mSiC™ Products and Solutions:
Adopt SiC with Ease, Speed and Confidence

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

SMART | CONNECTED | SECURE

Silicon Carbide BU

October 22, 2024

Microchip SiC Started in 2003

First SiC Device
Shipped (Q4/2003)

PowerSicel
Acquired by
Advanced Power
Technology (APT)

APT Acquired
by Microsemi

SiC Process
and Technology
Transfer for
SIT/JFET

Internal SiC Fab
in Bend, OR

SiC SBDs
Expanded Range
(700V – 1700V)

SiC MOSFETs
Released
(650V and 1200V)

SiC Modules
Released

Dual SiC Fabs
(Internal &
External)

Microsemi
Acquisition

AgileSwitch®
Acquisition

Process Transfer &
Expansion to Fab 5

SiC MOSFETs
Expanded Range
(700-1700V)

AEC Release
SiC SBDs

3.3 kV SiC
MOSFETs and SBDs
Released

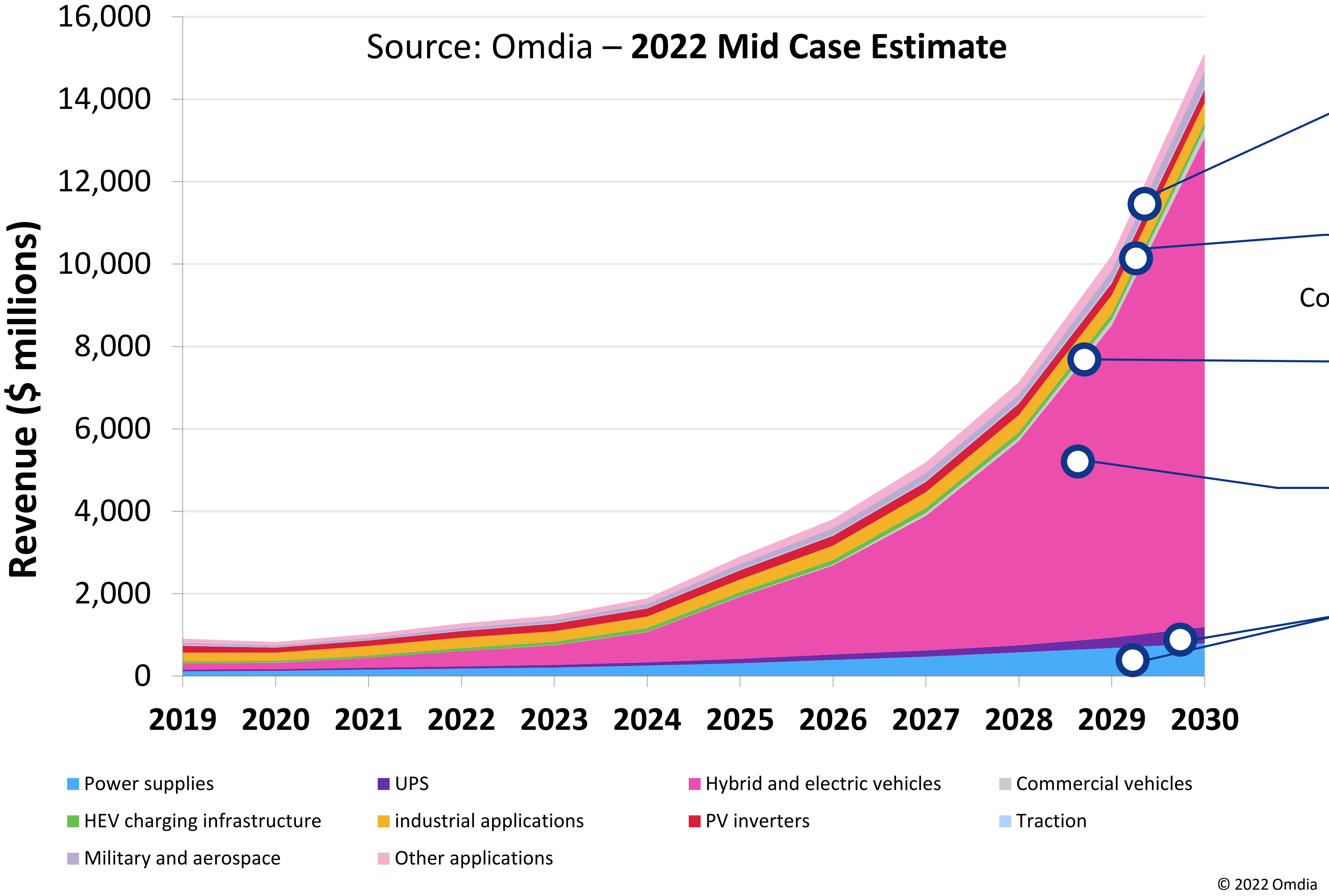
$880 Million
Fab 5 Investment Announced

$162 Million
CHIPs Act (prelim)
Announced

AEC Release
SiC MOSFETs

2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 | 2018 | 2020 | 2022 | 2024

Microchip in the SiC Power Market



Mil/Aero
Leading supplier to Military and Aerospace

EV Charging Infrastructure
Complete SiC Solutions to Streamline Adoption

Commercial EV and Traction
Delivering intelligent SiC to extend range

Consumer EV
Microchip major supplier to OEM/Tier 1

Power Supplies and UPS
Diverse SiC product portfolio to satisfy mainstream and niche power supply market

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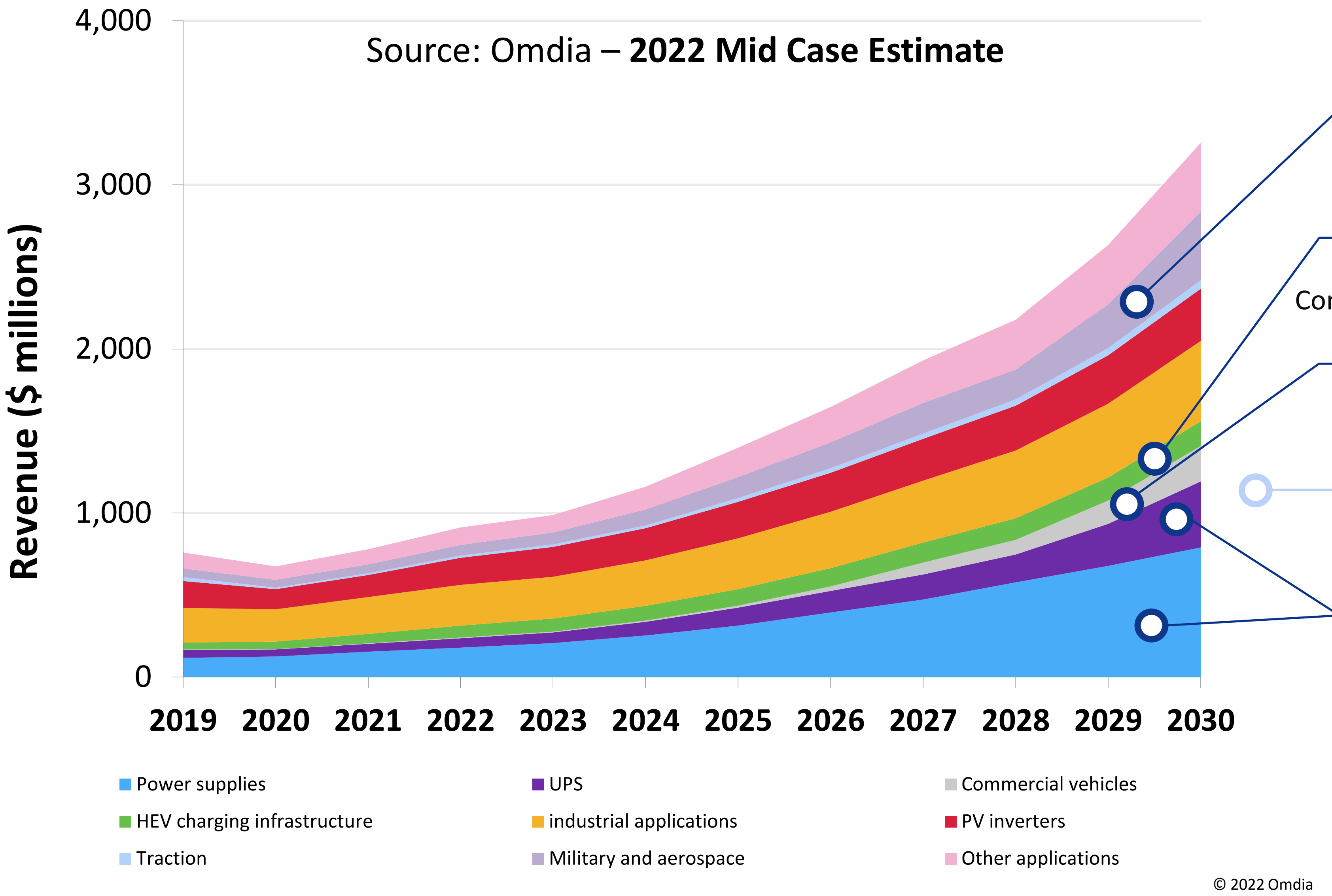
Microchip in the SiC Power Market (non-EV)



Mil/Aero
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Delivering intelligent SiC to extend range

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Microchip major supplier to OEM/Tier 1

Power Supplies and UPS
Diverse SiC product portfolio to satisfy mainstream and niche power supply market

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mSiC™ Product Portfolio | 700V, 1200V, 1700V, 3.3 kV

Products	Packages	Portfolio
Bare Die		• 700V – 3.3 kV, 15 – 750 mΩ SiC MOSFETs • 700V – 3.3 kV, 10 – 90A SiC Schottky Barrier Diodes (SBDs)
Discretes		• 700V – 3.3 kV, 15 – 750 mΩ SiC MOSFETs • 700V – 3.3 kV, 10 – 100A SiC Schottky Barrier Diodes
Modules		• 700V – 1700V, 1.5 – 40 mΩ SiC MOSFETs • 700V – 1700V, 50 – 600A SiC Schottky Barrier Diodes • 650V – 1200V, 25 – 100A Hybrid (Si IGBT + SiC SBD) • Custom Power Modules
Gate Drivers		• 1200V – 3.3 kV Plug-and-Play Gate Drivers • Augmented Switching™ Technology • Isolated 5A Gate Driver

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Microchip SiC Portal

www.microchip.com/SiC

Includes

- SiC Bare Die
- SiC Discretes
- SiC Modules
- SiC Gate Drivers
- Featured Videos
- SiC Design Resources
  - Reference Designs and Application Notes
  - Models and Simulation Tools
  - Product Selection Tools
- Support Options

SCAN ME

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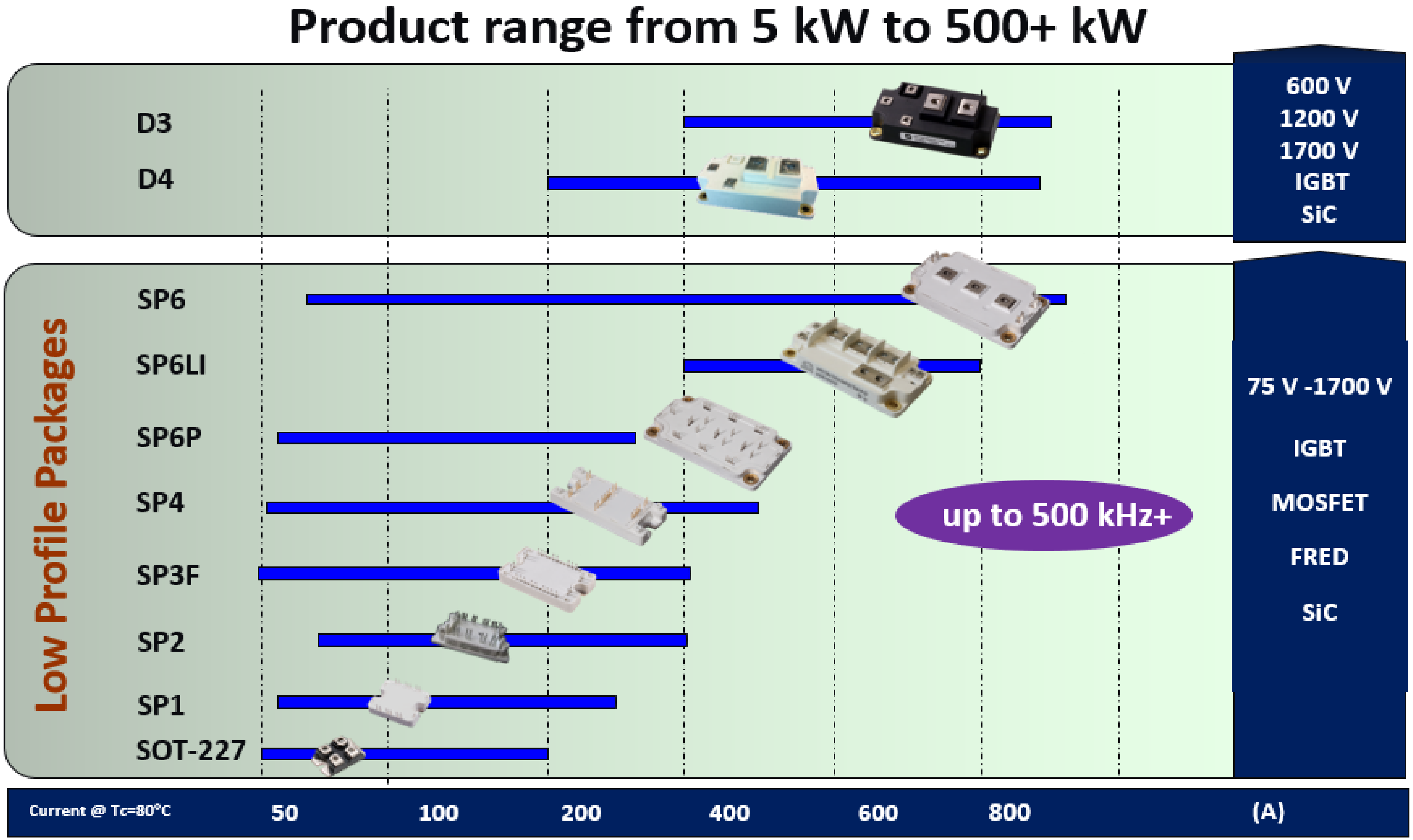
mSiC™ Products | Power Module Product Lines

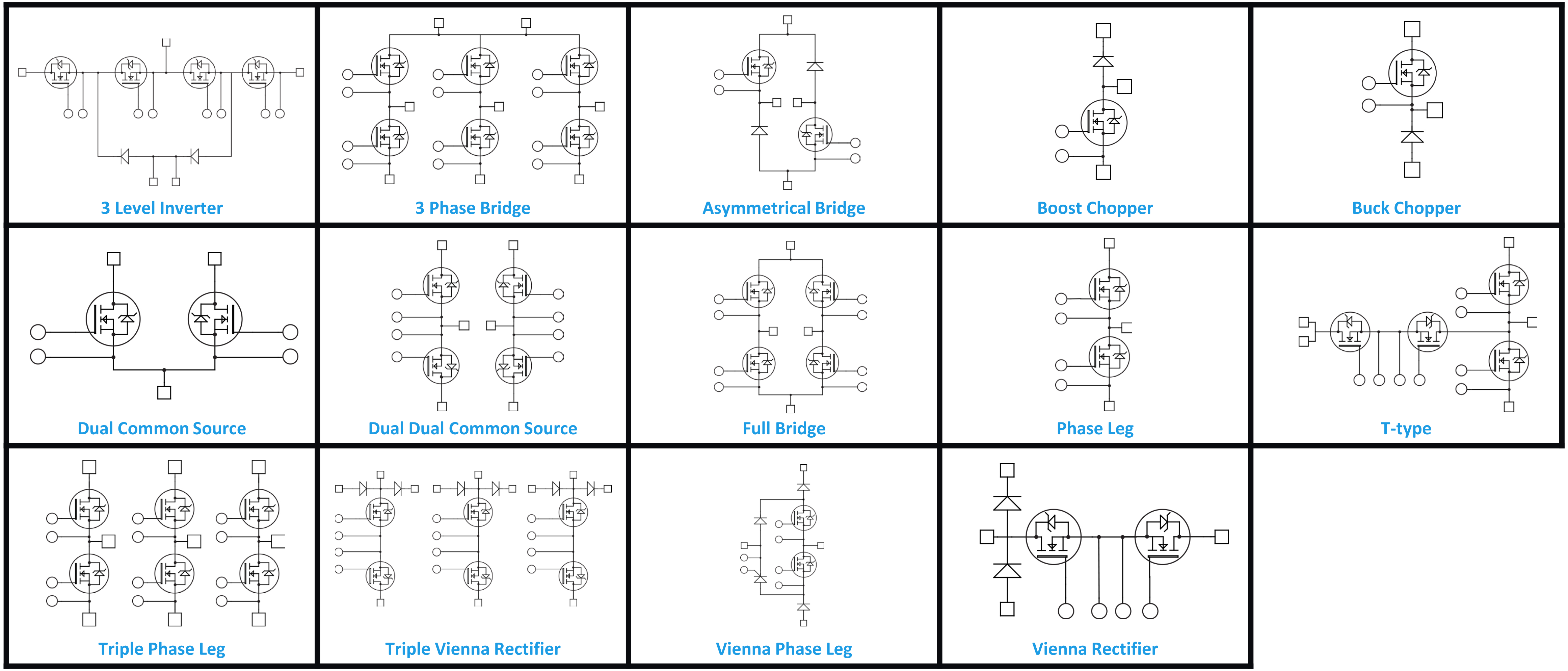


- STANDARD MODULES
- MODIFIED STANDARD MODULES
- CUSTOM MODULES

mSiC™ Modules (MOSFET) | 700V – 1700V

Broad range of configurations

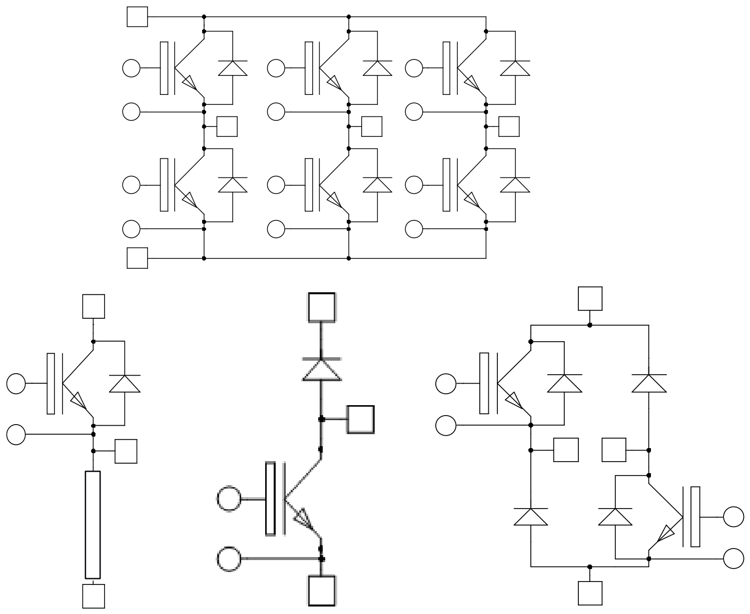
mSiC™ Modules Products Page



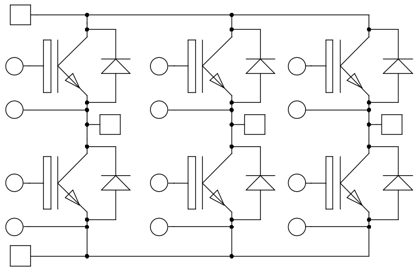
mSiC™ Modules (Hybrid) | 650V – 1200V

Broad range of configurations

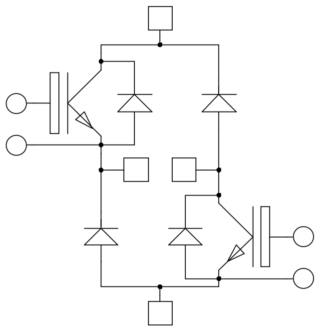
mSiC™ Modules Products Page



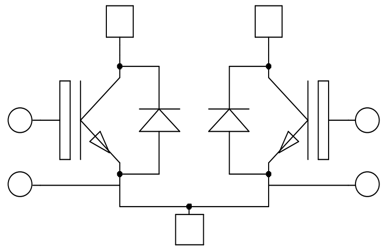
3 Phase Bridge + Brake, Soft Start and Solenoid Power



