0.75	°C/W
Maximum Thermal Resistance, junction-to-ambient	$R_{th,JA,max}$	40	

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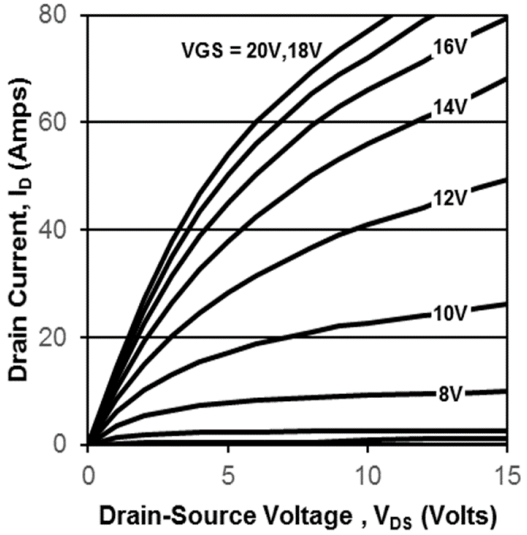
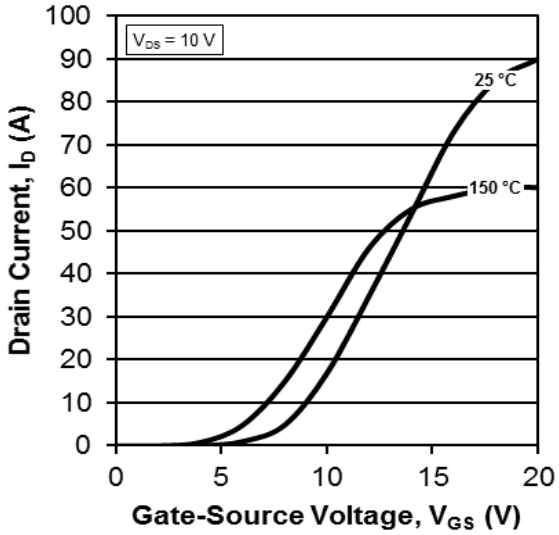
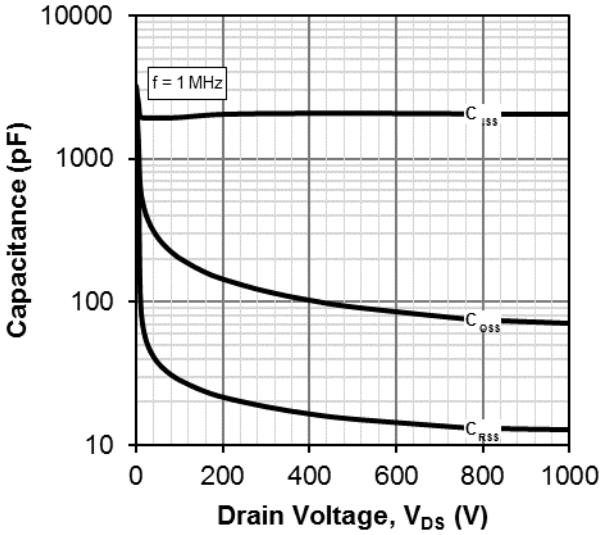
Static Characterization

- Forward characteristics
- Reverse characteristics
- Transfer characteristics
- Junction capacitances