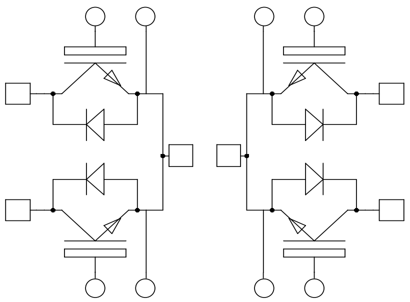
3 Phase Bridge



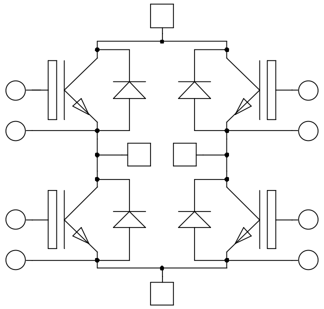
Asymmetrical Bridge



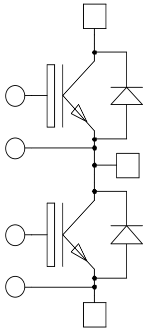
Dual Common Source



Dual Dual Common Source



Full Bridge



Phase Leg

Flexibility with mSiC™ Module Architectures

Standard, modified and custom modules

Power Semiconductor Die

IGBT, MOSFET, Diode, SiC

- Soldered to the substrates
- Connected by ultrasonic Al wire bonds

Substrates

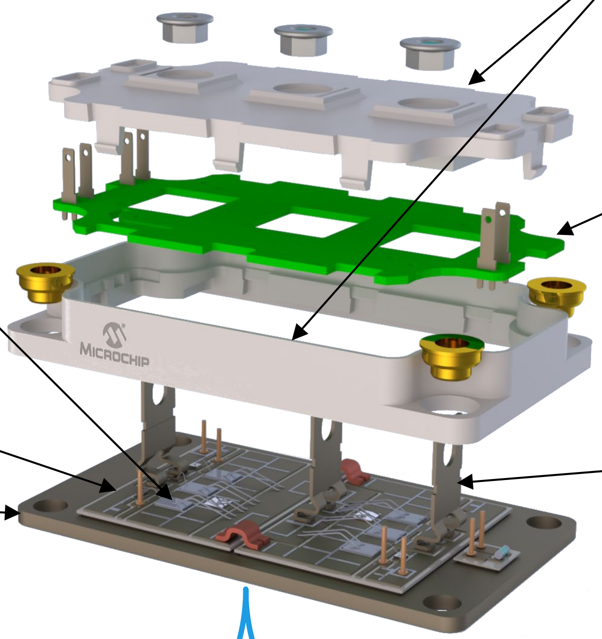
Al_2O_3, AlN, Si_3N_4

- Provide isolation
- Good heat transfer to the base plate

Base Plate

Improve the heat transfer to the heatsink

- Cu material for good thermal transfer
- AlSiC for improved reliability



Package

Standard or Custom

- Environmental protection
- Mechanical robustness

Internal Printed Circuit Board

Not available in all modules

- Used to route gate signals tracks to small signal terminals
- Used to mount gate circuit and protection in case of intelligent power module

Terminals

Screw on or Solder pins

- Power and signal connections
- Minimum parasitic resistance and inductance

High Design Flexibility

Empowering balance with price, performance and reliability

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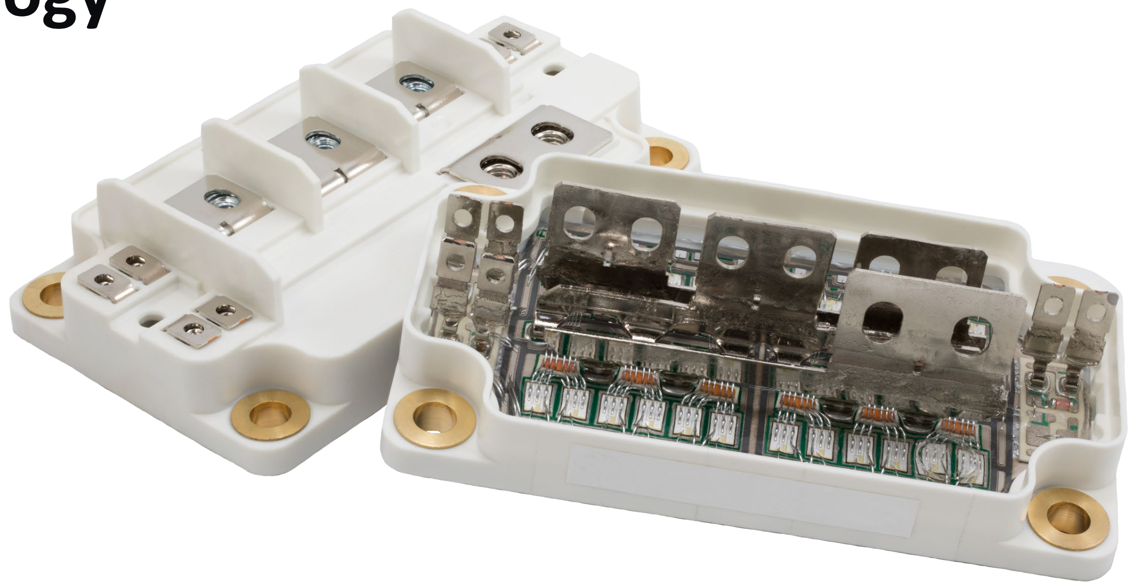
mSiC™ Modules | Lowest Inductance

SP6LI Power Module – Enabling Higher Power Density and Efficiency

- Extremely low stray inductance, < 2.9 nH
- Dedicated to SiC MOSFET technology
- High switching frequency
- High efficiency
- High current



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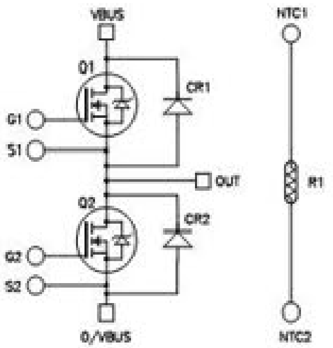
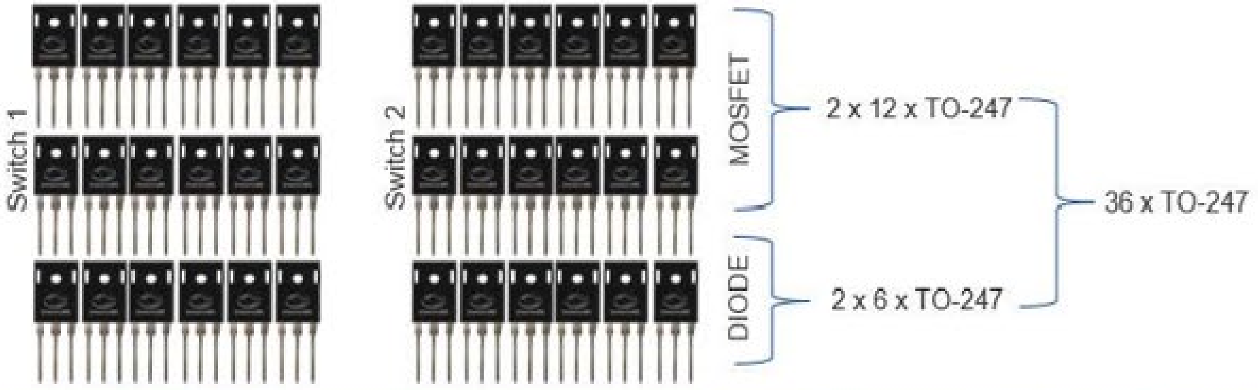
Low Inductance SP6LI Package vs Discretes



MSCSM120AM02CT6LIAG

Or…

24 x MSC025SMA120B + 12 x MSC050SDA120B



	SP6LI power module	TO-247 discrete package	Power module benefits
MOSFET Electrical ratings	1200 V – 754 A @ Tc=80°C per switch	1200 V – 73 A @ Tc=100°C (non isolated) each	Higher power density ✓✓✓
Size	62 mm x 108 mm / 2.44'' x 4.25''	36 x (15.87 mm x 21.13 mm / 0.625'' x 0.832'')	Easier mounting ✓✓
Mounting pcb area	6'696 mm2 / 10.37 sq. in.	Min. 13'950 mm2 / 21.62 sq. in. (mounting dependant)	Smaller system size ✓✓
Weight	320 g w/ Cu baseplate – 220 g w/ AlSiC	36 x 6.2 g = 223.2 g (no isolation)	More compact design ✓✓
Stray inductance	3 nH	20 nH	Higher efficiency ✓✓✓
Isolation	4 kV AC, 1mn - per design	None, to be added during assemlby	Higher reliability ✓✓✓
Thermal Management	Very good and repeatable	Complicated	Better thermal performance ✓✓✓
Temperature sensor	Yes, NTC	No, to be added externally	More accurate protection ✓✓✓
Assembly time	4 mounting holes + 14 electrical screws	36 mounting holes + 108 solder pins (additional labor)	Faster assembly time ✓✓✓

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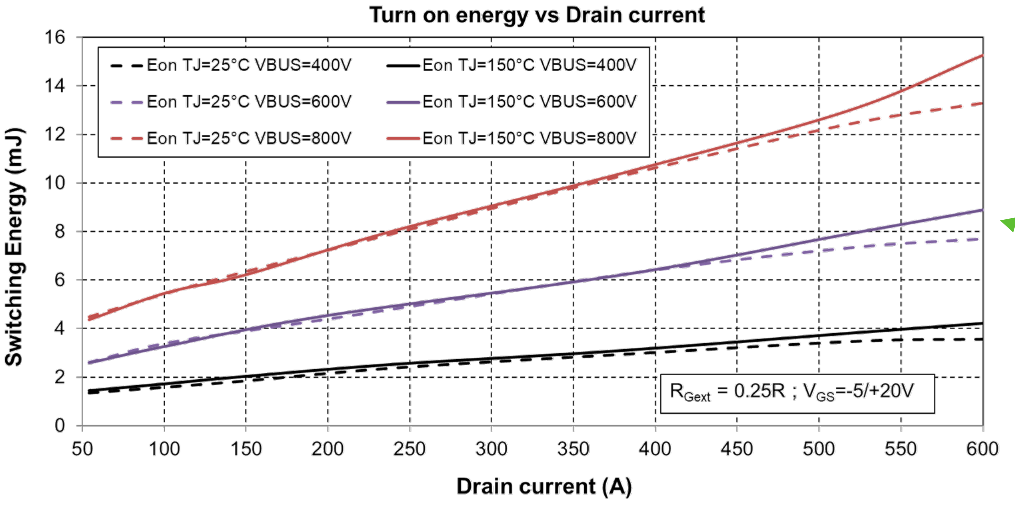
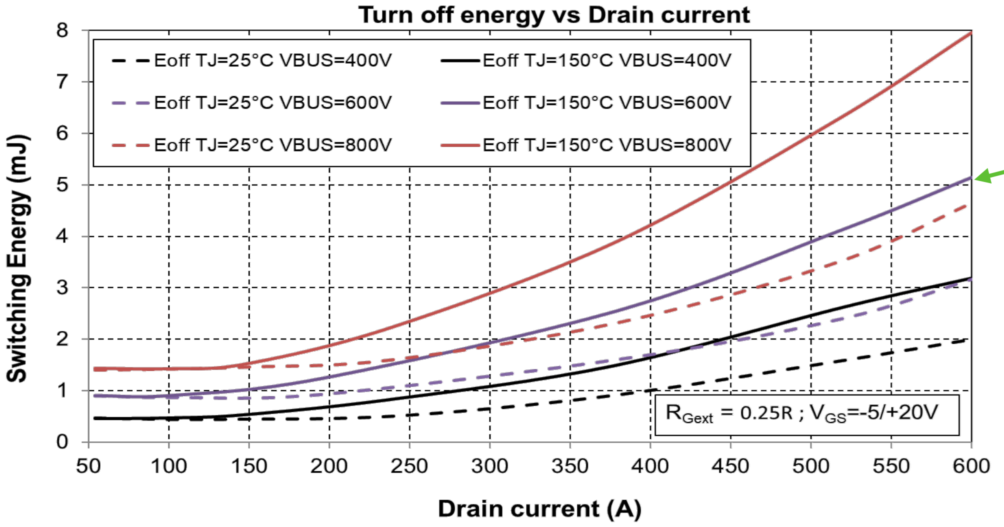
SP6LI = High current @ high switching frequency

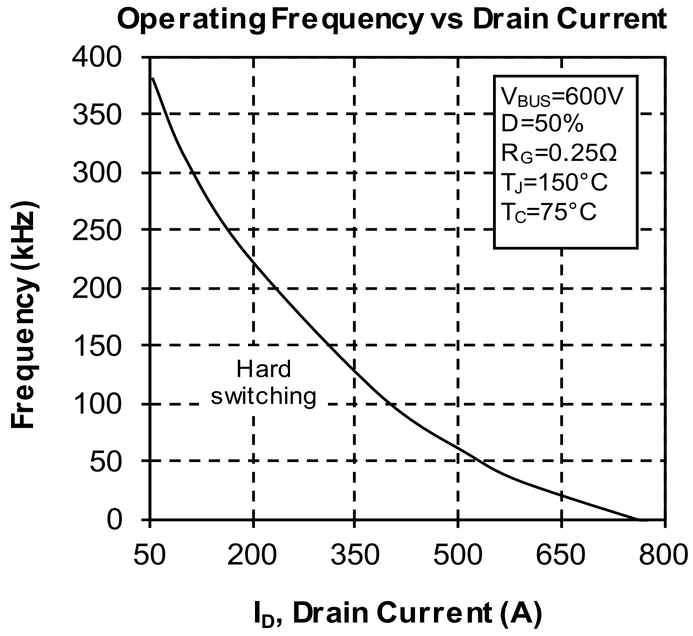
MSCMC120AM02CT6LINMG – 1200V/2 mΩ full SiC Phase Leg with AlSiC base plate and Si_3N_4 substrates





Vbus = 600V
Id = 600A
Tj = 150°C

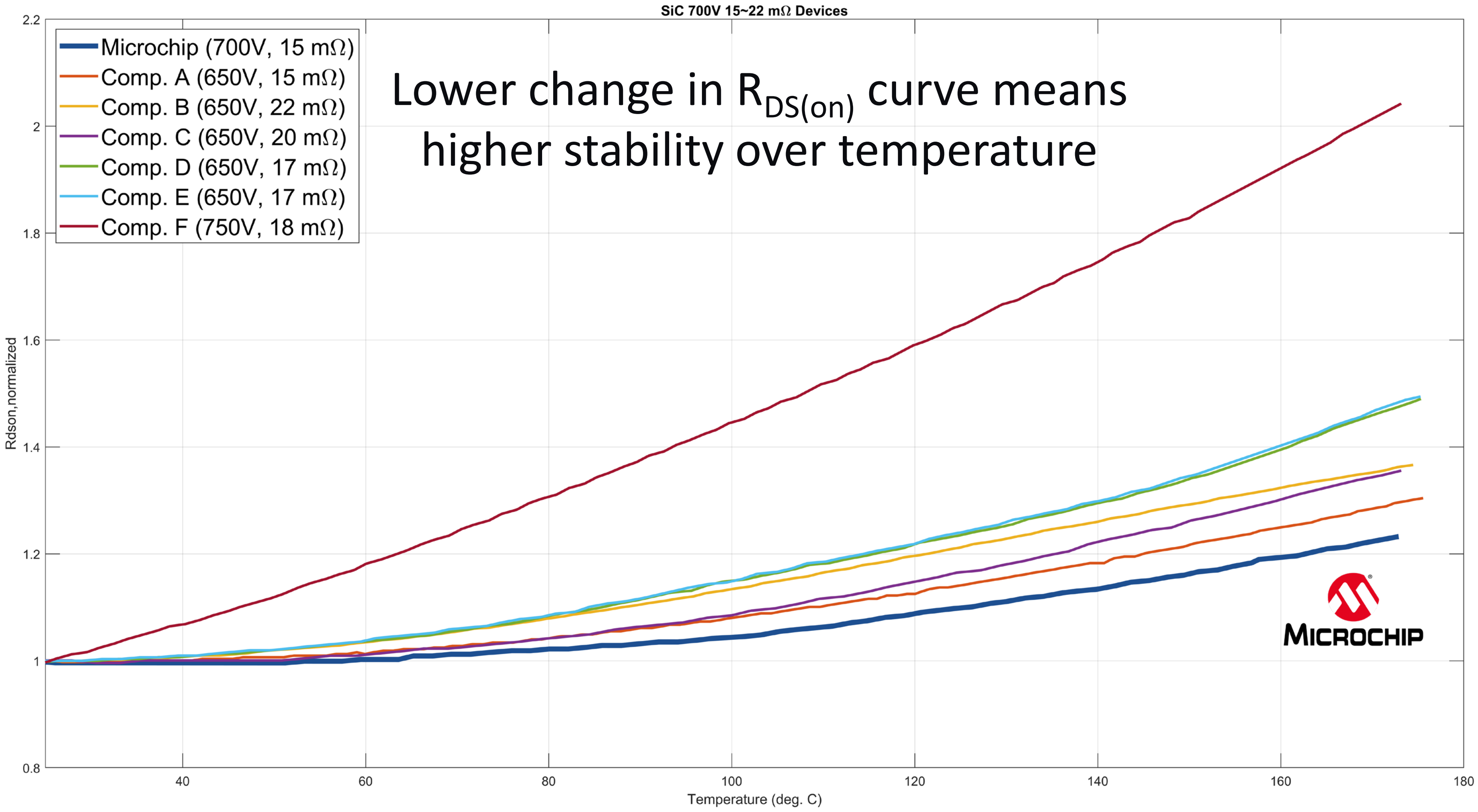
Eon = 8.9 mJ ; Eoff = 5.2 mJ



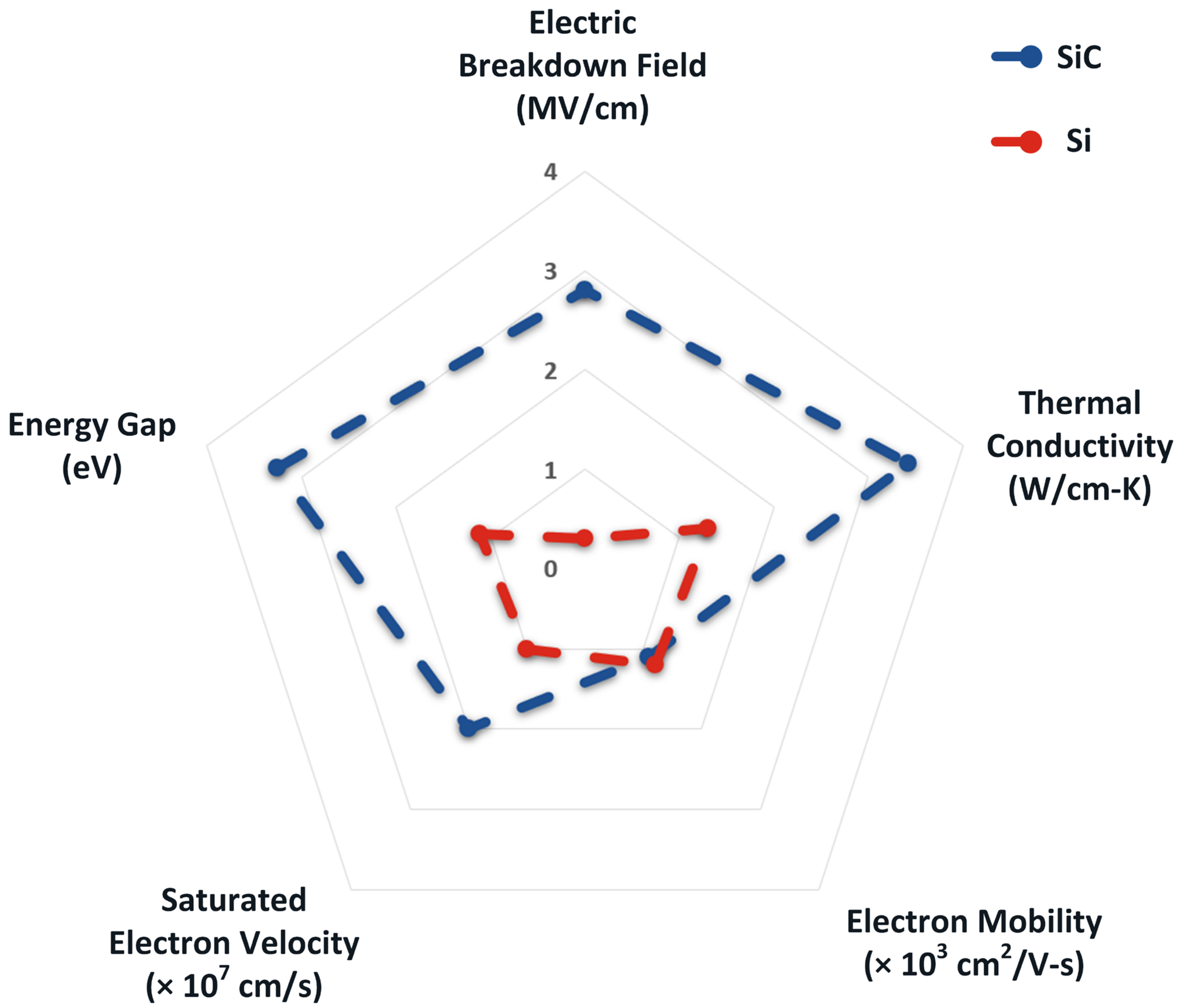
Hard Switching capabilities
540A @ Fsw = 50 kHz
400A @ Fsw = 100 kHz
230A @ Fsw = 200 kHz