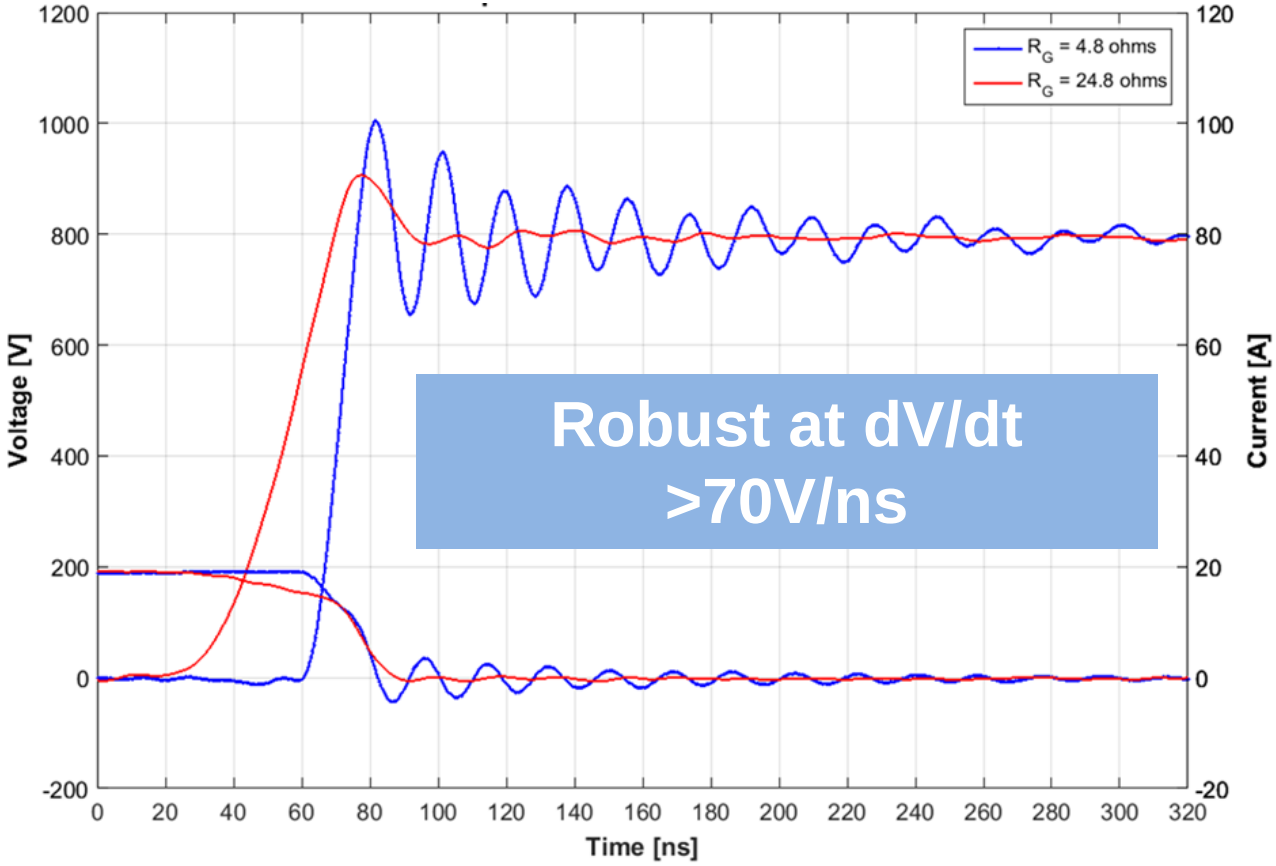




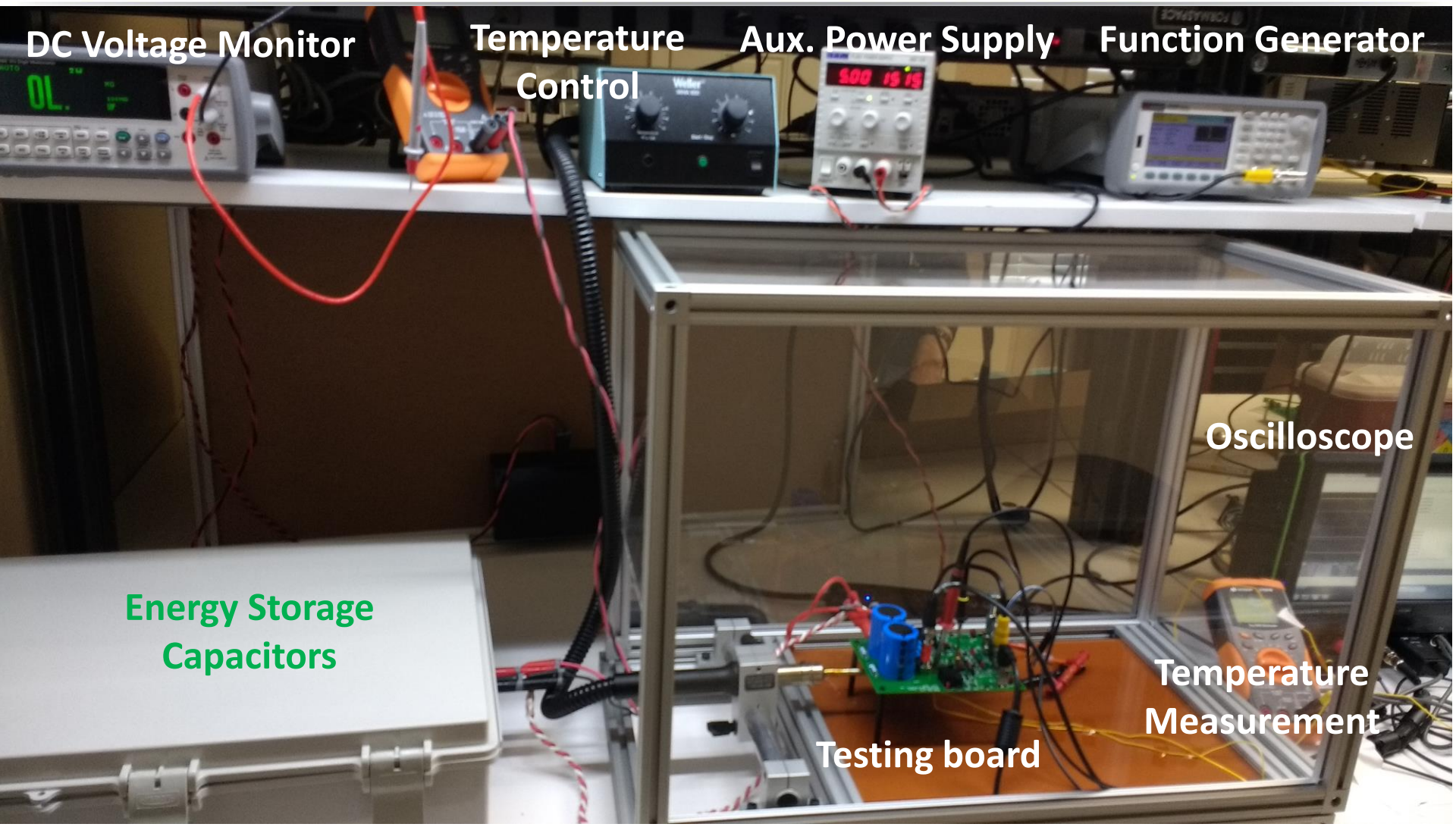


Dynamic Characterization

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



Dynamic Characterization (Cont.)



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Dynamic Characterization (Cont.)