Ruggedness | $R_{DS(on)}$ vs. Junction Temperature

Microchip with higher stability over temperature



Si vs SiC Material Properties



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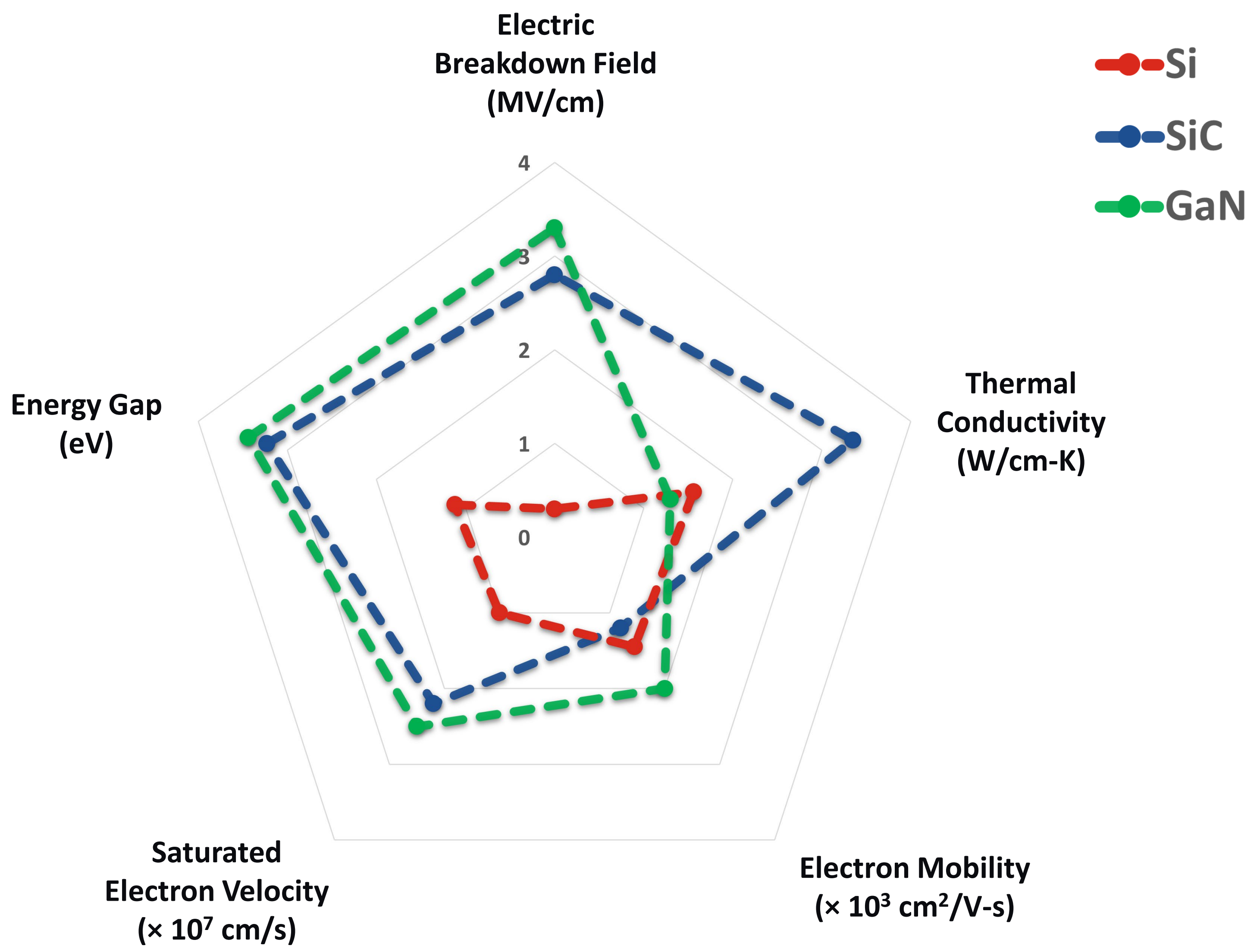
Si vs GaN vs SiC Material Properties



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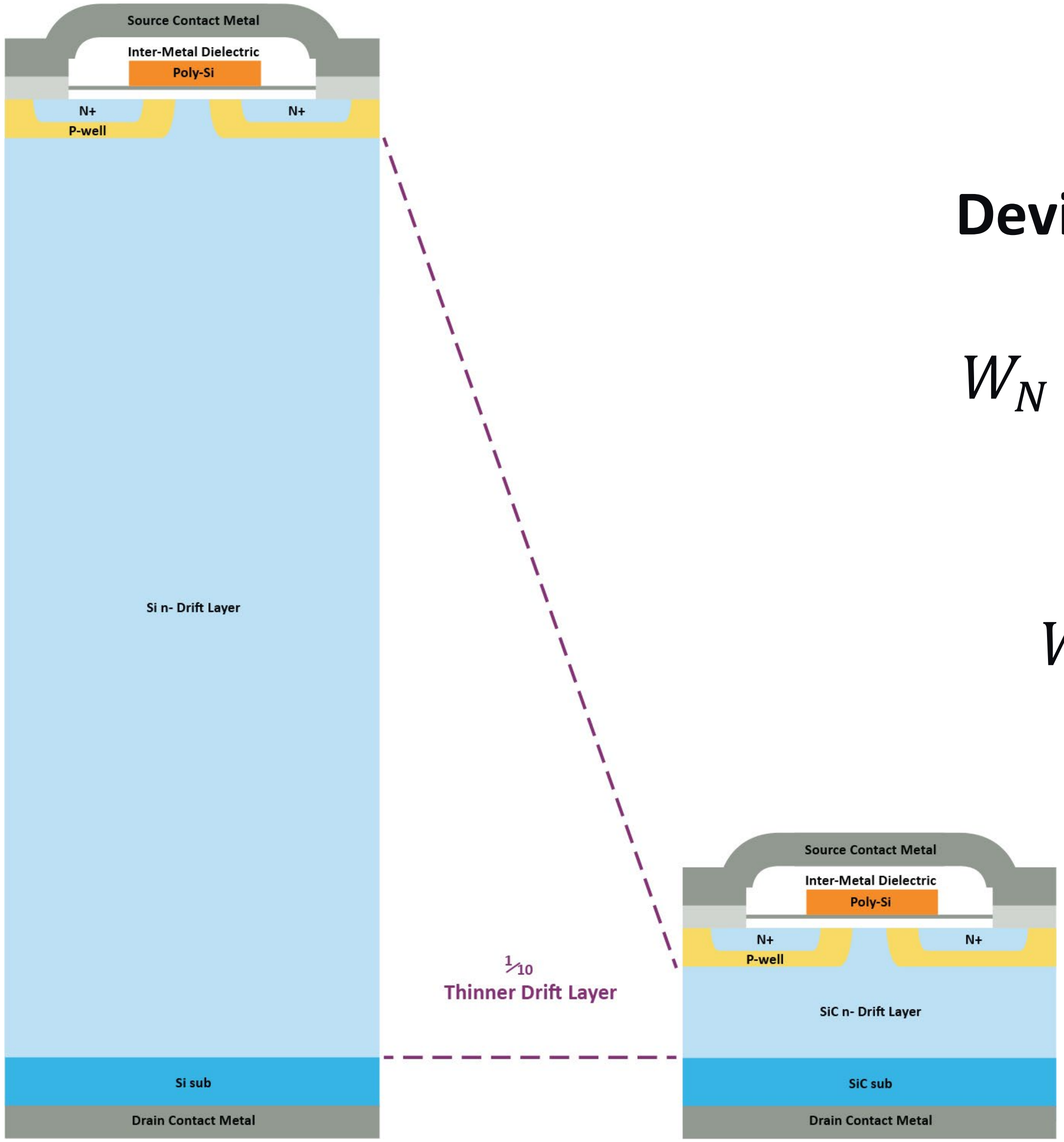
Drift Layer Thickness Comparison



Device Thickness

$$W_N = \left(\frac{3}{2}\right)\left(\frac{V_B}{E_C}\right)$$

$$W_N \propto \frac{1}{E_C}$$

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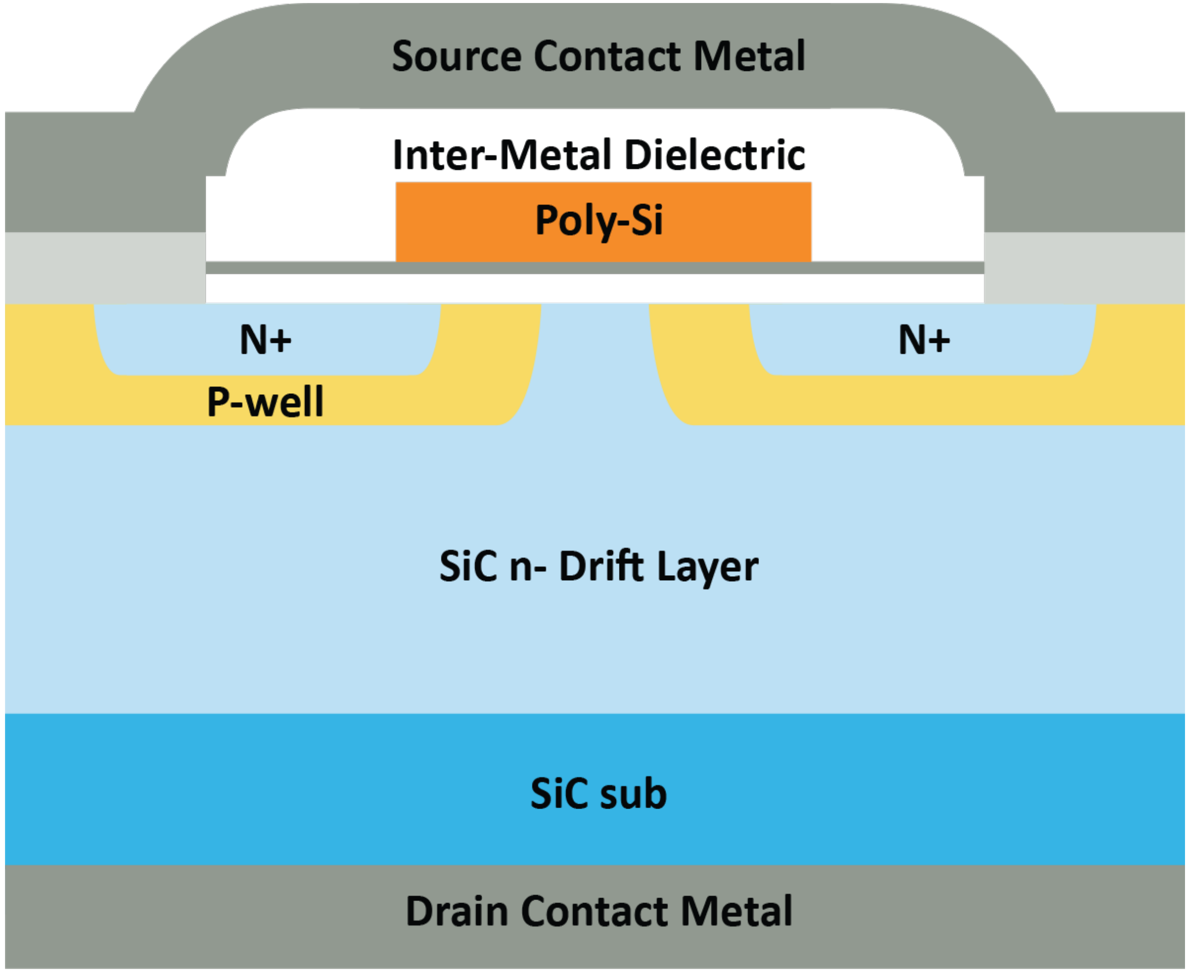
SiC MOSFET Planar (Gate) Drift Resistance

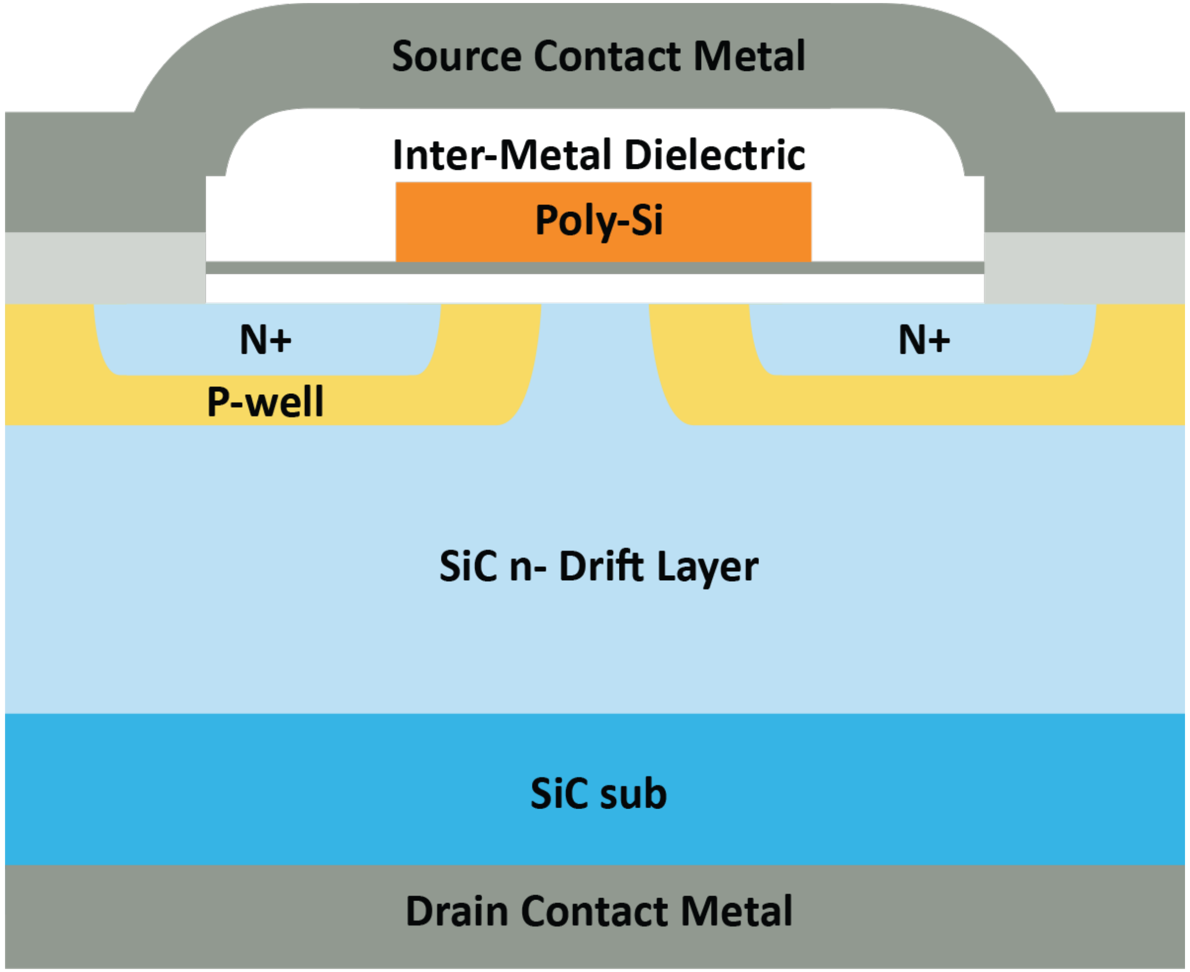


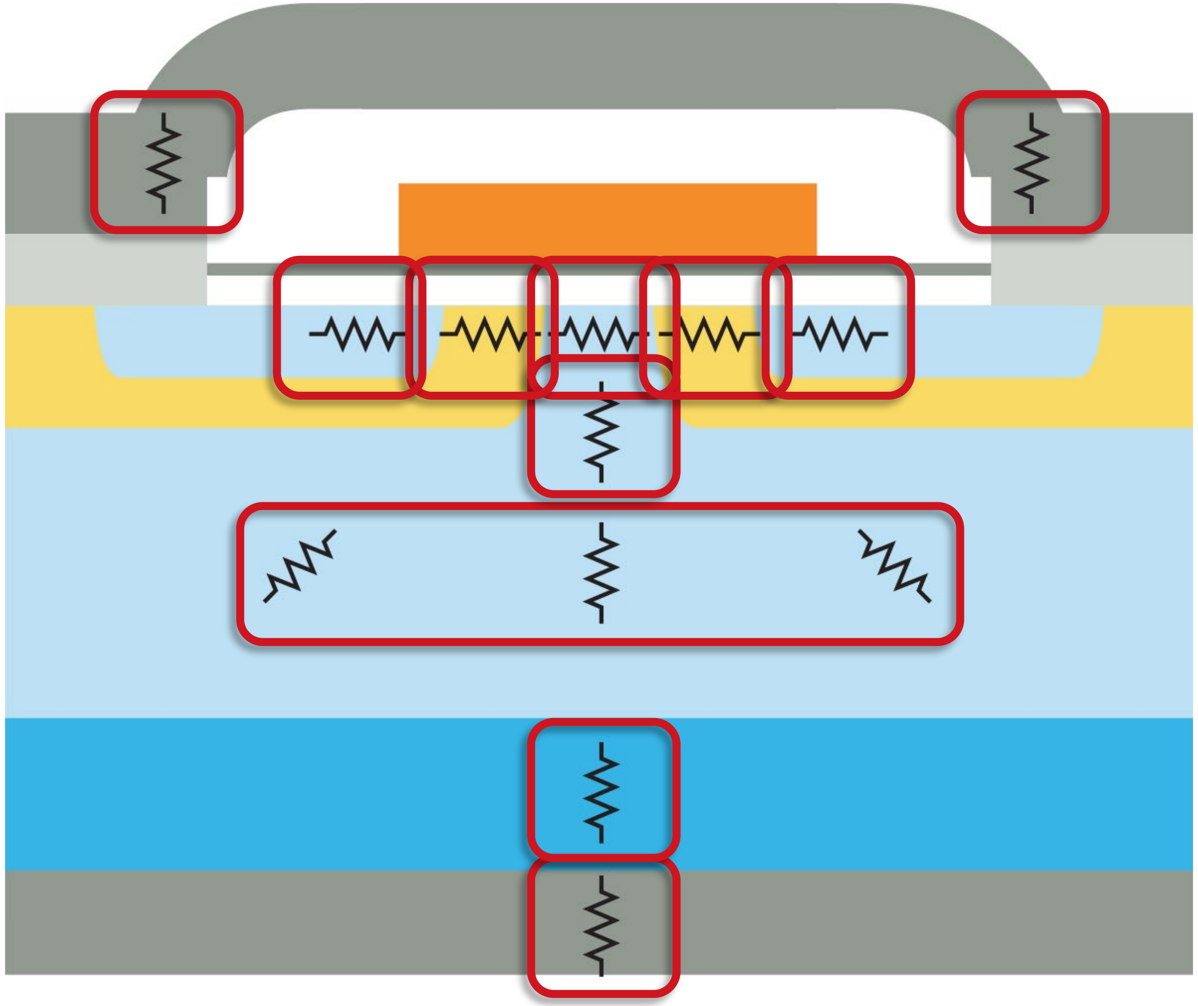
Drift Layer Resistance

$$R_{ON,SP} = \left(\frac{3}{2}\right)^3 \frac{V_B^2}{\mu_N \ \varepsilon_S \ E_C^3}$$