Dynamic characterization testing has yielded results indicating Monolith devices exhibit impressive performance

Figure 17 - Switching Energy vs. Drain Current

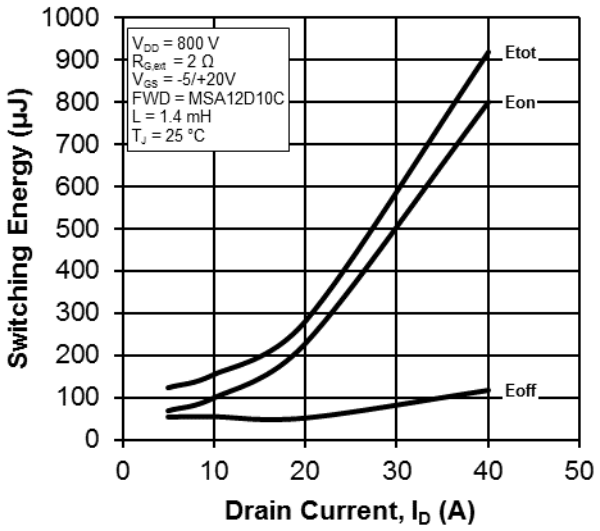


Figure 18 - Switching Energy vs. Gate Resistance

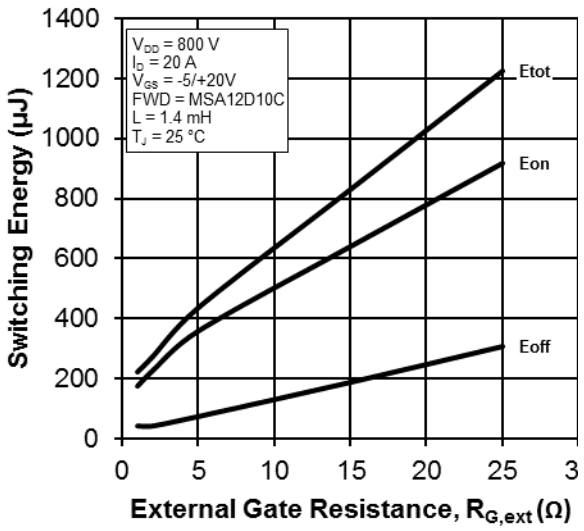
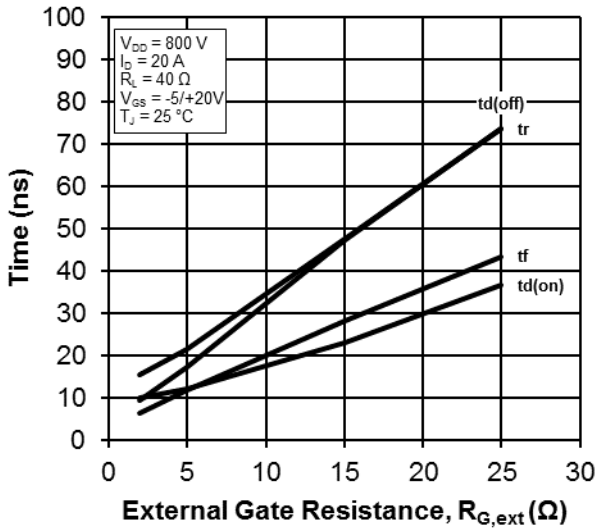
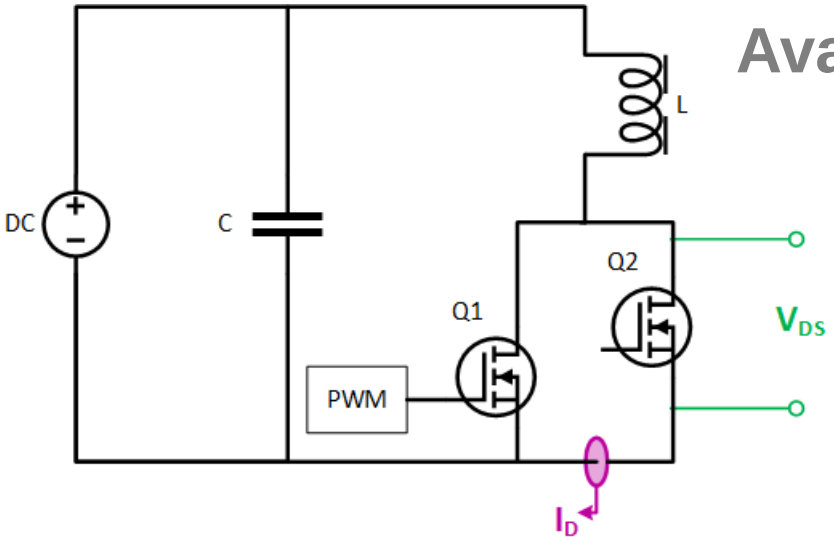


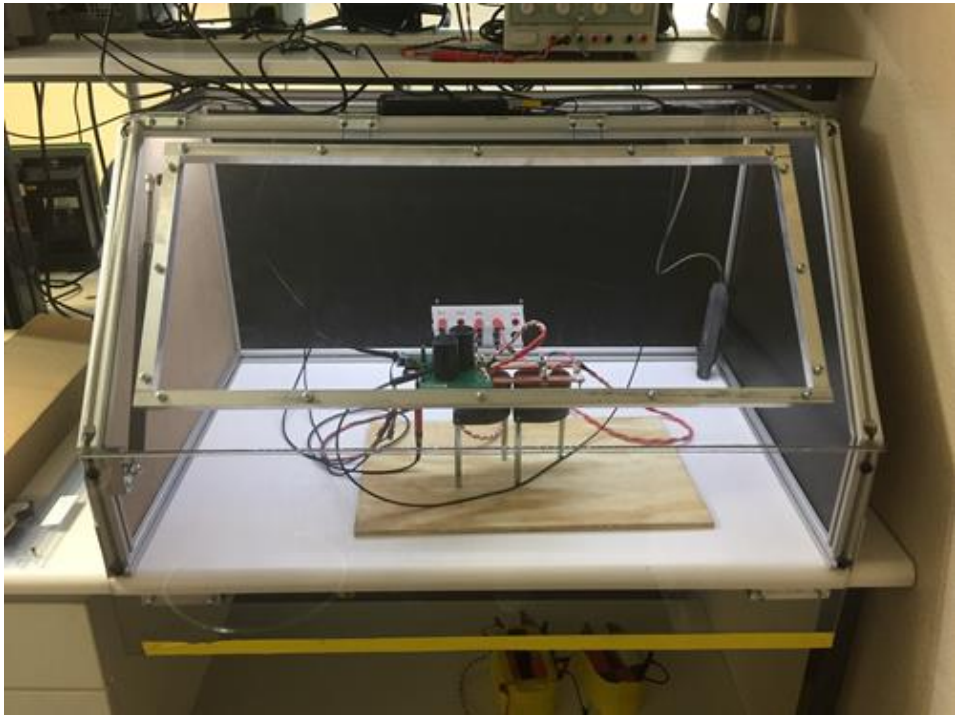
Figure 19 - Switching Times vs. Gate Resistance