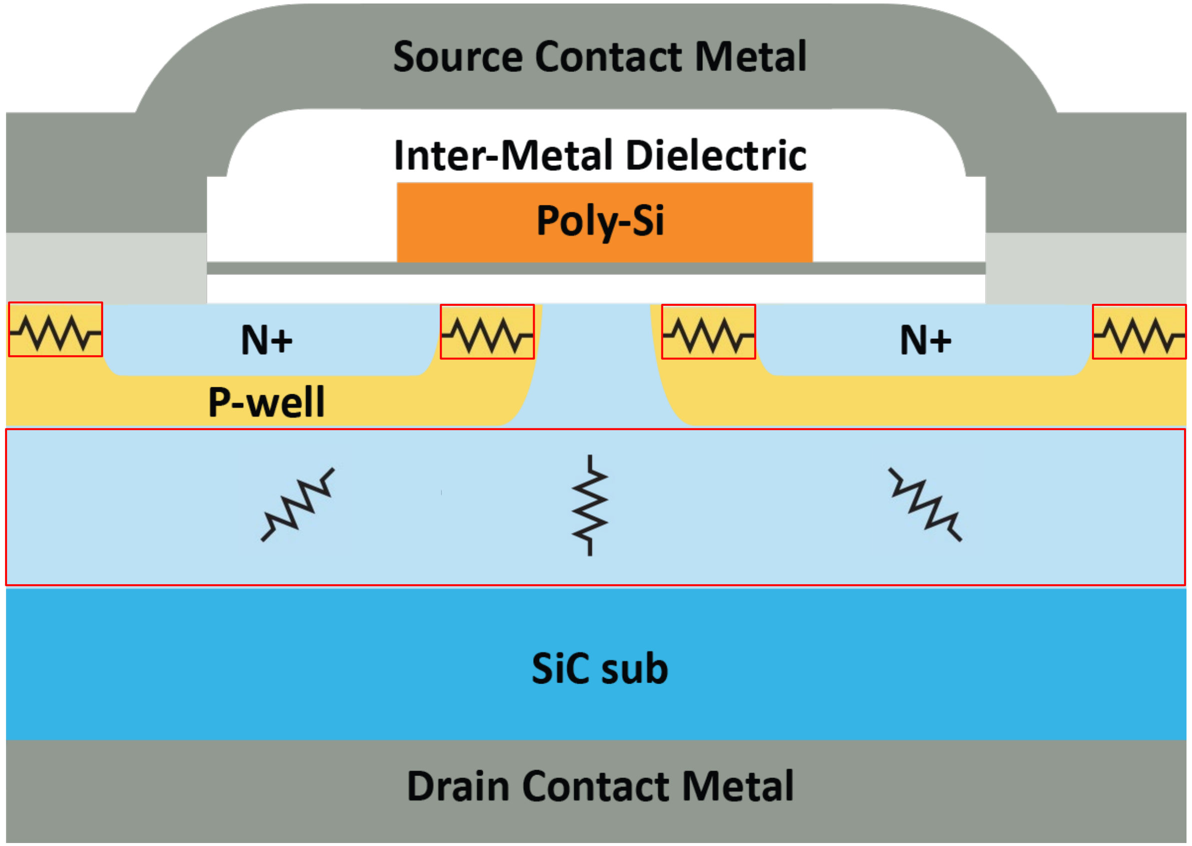
$$R_{ON,SP} \propto \frac{1}{E_C^3}$$

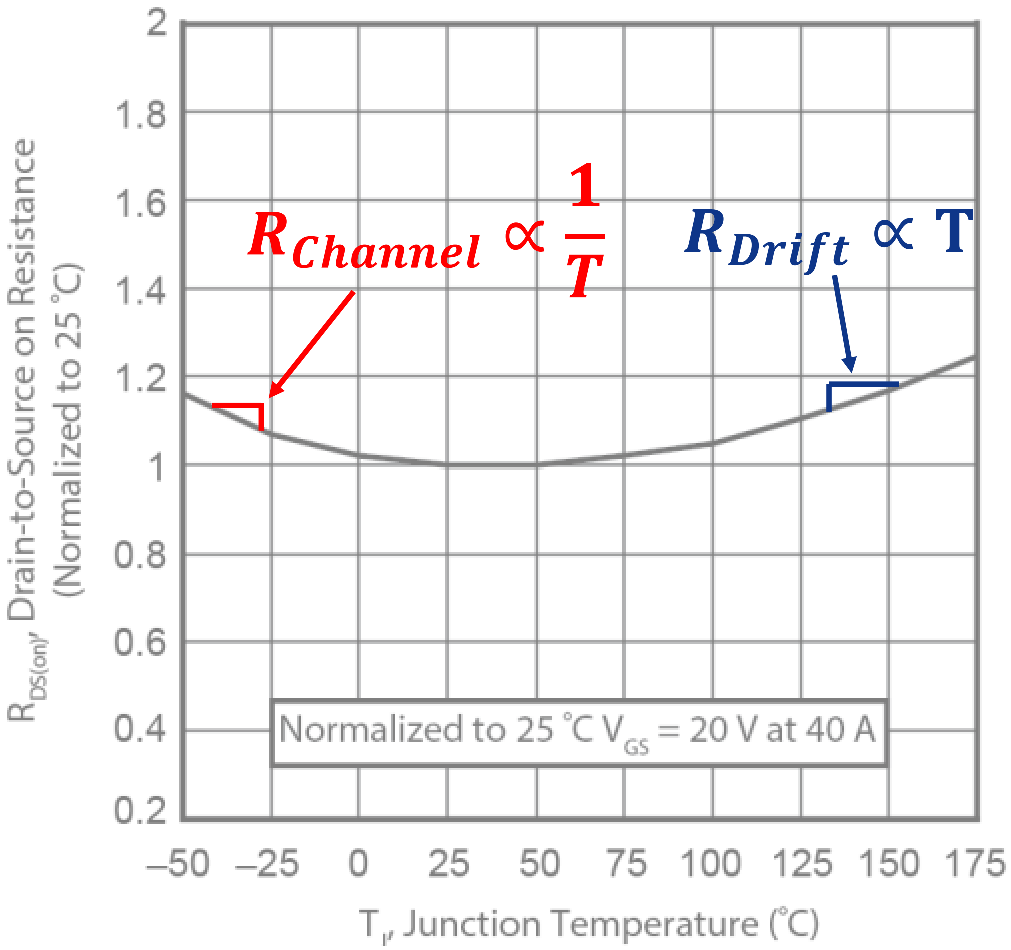
SiC MOSFET Resistance



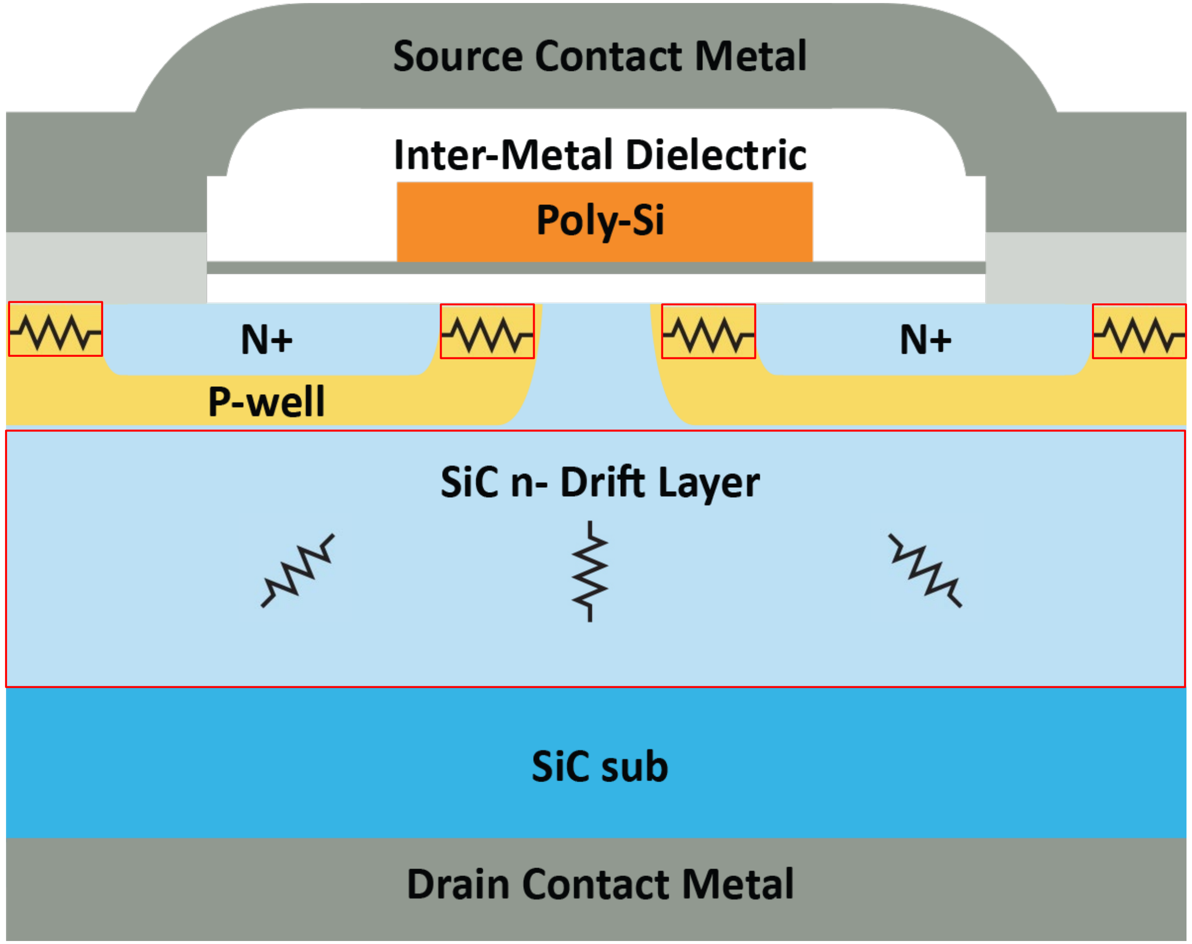


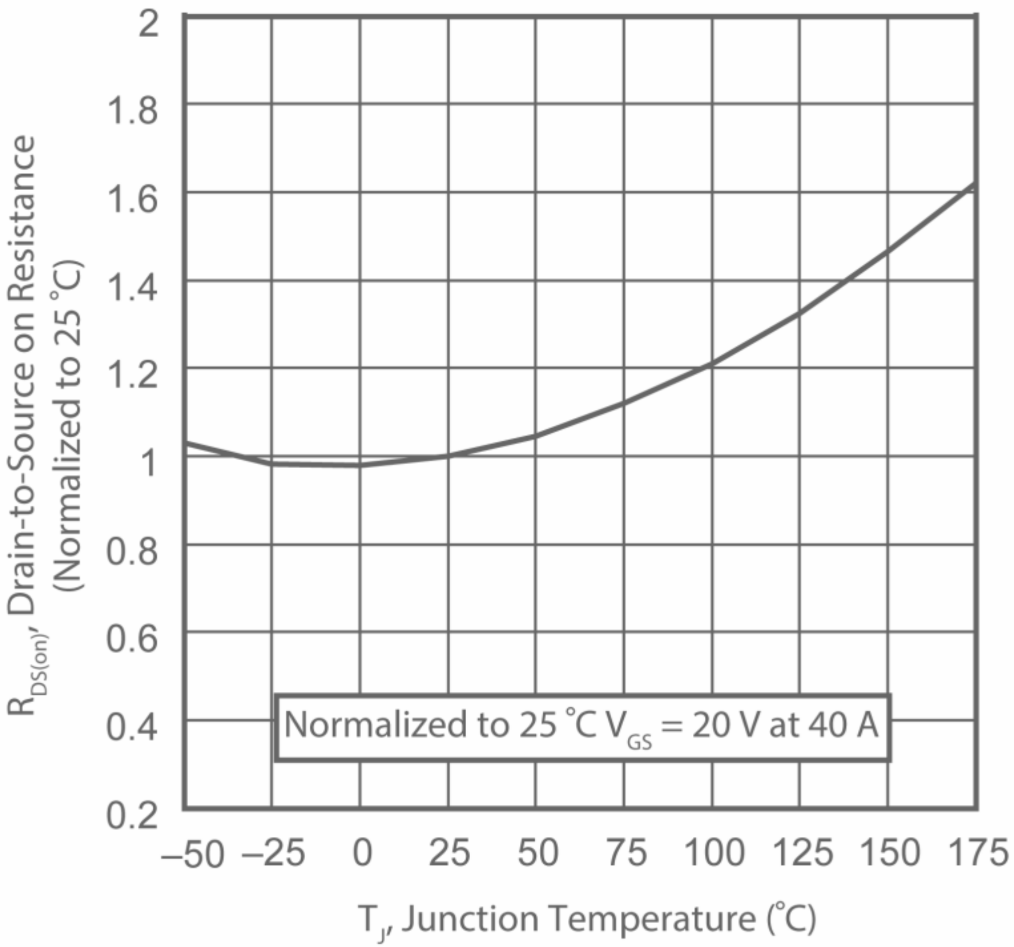
700V SiC MOSFET $R_{DS(on)}$ vs. Temperature



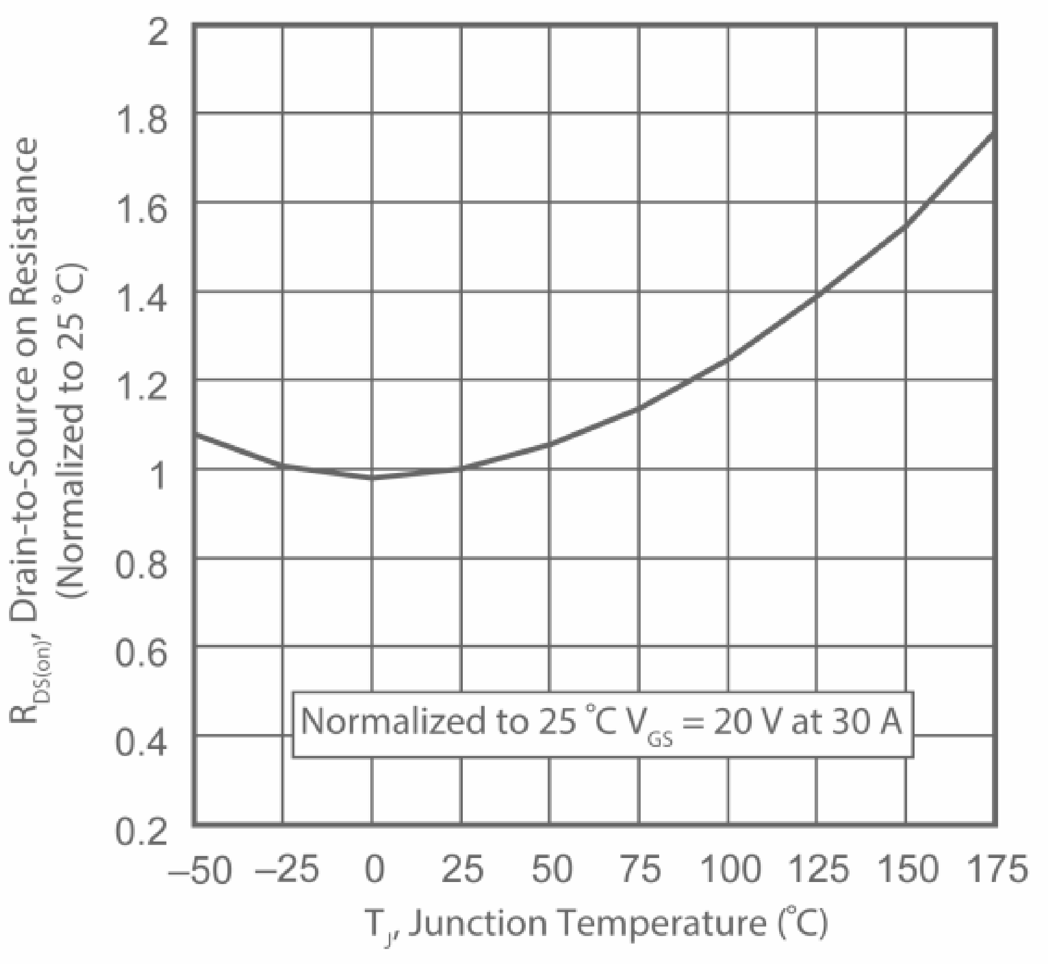


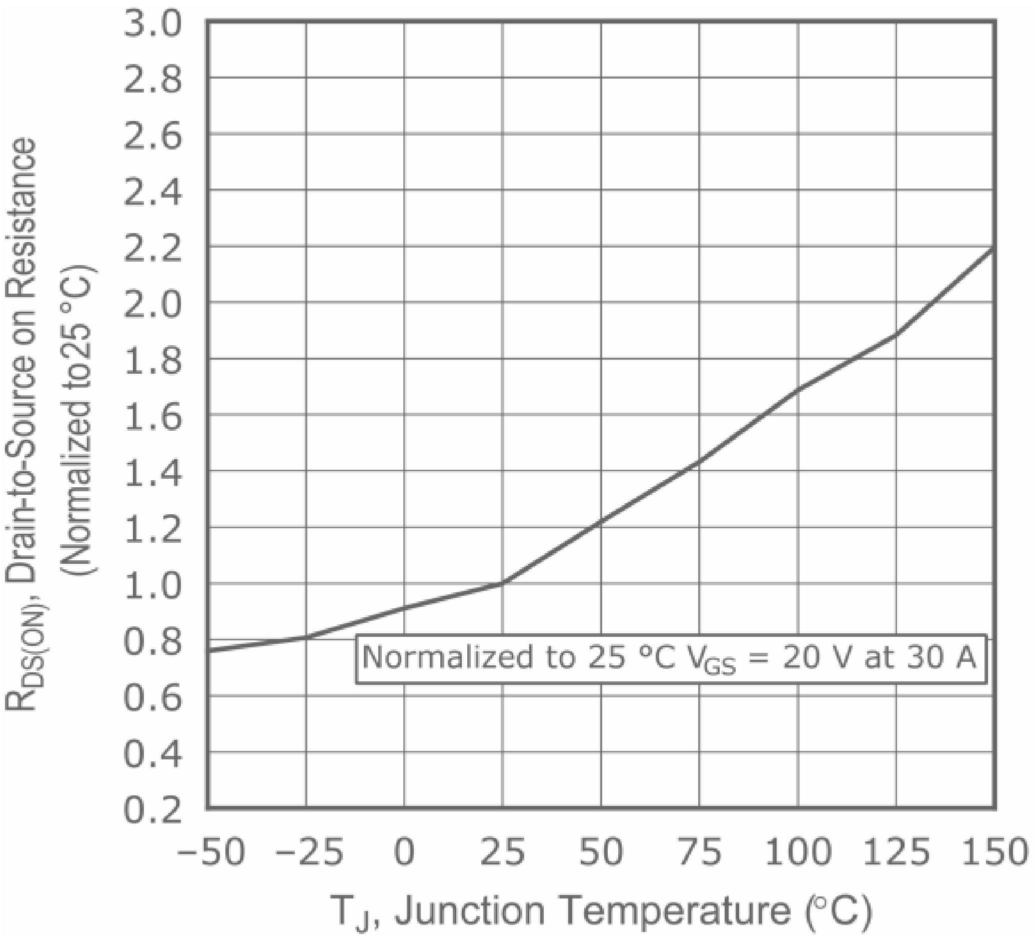
1200V SiC MOSFET $R_{DS(on)}$ vs. Temperature