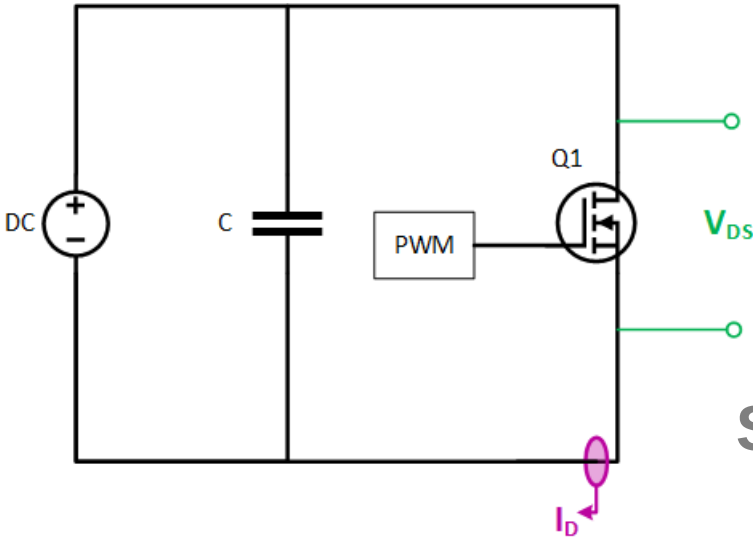
Device Ruggedness

Avalanche Test Circuit





Short-circuit Test Circuit



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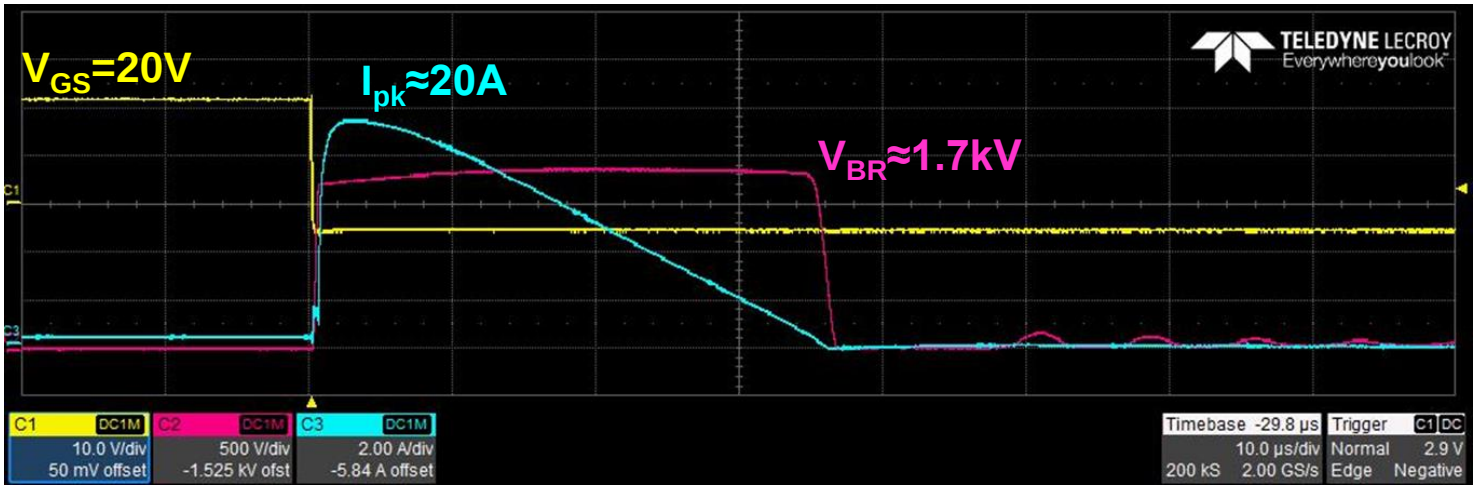
Device Ruggedness (Cont.)

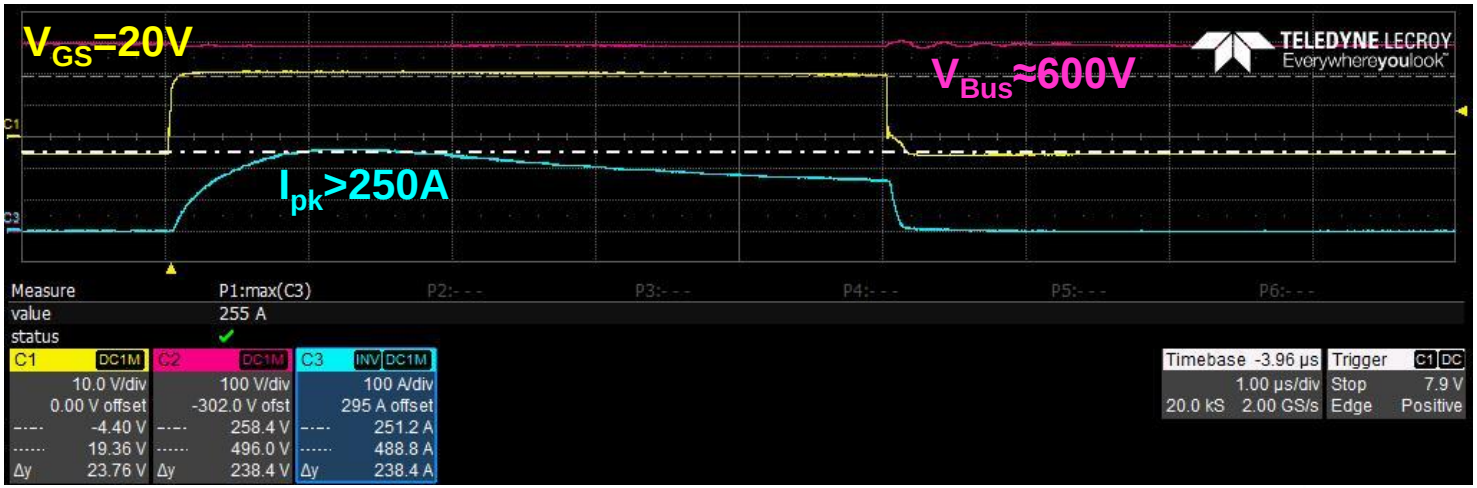
Avalanche



Results indicate withstand:

- E_{AV} ≈ 1J

Short-circuit

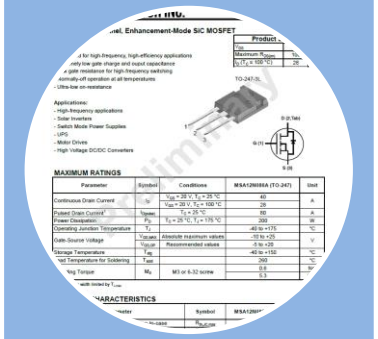


Results indicate device surviving:

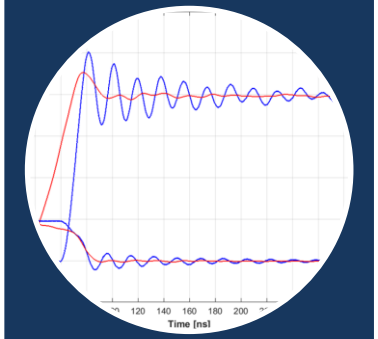
- V_{Bus} ≈ 600V
- T_{On} = 5µsec

Extended Customer Application Support

Device Team



Data Sheet



Apps Team

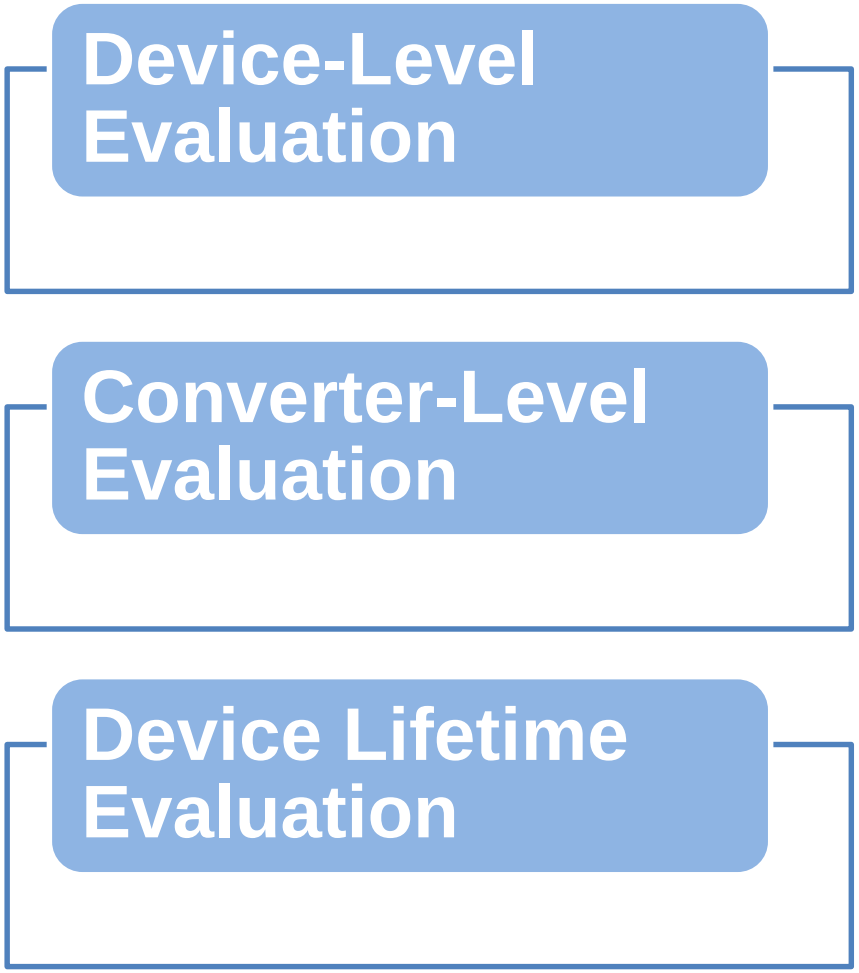
What is the link here?

Customer

Littelfuse MONOLITH SEMICONDUCTOR INC.

Monolith Evaluation Kit Development

- Goal is to provide customers with all tools needed to fully evaluate device performance and reliability
- In addition to evaluation kits
  - Extensive app notes
  - Consulting services