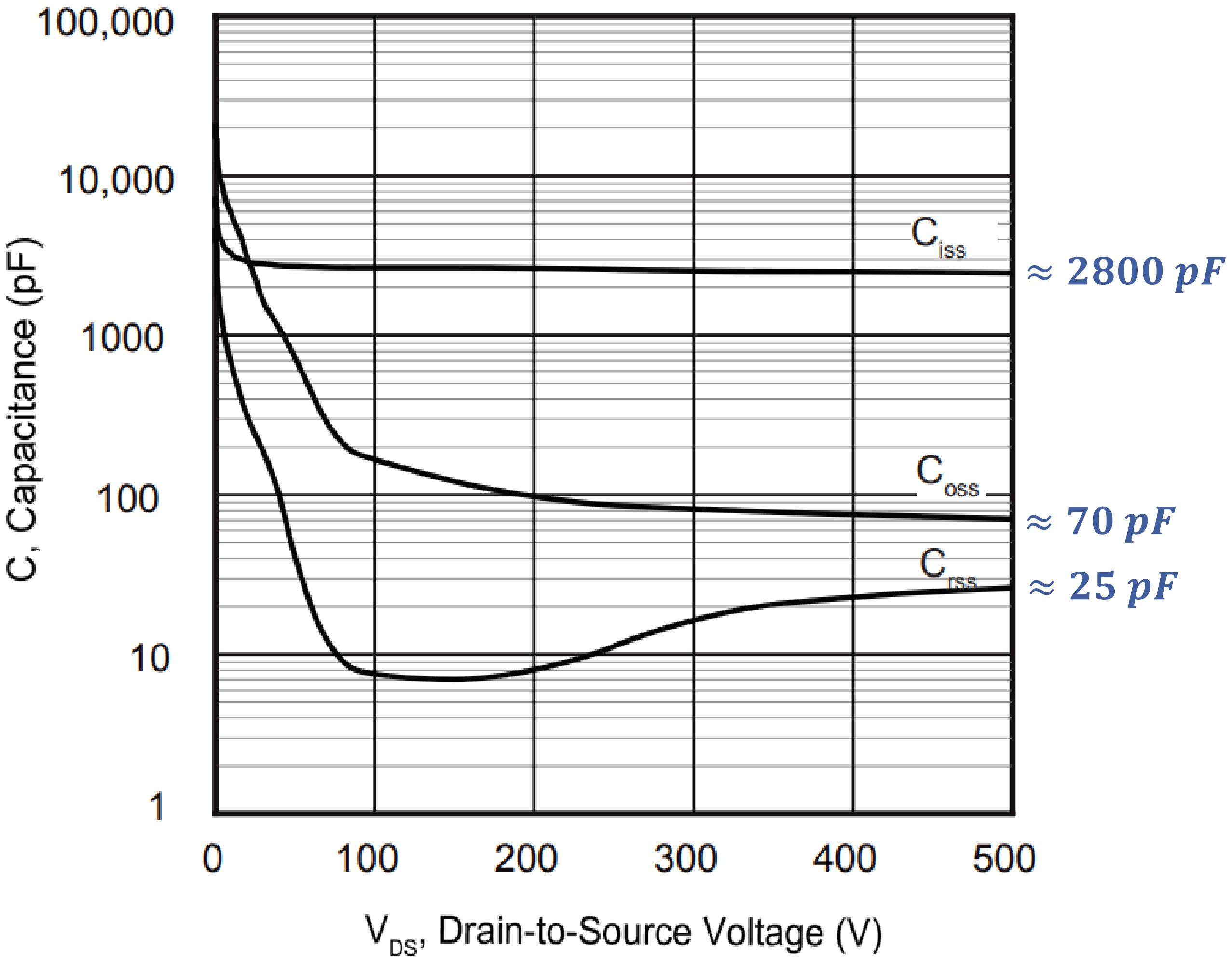
1700V/3.3 kV SiC MOSFET $R_{DS(on)}$ vs. Temperature



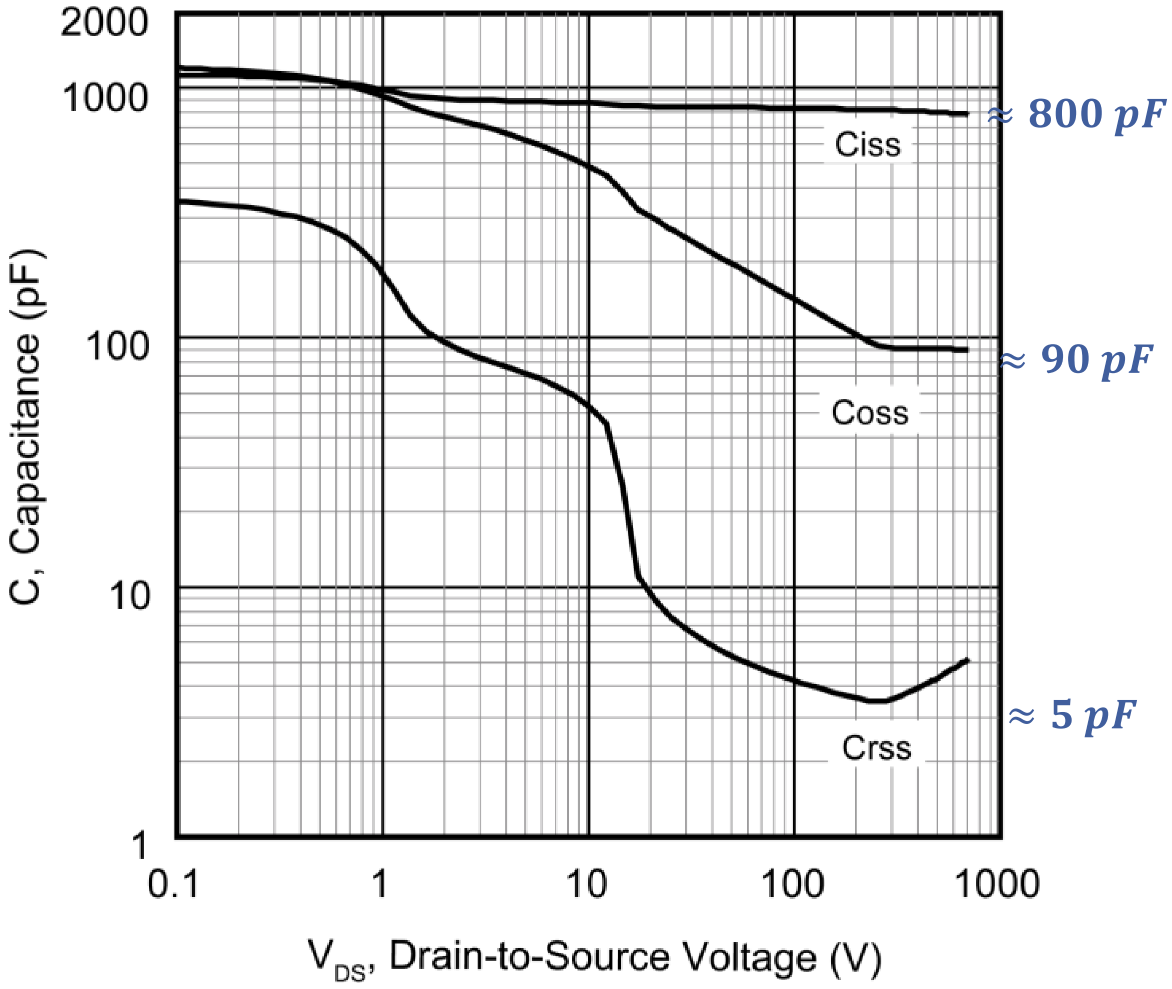


Si vs SiC Device Capacitance Comparison

Si SJ Power MOSFET (99 mΩ, 600V)



SiC Power MOSFET (90 mΩ, 700V)



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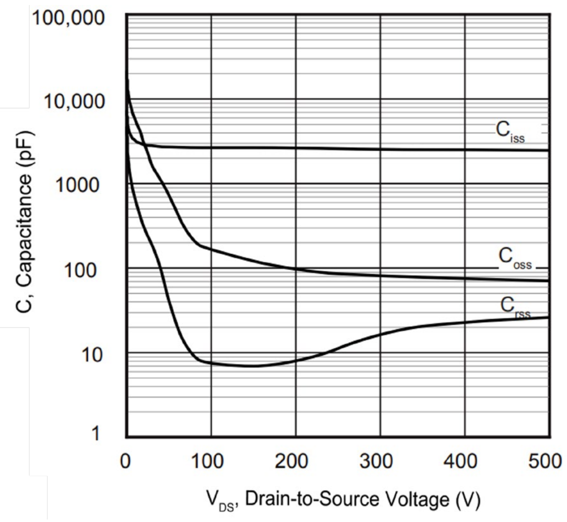
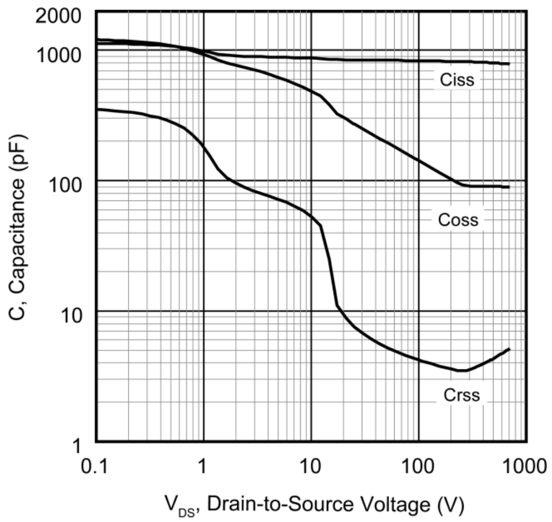
Si vs SiC Device Charge Comparison

Si SJ Power MOSFET (99 mΩ, 600V)



$$Q = \int C \, dv$$

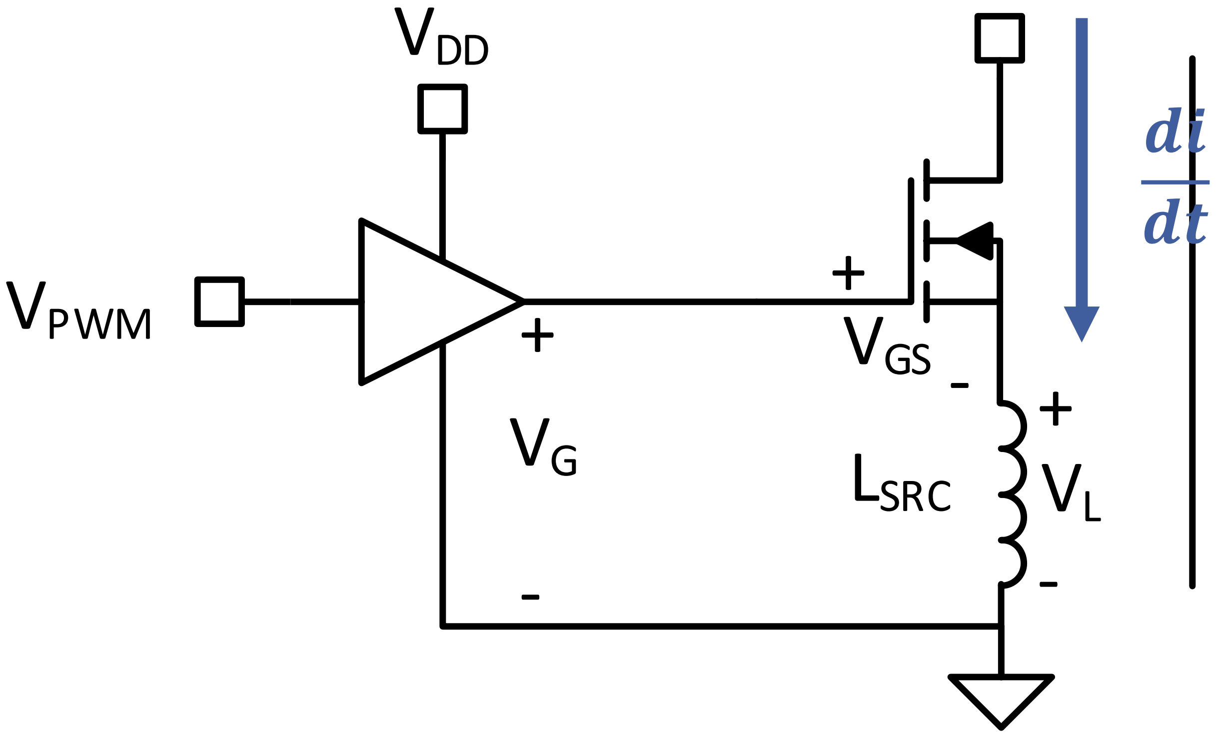
SiC Power MOSFET (90 mΩ, 700V)



Symbol	Values			Unit	Note / Test Condition
	Min.	Typ.	Max.		
Q_{gs}	-	14	-	nC	V_{DD}=480 V, I_D=18.1 A, V_{GS}=0 to 10 V
Q_{gd}	-	61	-		
Q_g	-	119	-		

Q_g	V_{GS} = –5 V/20 V, V_{DD} = 470 V, I_D = 15 A	38	nC
Q_{gs}		10	
Q_{gd}		6	

Effect of Source Inductance



$$V_{GS} = V_G - V_L$$

$$V_L = L_{SRC}\,\frac{di}{dt}$$

$$L_{SRC} = L_{Bond\_Wire} + L_{Lead}$$

Example:

Given $L_{SRC} = 2\,nH$ and $\frac{di}{dt} = 1\,\frac{A}{ns}$

$$V_L = L_{SRC}\,\frac{di}{dt} = 2V$$

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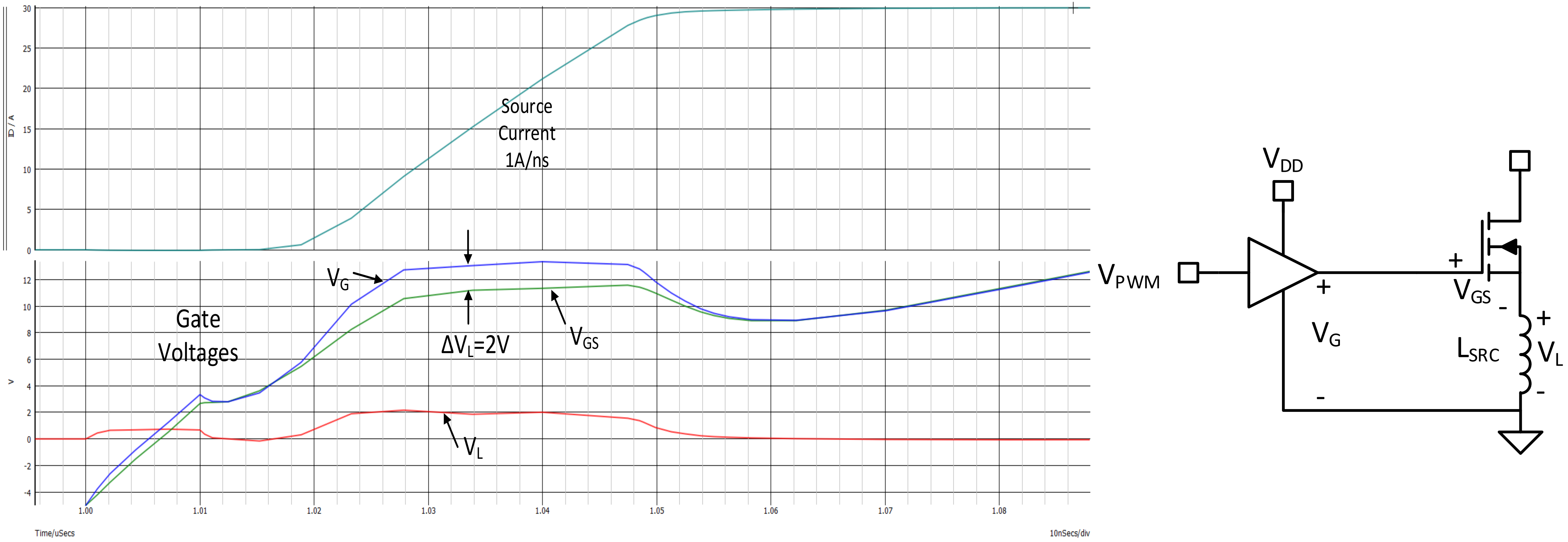
Effect of Source Inductance (SPICE Simulation)

- **Simulation shows the effect of source inductance on the gate-to-source voltage**



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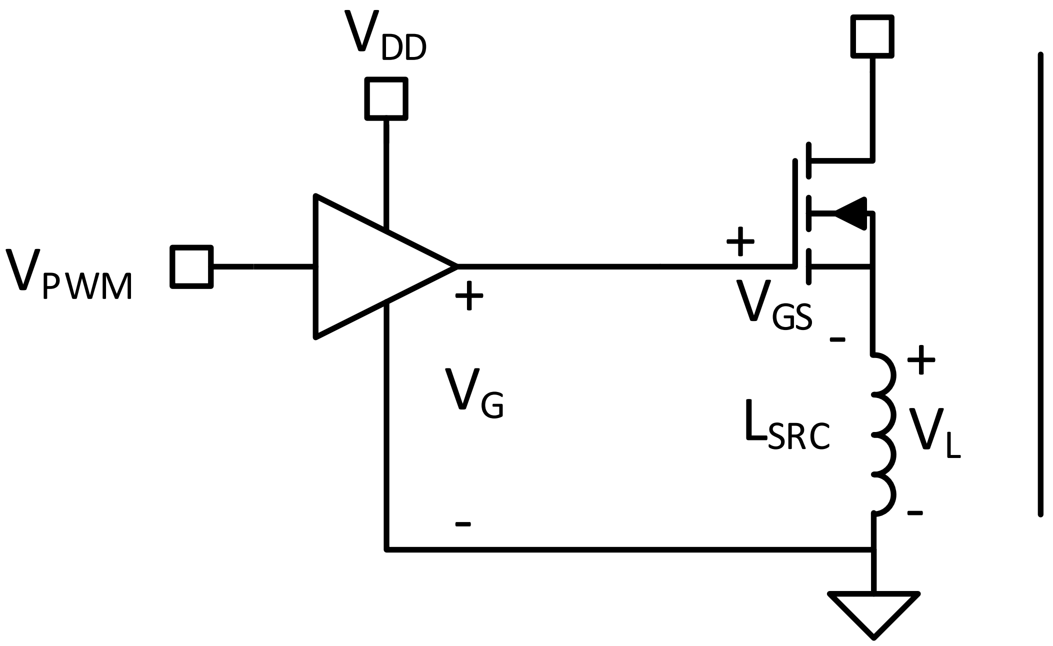
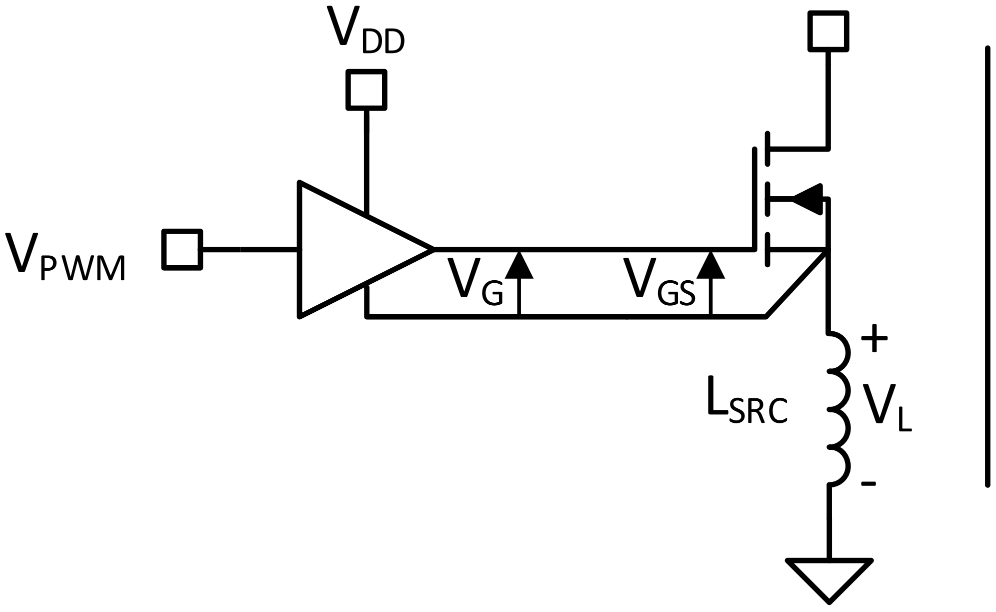
Device Packages with Kelvin Source