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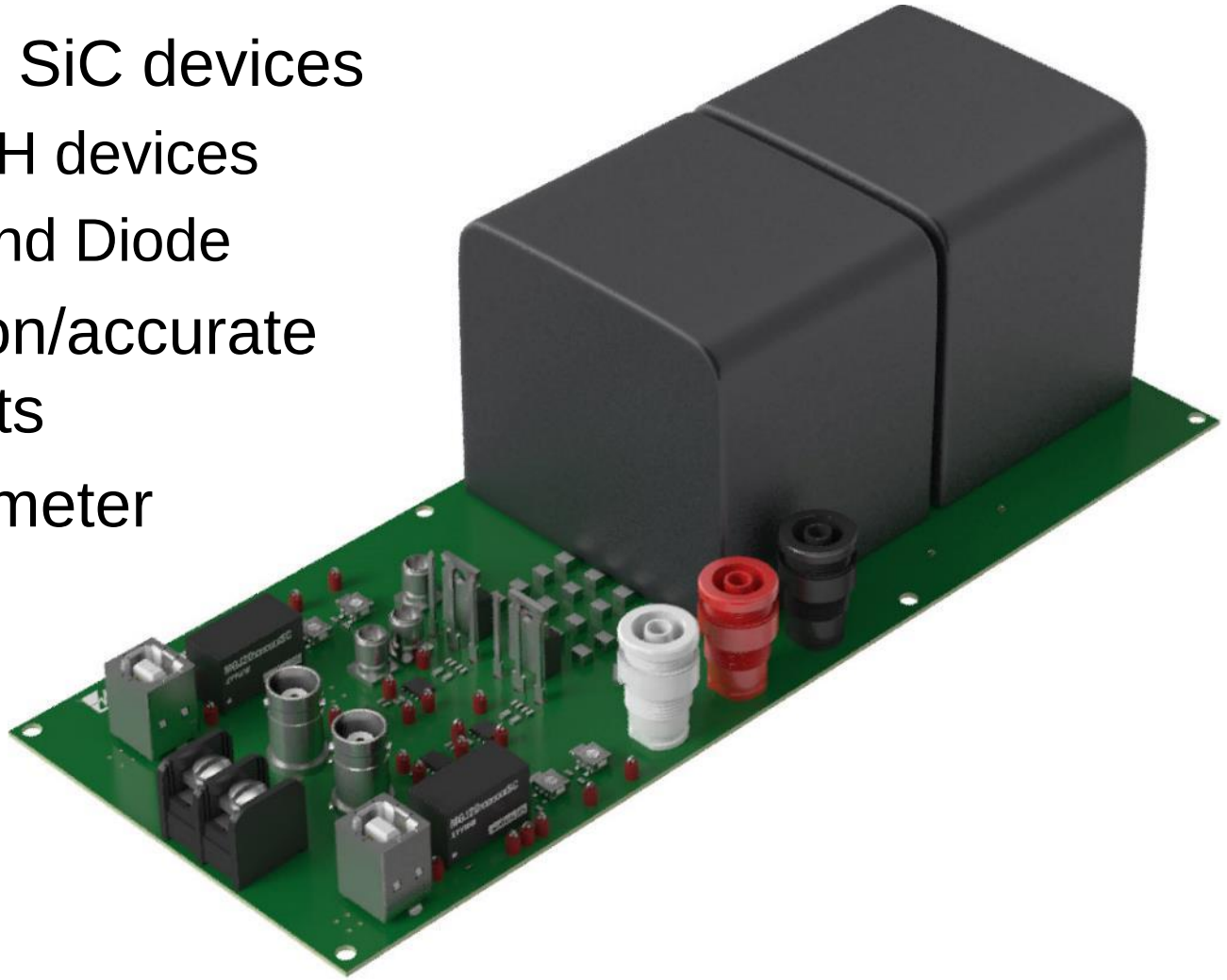
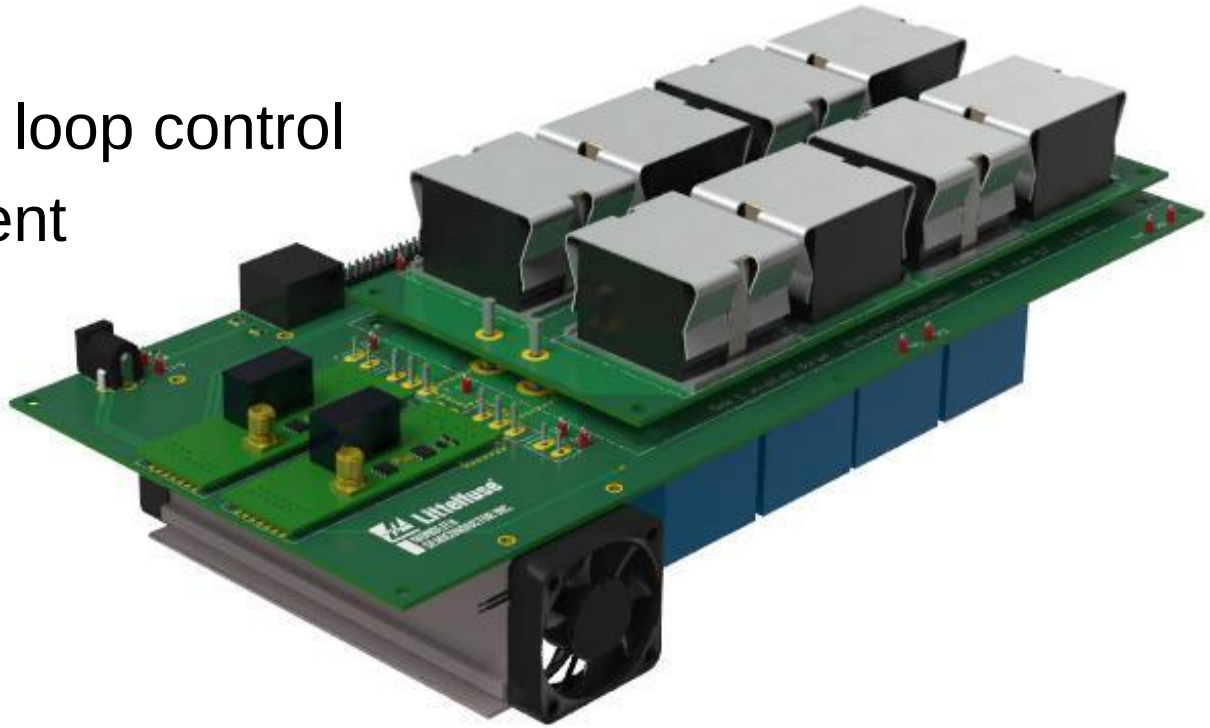
Dynamic Characterization Platform