- **In a 4-lead package, Kelvin source sense pin is wire bonded directly to the die**
  - Isolates the gate drive return from the inductive effects of the MOSFET source pin and bond wire
  - Faster turn-on and turn-off
  - Greatest improvement is with turn-on



$$V_{GS} = V_G - V_L$$



$$V_{GS} = V_G$$

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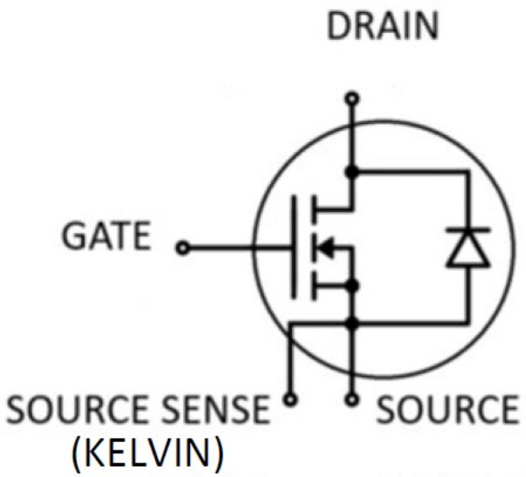
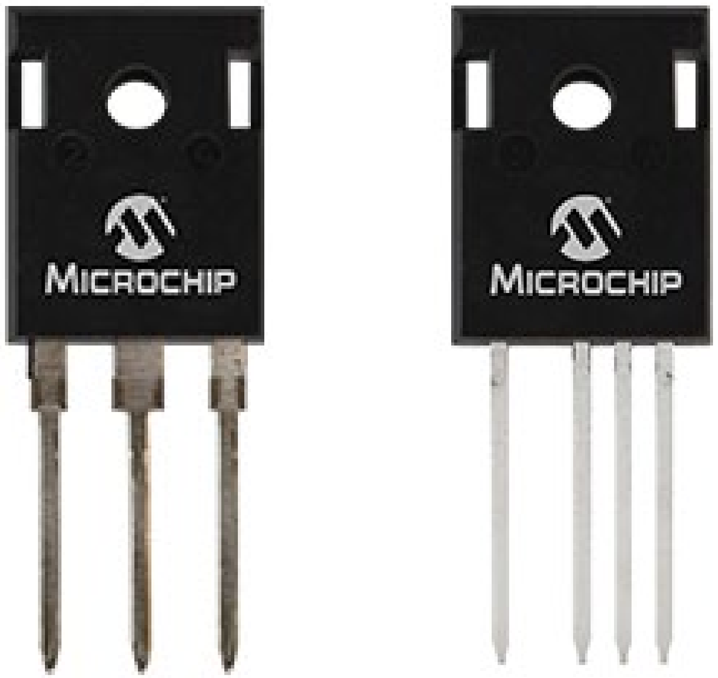
TO-247 3L vs 4L Package

- **Advantages of 4-Lead package**
  - Faster Turn-on and Turn-off Time
    - Lower Power Dissipation
  - Longer Creepage distance between Drain and Source
    - Higher Voltage Operation / Agency Requirements
  - Improved PCB layout for both Power and Gate Drive traces

- **Disadvantage of 4 Lead Package**
  - Faster Turn-on and Turn-off
    - Higher Bus Voltage Overshoot, Ringing and EMI

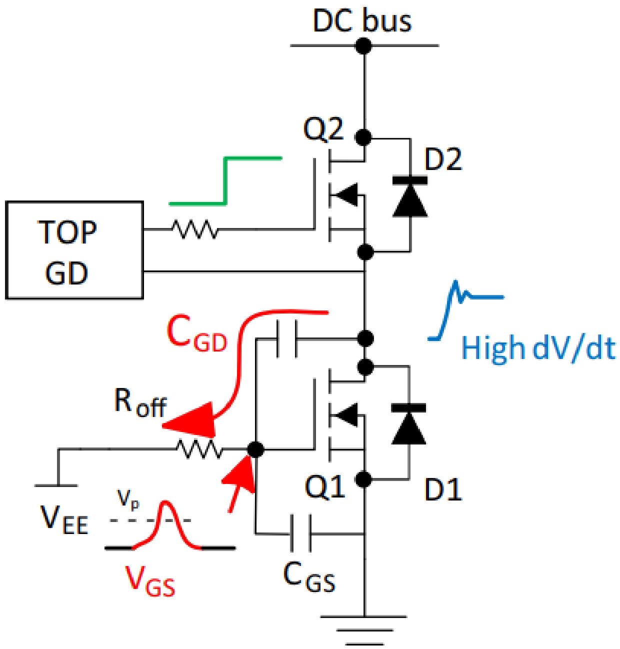


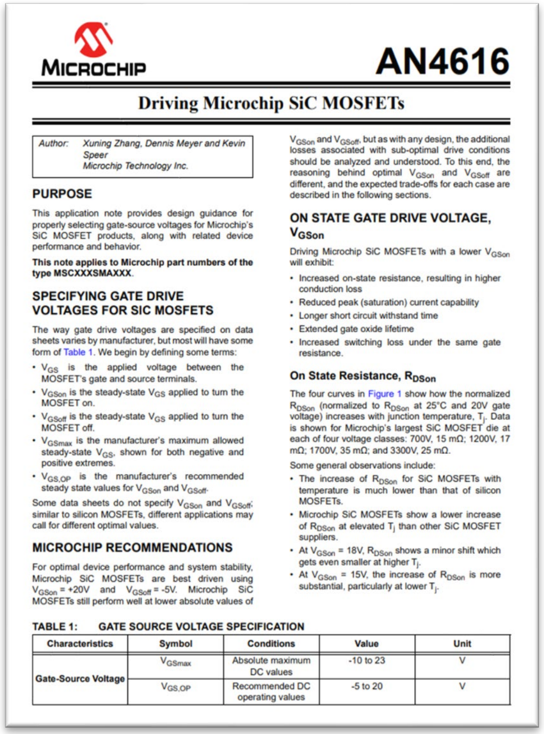


MICROCHIP

Gate Drive Voltages

- $V_{GS_{ON}}$ typically 18V or 20V, some devices in the market at 15V
- $V_{GS_{OFF}}$ typically negative e.g. -3V or -5V, some devices in the market at “0V”
- V_{TH} *or* V_P threshold voltage, negative temperature coefficient





MICROCHIP AN4616

Driving Microchip SiC MOSFETs

Author: Xuning Zhang, Dennis Meyer and Kevin Speer
Microchip Technology Inc.

PURPOSE

This application note provides design guidance for properly selecting gate-source voltages for Microchip's SiC MOSFET products, along with related device performance and behavior.

This note applies to Microchip part numbers of the type MSCXXXSMAXXX.

SPECIFYING GATE DRIVE VOLTAGES FOR SIC MOSFETS

The way gate drive voltages are specified on data sheets varies by manufacturer, but most will have some form of Table 1. We begin by defining some terms:

- V_{GS} is the applied voltage between the MOSFET's gate and source terminals.
- V_{GSon} is the steady-state V_{GS} applied to turn the MOSFET on.
- V_{GSoff} is the steady-state V_{GS} applied to turn the MOSFET off.
- V_{GSmax} is the manufacturer's maximum allowed steady-state V_{GS}, shown for both negative and positive extremes.
- $V_{GS,OP}$ is the manufacturer's recommended steady state values for V_{GSon} and V_{GSoff}.

Some data sheets do not specify V_{GSon} and V_{GSoff}; similar to silicon MOSFETs, different applications may call for different optimal values.

MICROCHIP RECOMMENDATIONS

For optimal device performance and system stability, Microchip SiC MOSFETs are best driven using V_{GSon} = +20V and V_{GSoff} = -5V. Microchip SiC MOSFETs still perform well at lower absolute values of V_{GSon} and V_{GSoff}, but as with any design, the additional losses associated with sub-optimal drive conditions should be analyzed and understood. To this end, the reasoning behind optimal V_{GSon} and V_{GSoff} are different, and the expected trade-offs for each case are described in the following sections.

ON STATE GATE DRIVE VOLTAGE, V_{GSon}

Driving Microchip SiC MOSFETs with a lower V_{GSon} will exhibit:

- Increased on-state resistance, resulting in higher conduction loss
- Reduced peak (saturation) current capability
- Longer short circuit withstand time
- Extended gate oxide lifetime
- Increased switching loss under the same gate resistance.

On State Resistance, R_{DSon}

The four curves in Figure 1 show how the normalized R_{DSon} (normalized to R_{DSon} at 25°C and 20V gate voltage) increases with junction temperature, T_j. Data is shown for Microchip's largest SiC MOSFET die at each of four voltage classes: 700V, 15 mΩ; 1200V, 17 mΩ; 1700V, 35 mΩ; and 3300V, 25 mΩ.

Some general observations include:

- The increase of R_{DSon} for SiC MOSFETs with temperature is much lower than that of silicon MOSFETs.
- Microchip SiC MOSFETs show a lower increase of R_{DSon} at elevated T_j than other SiC MOSFET suppliers.
- At V_{GSon} = 18V, R_{DSon} shows a minor shift which gets even smaller at higher T_j.
- At V_{GSon} = 15V, the increase of R_{DSon} is more substantial, particularly at lower T_j.

TABLE 1: GATE SOURCE VOLTAGE SPECIFICATION

Characteristics	Symbol	Conditions	Value	Unit
Gate-Source Voltage	V_{GSmax}	Absolute maximum DC values	-10 to 23	V
	$V_{GS,OP}$	Recommended DC operating values	-5 to 20	V

[Driving mSiC™ MOSFETs (microchip.com)](microchip.com)

MICROCHIP

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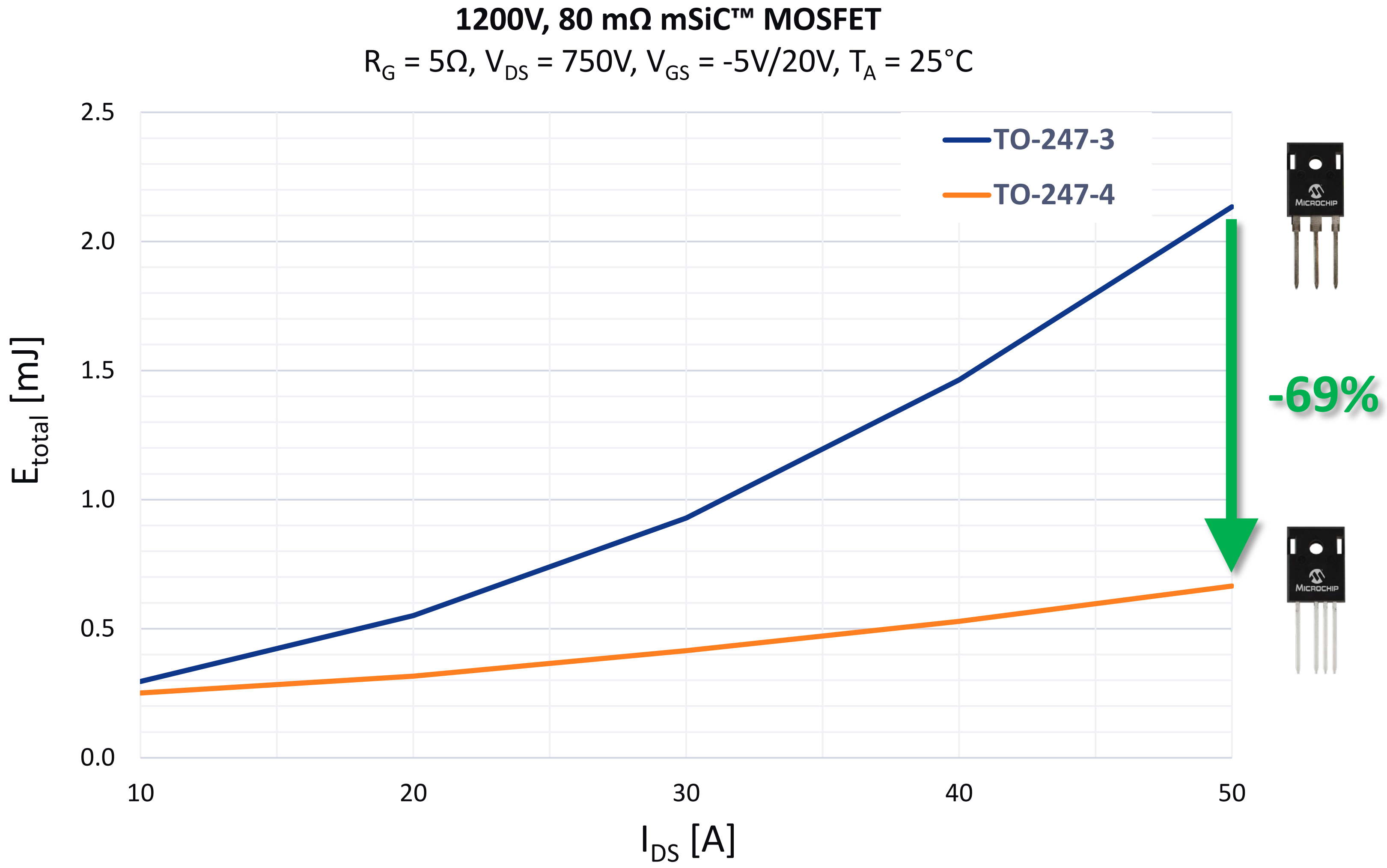
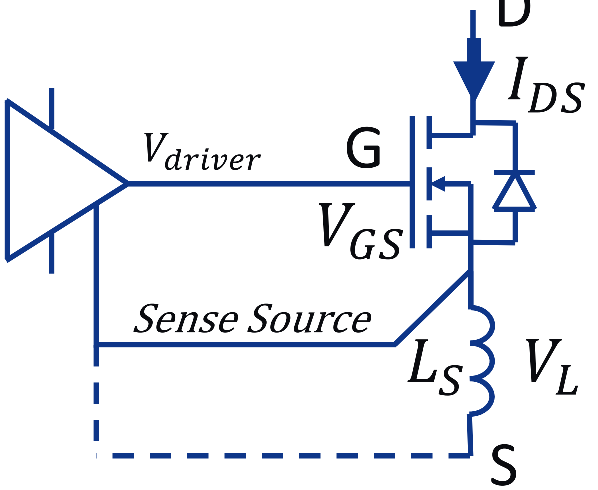
mSiC™ Products | Lower Switching Losses

Source sense pin for faster turn on and lower switching losses

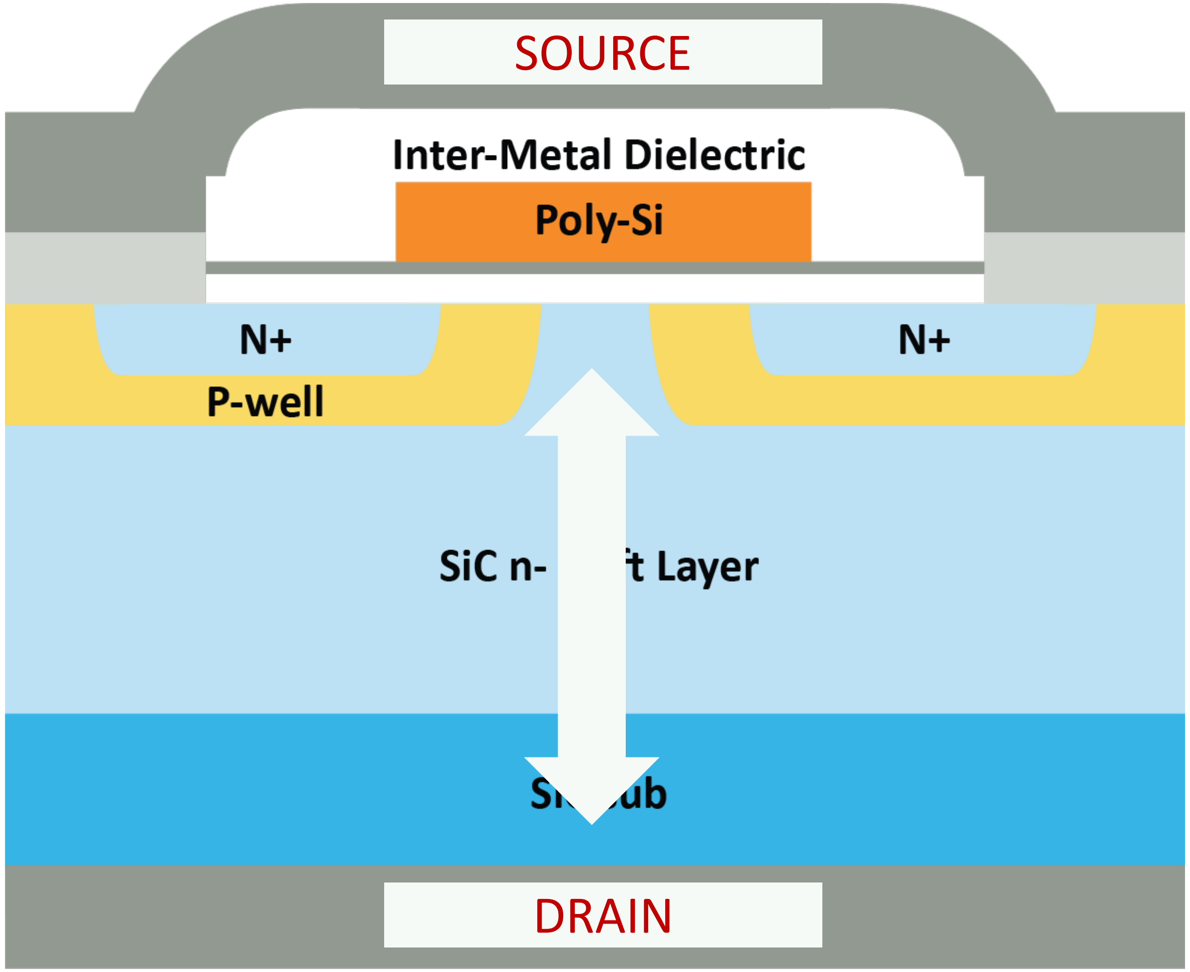




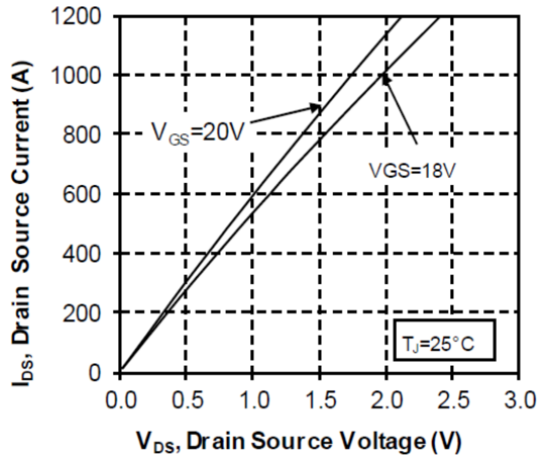
$$V_{GS} = V_{driver} - L_s \frac{dI_{DS}}{dt}$$

$$V_{GS} = V_{driver} - V_L$$

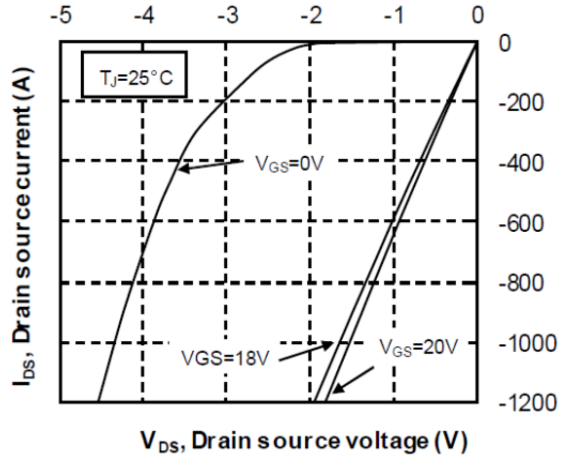
Channel Conduction: 1st & 3rd Quad. Operation



Output Characteristics, T_J = 25 °C



3rd Quadrant Characteristics, T_J=25 °C



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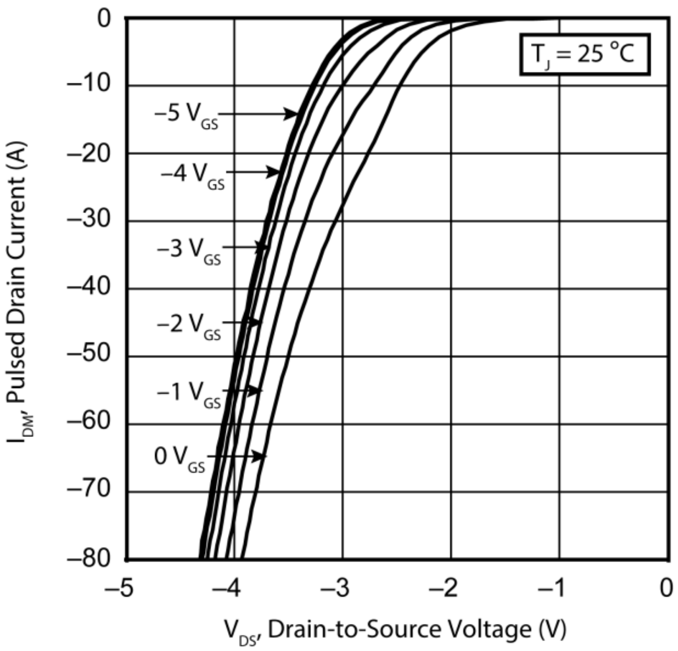
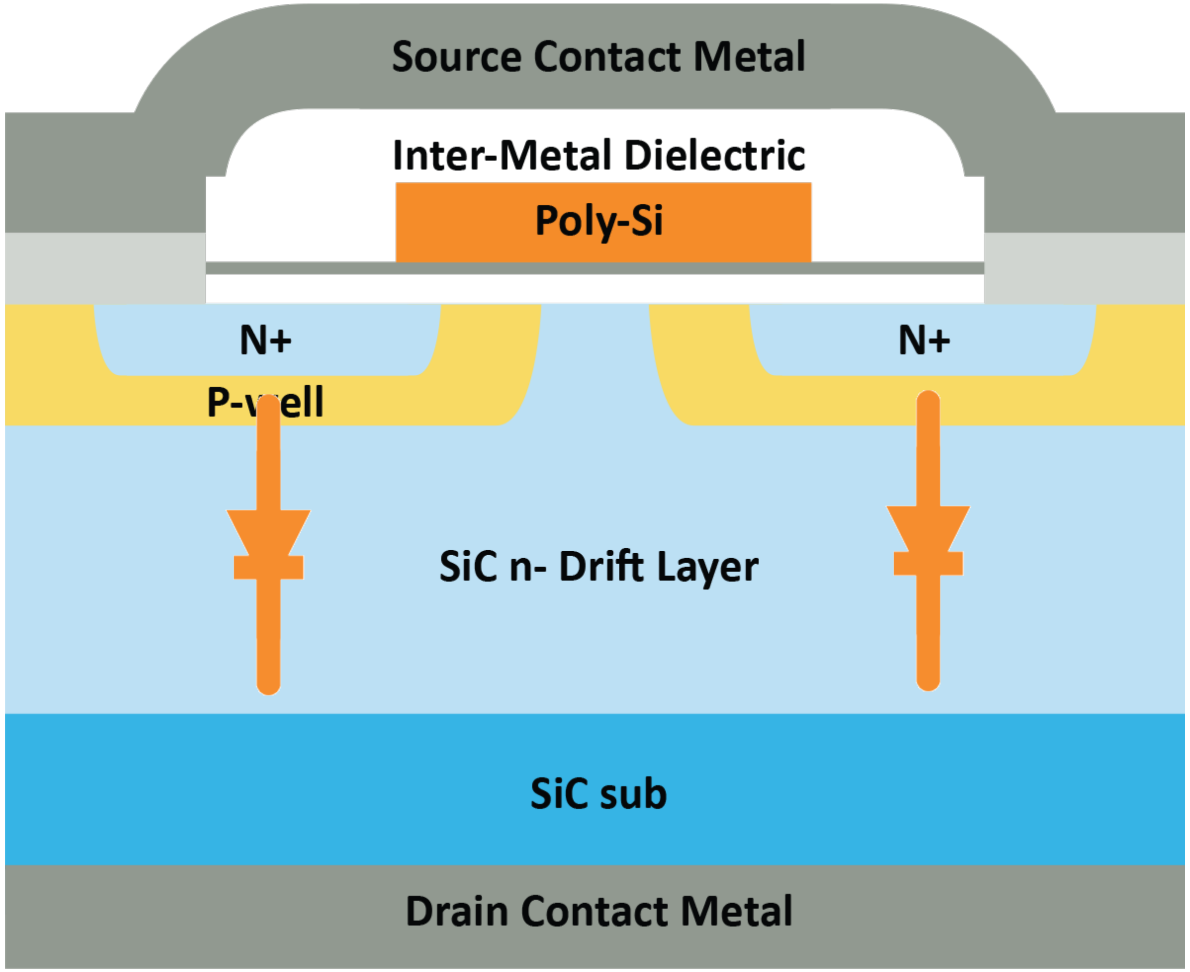
SiC MOSFET Body Diode



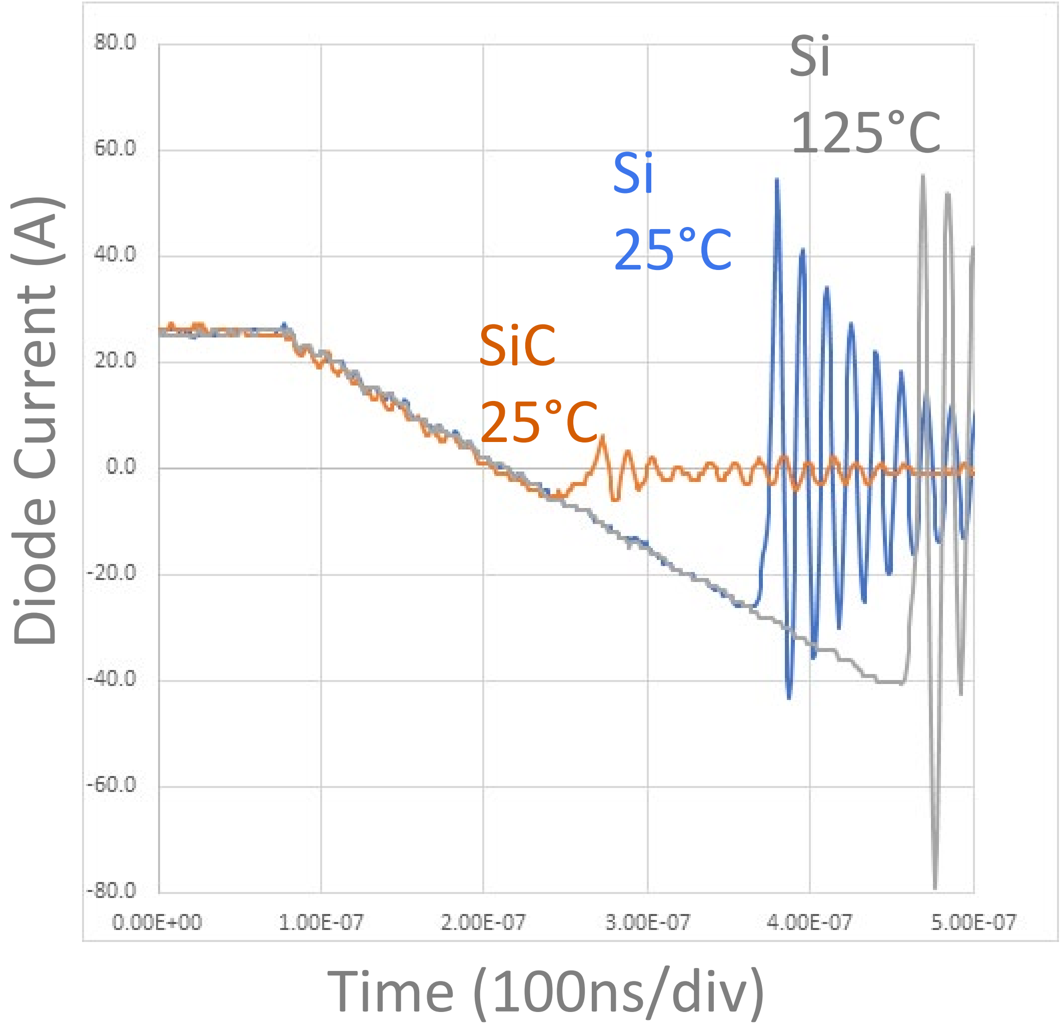


Si vs. SiC Body Diode Reverse Recovery

- **Switching is 25A forward, 200 A/uS rate**
- **SiC device shows no significant temperature dependence at 200 A/uS.**
  - At 1500-2000 A/uS there will be about a 20% increase over 25C.

400V bus voltage, 100 kHz switching frequency

	$I_{RR,PK}$ (A)	t_{rr} (ns)	Q_{rr} (nC)	E_{rr} (µJ)	P_{rr} (W)
Si (25°C)	23	175	2188	875	87.5
Si (125°C)	40	270	5400	2160	216
SiC (25°C)	4	60	120	48	4.8



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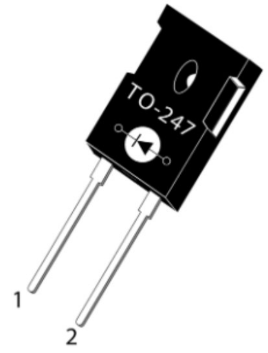
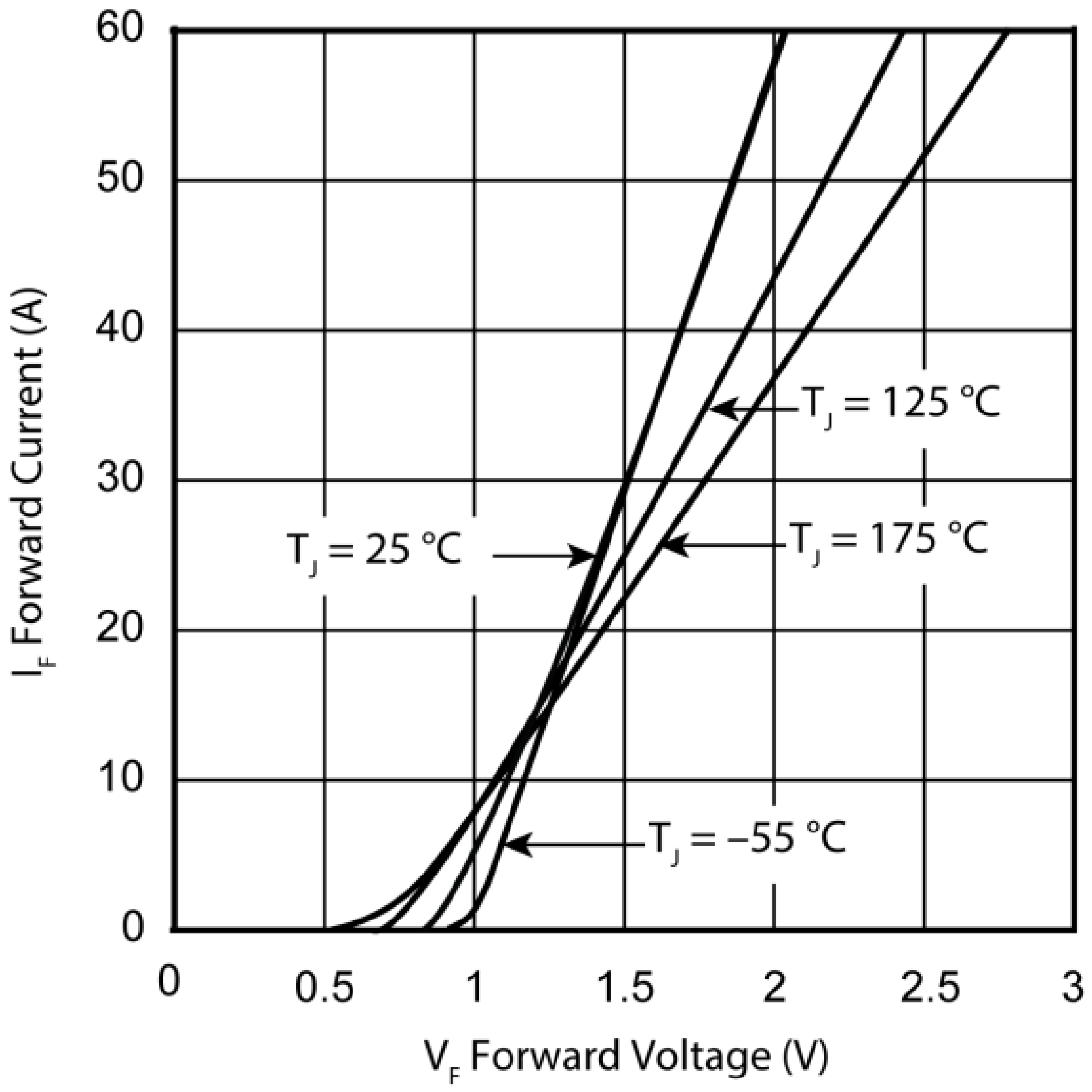
SiC Schottky Barrier Diode (SBD)

- Low forward voltage
- Low leakage current
- No reverse recovery





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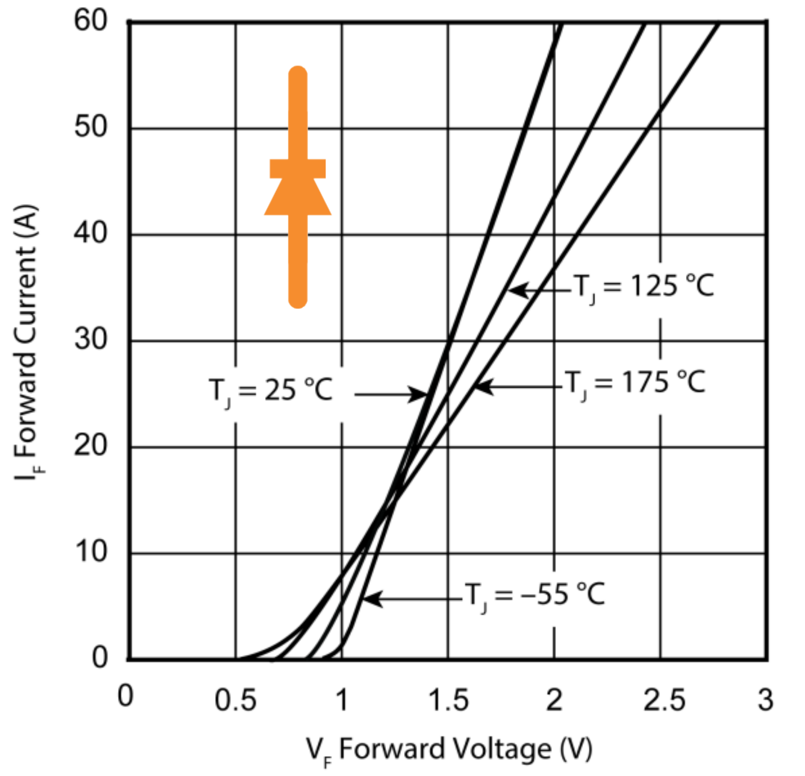
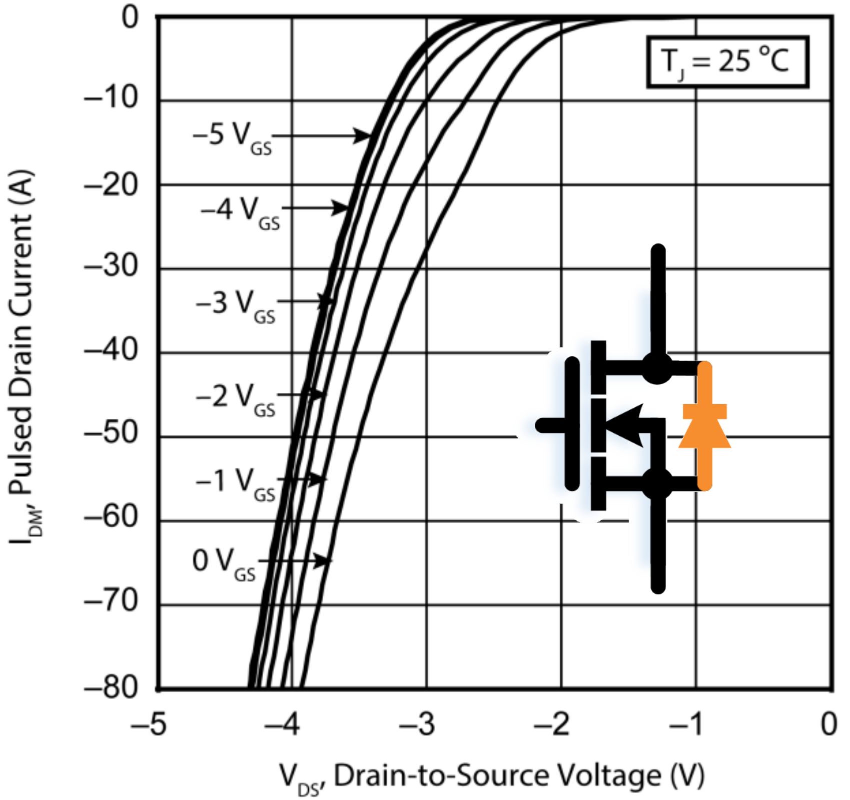
SiC SBD and SiC Body Diode Comparison

SiC SBD



$$V_F \propto T$$

SiC Body Diode



$$V_F \propto \frac{1}{T}$$

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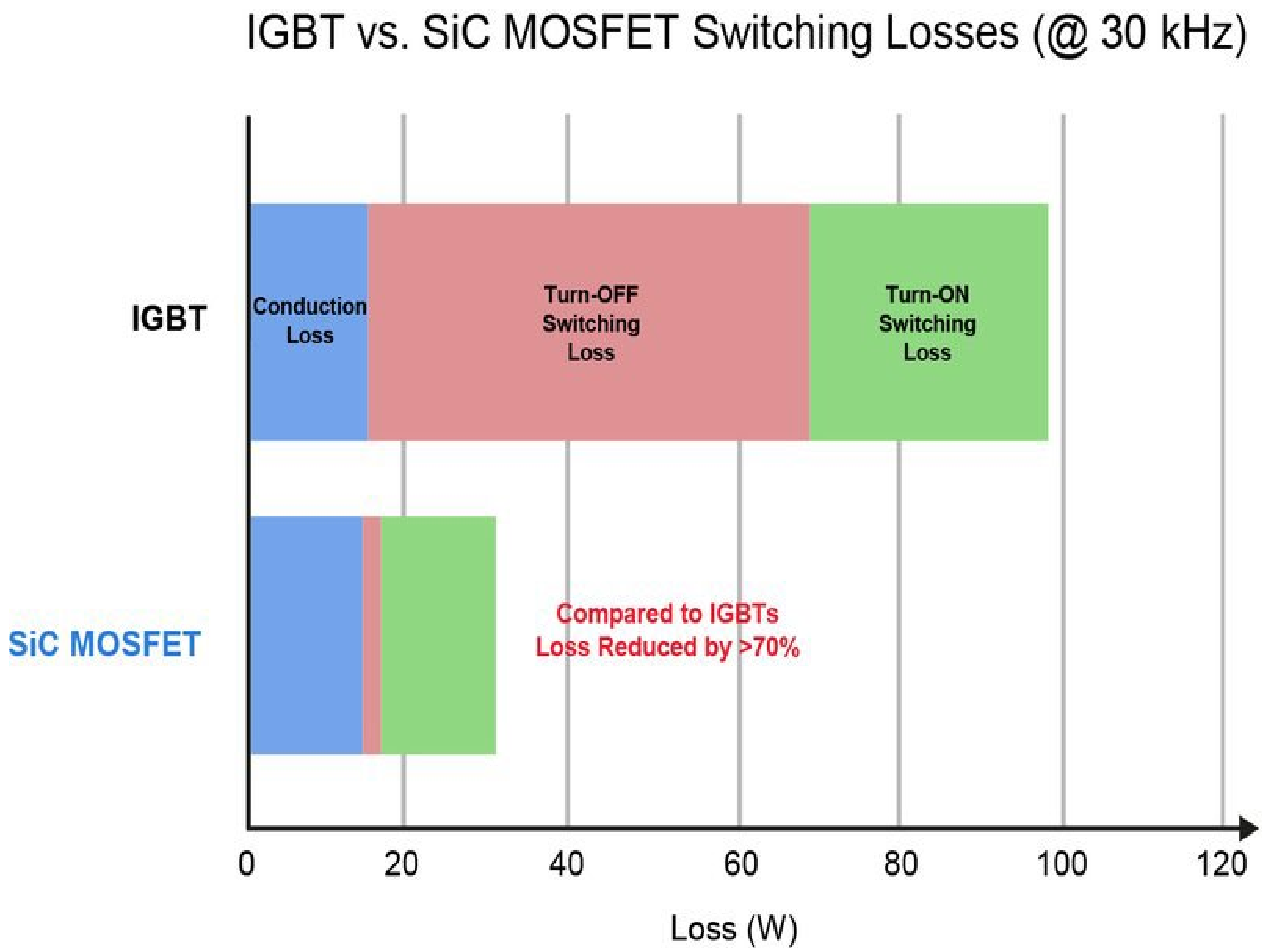
SiC Benefits Compared To Si IGBT