- Optimized for SiC devices
  - SMD and TH devices
  - MOSFET and Diode
- High resolution/accurate measurements
- Flexible parameter tuning



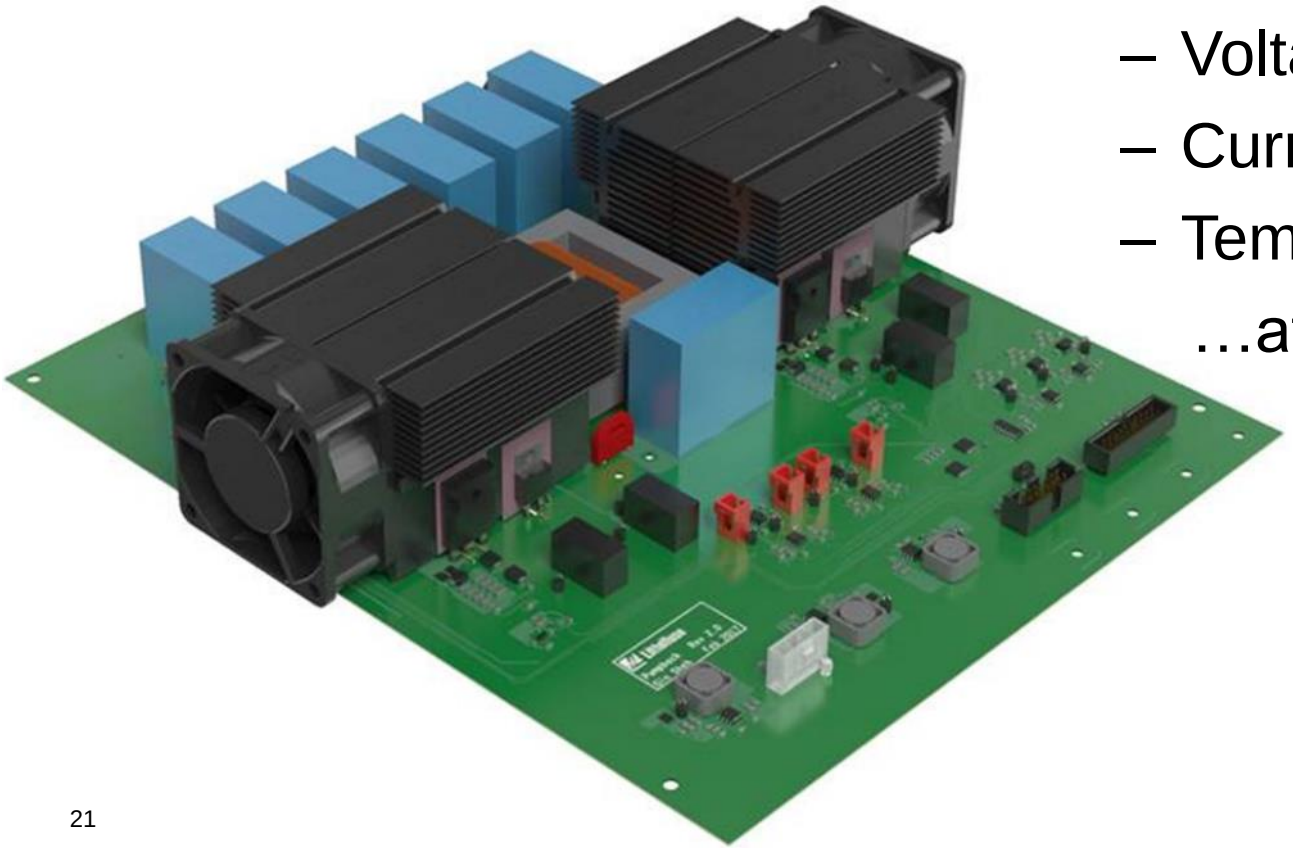
5kW Evaluation Converter Platform

- Offers platform for evaluating devices in continuous switching environment
- Modular design allows for flexible parameter tuning
  - Open/closed loop control
  - Voltage/current
  - F_{sw}
  - Driving solutions



Reliability Evaluation Platform

- Pump-back converter topology



- Allows for testing of devices under real-life operating conditions
  - Voltage
  - Current
  - Temperature

  …at the same time!

Reliability Evaluation Platform (Cont.)

- Scalable system
- Devices stressed at full rating with minimal real power consumption
- Integrated signal monitoring and data logging
- Modularity allows for test unit replacement without interruption of paralleled units

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

Wrap Up

- SiC MOSFETs starting to gain customer acceptance
  - Multiple suppliers
  - Wider offering of voltage, current and package
- Monolith is committed to offering exceptional applications support on top of solid device technology
  - In-depth knowledge of device characteristics
  - Customer tools to accelerate design processes
- Monolith + Littelfuse partnership offers strong position
- For additional product information or to request samples, click here.

Acknowledgements

arpa·e
CHANGING WHAT'S POSSIBLE

U.S. DEPARTMENT OF ENERGY

ARL

SWITCHES

PowerAmerica

College of Engineering
Electrical and Computer Engineering

Littelfuse

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