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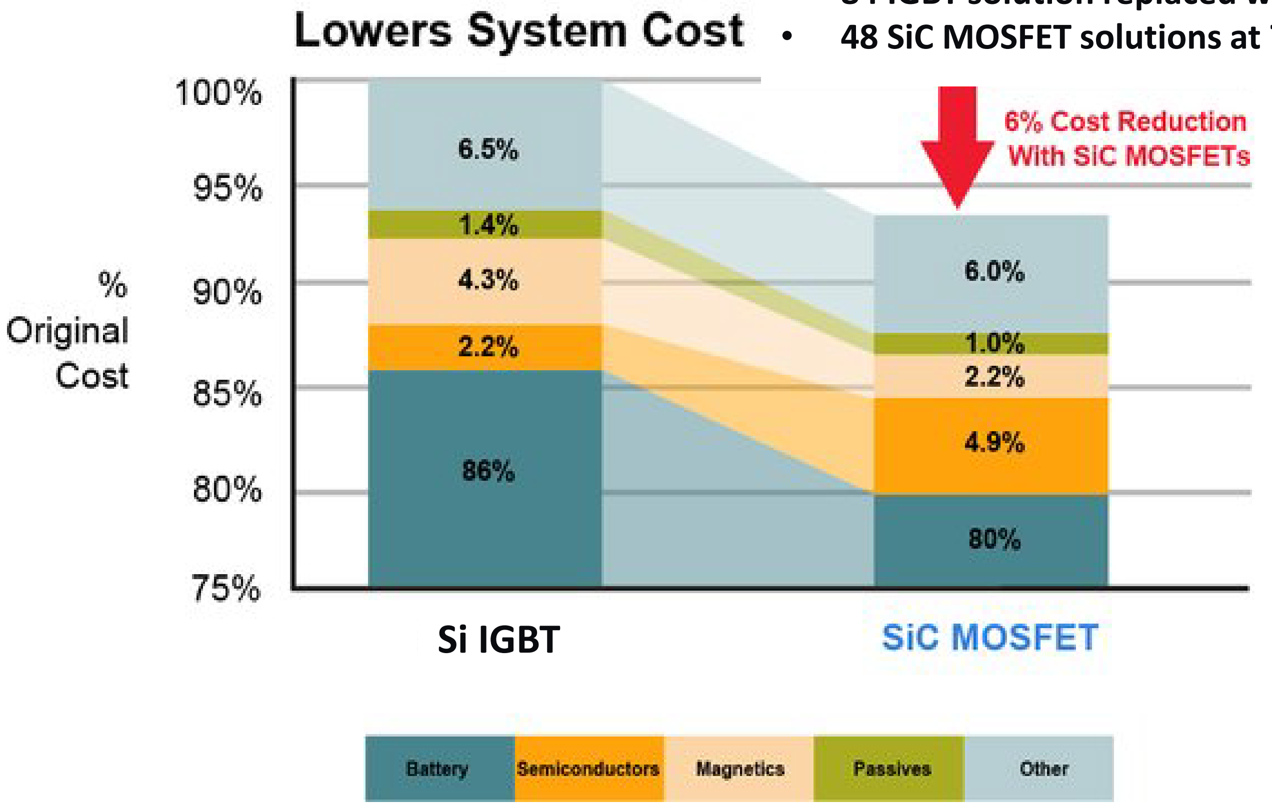
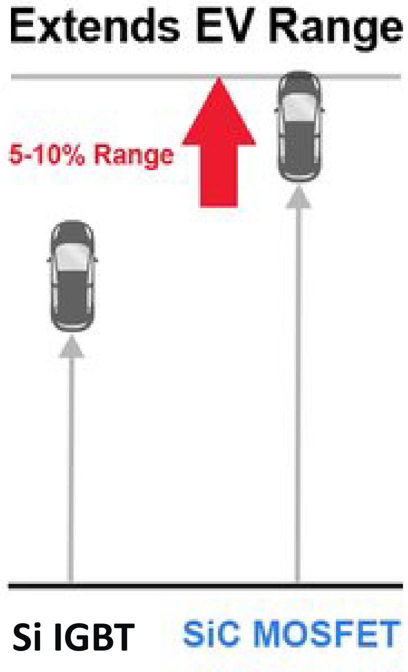
SiC Increases Efficiency, Lowers System Cost

Key Takeaway: SiC offers better performance and overall lower system cost

350 V Battery
225 kW 3-Phase Inverter
- **84 IGBT solution replaced with…**
- **48 SiC MOSFET solutions at 700 V**





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mSiC™ Bare Die | 700V – 3.3 kV

Adopt SiC with Ease, Speed and Confidence

mSiC™ Bare Die Products Page

mSiC MOSFETs

Voltage	V_{GS}	$R_{DS(on)}$	Waffle Pack
3.3 kV	20V-18V	25 mΩ	MSC025SMA330D/S
		27 mΩ	MSC027SMA330D/S
		80 mΩ	MSC080SMA330D/S
		400 mΩ	MSC400SMA330D/S
1700V	20V-18V	35 mΩ	MSC035SMA170D/S
		750 mΩ	MSC750SMA170D/S
1200V	20V-18V	17 mΩ	MSC017SMA120D/S
		25 mΩ	MSC025SMA120D/S
		40 mΩ	MSC040SMA120D/S
		80 mΩ	MSC080SMA120D/S
		180 mΩ	MSC180SMA120D/S
		360 mΩ	MSC360SMA120D/S
700V	20V-18V	15 mΩ	MSC015SMA070D/S
		35 mΩ	MSC035SMA070D/S
		60 mΩ	MSC060SMA070D/S
		90 mΩ	MSC090SMA070D/S

mSiC Diodes

Voltage	Current	Waffle Pack
3.3 kV	90A	MSC090SDA330D/S
	30A	MSC030SDA330D/S
1700V	50A	MSC050SDA170D/S
	30A	MSC030SDA170D/S
	10A	MSC010SDA170D/S
1200V	50A	MSC050SDA120D/S
	30A	MSC030SDA120D/S
	20A	MSC020SDA120D/S
	15A	MSC015SDA120D/S
	10A	MSC010SDA120D/S
700V	50A	MSC050SDA070D/S
	30A	MSC030SDA070D/S
	10A	MSC010SDA070D/S

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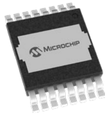
mSiC™ MOSFETs | 700V – 3.3 kV

Adopt SiC with Ease, Speed and Confidence

mSiC™ MOSFETs Products Page

Voltage	V_{GS}	$R_{DS(on)}$	 D2PAK (TO-263-7)	 D3PAK (TO-268)	 PSMT (TOLT)	 TO-247-3	 T0-247-4L	 TO-247 -4L Notched	 SOT-227
3.3 kV	20V-18V	25 mΩ							
		80 mΩ					MSC080SMA330B4		
		400 mΩ					MSC400SMA330B4		
1700V*	20V-18V	35 mΩ				MSC035SMA170B	MSC035SMA170B4		
		750 mΩ	MSC750SMA170SA	MSC750SMA170S		MSC750SMA170B	MSC750SMA170B4		
1200V	20V-18V	17 mΩ		MSC017SMA120S		MSC017SMA120B	MSC017SMA120B4	MSC017SMA120B4N	MSC017SMA120J
		25 mΩ		MSC025SMA120S		MSC025SMA120B	MSC025SMA120B4	MSC025SMA120B4N	MSC025SMA120J
		40 mΩ		MSC040SMA120S		MSC040SMA120B	MSC040SMA120B4	MSC040SMA120B4N	MSC040SMA120J
		80 mΩ	MSC080SMA120SD	MSC080SMA120S	MSC080SMA120SC	MSC080SMA120B	MSC080SMA120B4		MSC080SMA120J
		180 mΩ	MSC180SMA120SD	MSC180SMA120S	MSC180SMA120SC	MSC180SMA120B			
		360 mΩ	MSC360SMA120SD	MSC360SMA120S	MSC360SMA120SC	MSC360SMA120B			
700V	20V-18V	15 mΩ		MSC015SMA070S		MSC015SMA070B	MSC015SMA070B4	MSC015SMA070B4N	
		35 mΩ		MSC035SMA070S		MSC035SMA070B	MSC035SMA070B4	MSC035SMA070B4N	
		60 mΩ	MSC060SMA070SD	MSC060SMA070S	MSC060SMA070SC	MSC060SMA070B	MSC060SMA070B4		
		90 mΩ	MSC090SMA070SD	MSC090SMA070S	MSC090SMA070SC	MSC090SMA070B			

Auto and Commercial Parts Available

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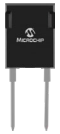
mSiC™ Diodes | 700V – 3.3 kV

Adopt SiC with Ease, Speed and Confidence

mSiC™ Diodes Products Page

Voltage	Current	 TO-220	 D3PAK	 TO-247	 TO-247 MAX	 TO-247 Dual Diodes	 SOT-227 Dual Diodes
3.3 kV	90A				MSC090SDA330B2		
	30A			MSC030SDA330B			
1700V	50A			MSC050SDA170B			
	30A			MSC030SDA170B			MSC2X30SDA170J MSC2X31SDA170J
	10A			MSC010SDA170B			MSC2X50SDA170J MSC2X51SDA170J
1200V	100A						MSC2X100SDA120 MSC2X101SDA120
	50A		MSC050SDA120S	🚗 MSC050SDA120B		MSC050SDA120BCT	MSC2X50SDA120J MSC2X51SDA120J
	30A	🚗 MSC030SDA120K	MSC030SDA120S	🚗 MSC030SDA120B		MSC030SDA120BCT	MSC2X30SDA120J MSC2X31SDA120J
	20A	🚗 MSC020SDA120K	MSC020SDA120S	🚗 MSC020SDA120B			
	15A	🚗 MSC015SDA120K		🚗 MSC015SDA120B			
	10A	🚗 MSC010SDA120K		🚗 MSC010SDA120B			
700V	100A						MSC2X100SDA070J MSC2X101SDA070J
	50A		MSC050SDA070S	🚗 MSC050SDA070B		MSC050SDA070BCT	MSC2X50SDA070J MSC2X51SDA070J
	30A	🚗 MSC030SDA070K	MSC030SDA070S	🚗 MSC030SDA070B		MSC030SDA070BCT	MSC2X30SDA070J MSC2X31SDA070J
	10A	🚗 MSC010SDA070K	MSC010SDA070S	🚗 MSC010SDA070B		MSC010SDA070BCT	

🚗 Auto and Commercial Parts Available

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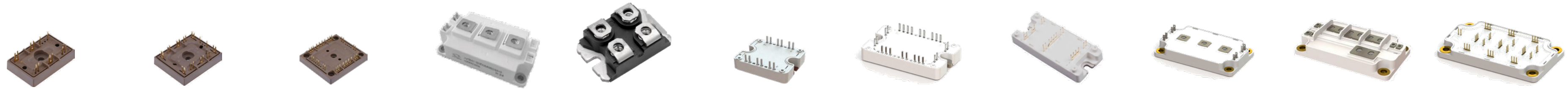
mSiC™ Modules (MOSFET) | 700V – 1700V

Adopt SiC with Ease, Speed and Confidence

mSiC™ Modules Products Page



Configuration	BL1 (mΩ)	BL2 (mΩ)	BL3 (mΩ)	D3 (mΩ)	SOT-227 (mΩ)	SP1F (mΩ)	SP3F (mΩ)	SP4 (mΩ)	SP6C (mΩ)	SP6LI (mΩ)	SP6P (mΩ)
3 Level Inverter							1.5 – 40		3.8 – 11.7		
3 Phase Bridge			25				15 – 25				
Asymmetrical Bridge		25									
Boost Chopper	25				12.5 – 40		11				
Buck Chopper	25				12.5 – 40		11				
Double Dual Common Source		25	12.5								
Dual Common Source	25		12.5				5 – 17.5		1.7 – 5.8		
Full Bridge		25	12.5				6.3 – 40		3.8 – 11.7		
Phase Leg	25			2.5 – 5.8		12.5 – 40	5 – 11.7		2.7 – 5.8	2.1 – 5.8	
T-type						25 – 35	12.5 – 17.5		4.2 - 8.8		
Triple Phase Leg							15 – 35				5 – 17.5
Triple Vienna Rectifier											7.5 – 12.5
Vienna Phase Leg							15	7.5			
Vienna Rectifier						15 – 25	7.5 – 12.5		3 – 8.3		

dsPIC33 for Digital Power Conversion

Performance For More Sophisticated Algorithms

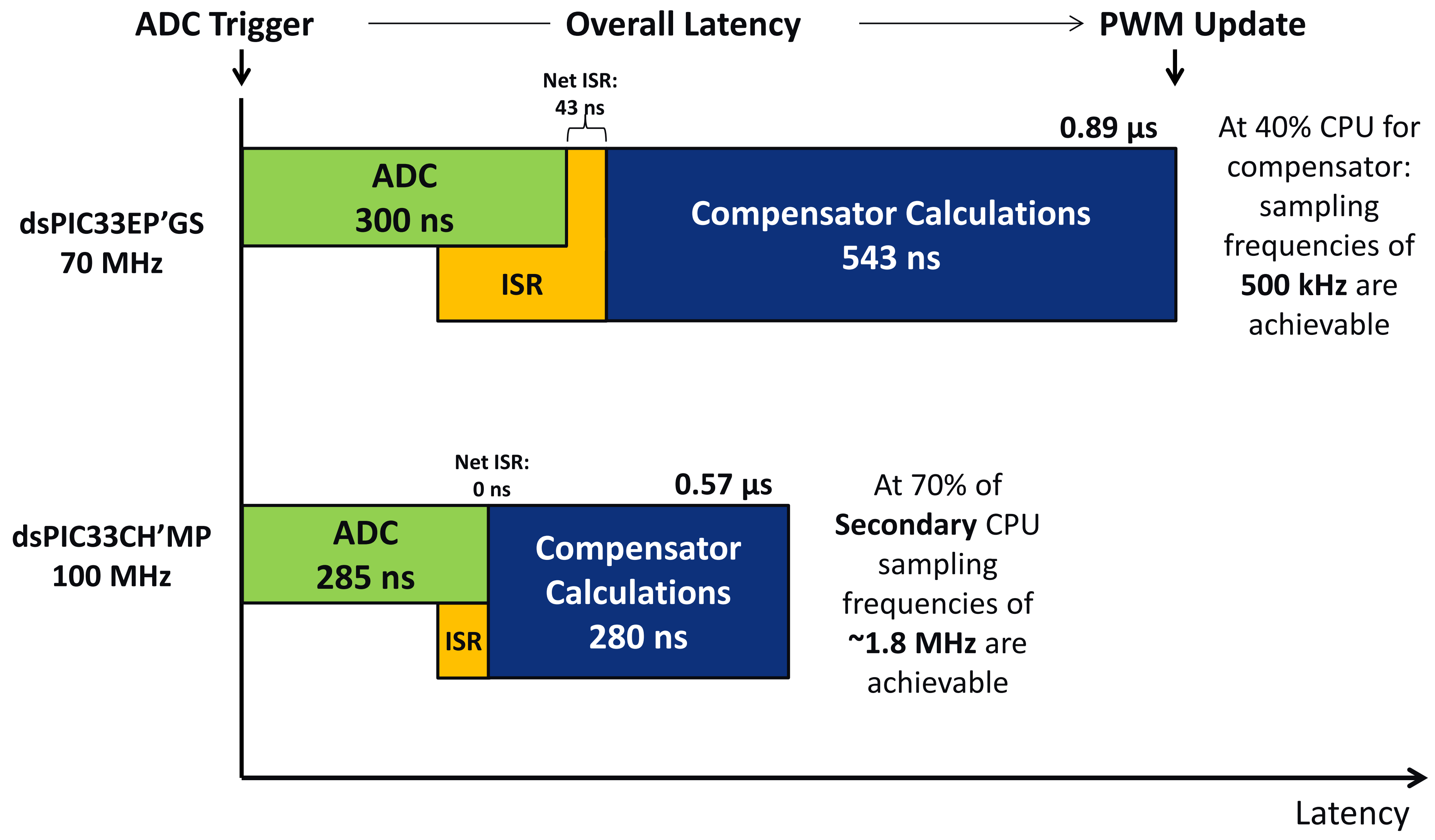
- **Adaptive algorithms**
  - For improved efficiency over widely varying load conditions
  - Implement phase shedding, real-time dead-time adjustment, variable switching frequency, variable bulk voltage, etc.
- **Predictive and non-linear algorithms**
  - For improved dynamic response to transient conditions
- **Higher switching frequencies**
  - Smaller inductors and capacitors - save cost and space, improve power density
- **Performance headroom**
  - For additional independent control loops or more outputs
  - Run-time diagnostics, communications, predictive maintenance

dsPIC33 C Family Features

- **DSC optimized for digital power and motor control applications**
  - High-speed 12-bit ADCs (285 ns) and High-resolution PWMs (250 ps)
  - 40-bit accumulators for unprecedented intermediate precision
  - Highly parallel CPU architecture: up to 8 operations per clock (per core)
  - Sustainable 100 MMACS performance (per core)
- **Single and Dual core versions**
- **Up to 1 MB Flash Memory**
- **Packages as small as 4x4 mm (28 leads)**
- **Up to 144 lead packages**

dsPIC33CH Performance Example

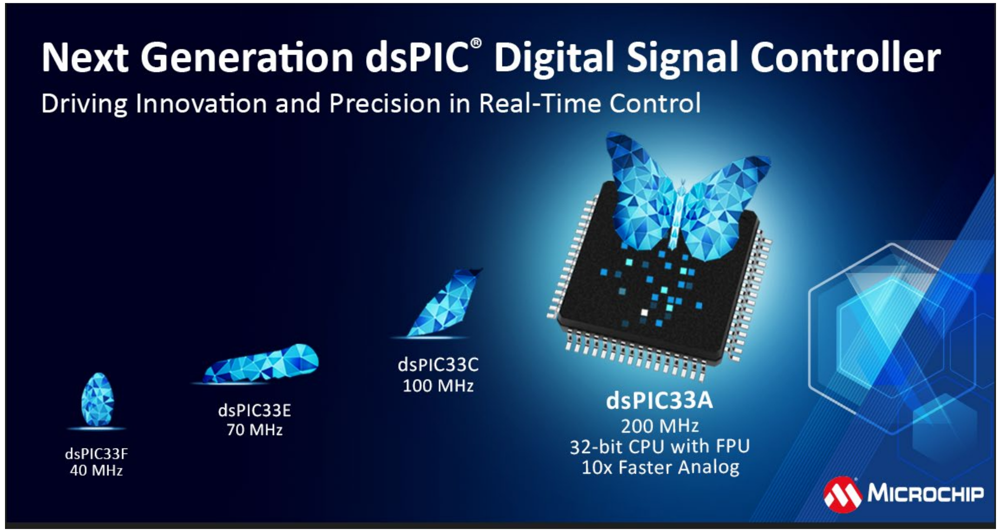
Digital Power 3P3Z Latency



32-bit dsPIC33A DSCs: Real-Time Control with Precision and Performance

The dsPIC33A features a 32-bit CPU running at 200 MHz, equipped with double precision FPU and DSP capabilities for efficient numerical processing, ideal for real-time control tasks. Its architecture ensures high performance, while a robust development toolset facilitates faster product development.

- 32-bit CPU Running at 200 MHz Speed with DSP Engine
- Single and Double Precision Floating-point Unit (FPU)
- Up to 128 Kbytes of Program Flash Memory (ECC)
- Up to 16 Kbytes of RAM Memory (ECC and MBIST)
- Up to 40 MSPS Conversion Rate on 12-bit ADCs
- 100 MHz GBW Opamps and High-Speed Comparators with 5 ns Response Time
- ISO 26262/IEC 61508/IEC 60730 Functional Safety Readiness
- 28-64 pin packages
- Automotive Q100 Qualification



Market / Application:

Motor control, digital power conversion, and advanced sensing for automotive, industrial automation, and sustainability solutions

Product Page Website:
[Digital Signal Controllers (DSCs)]

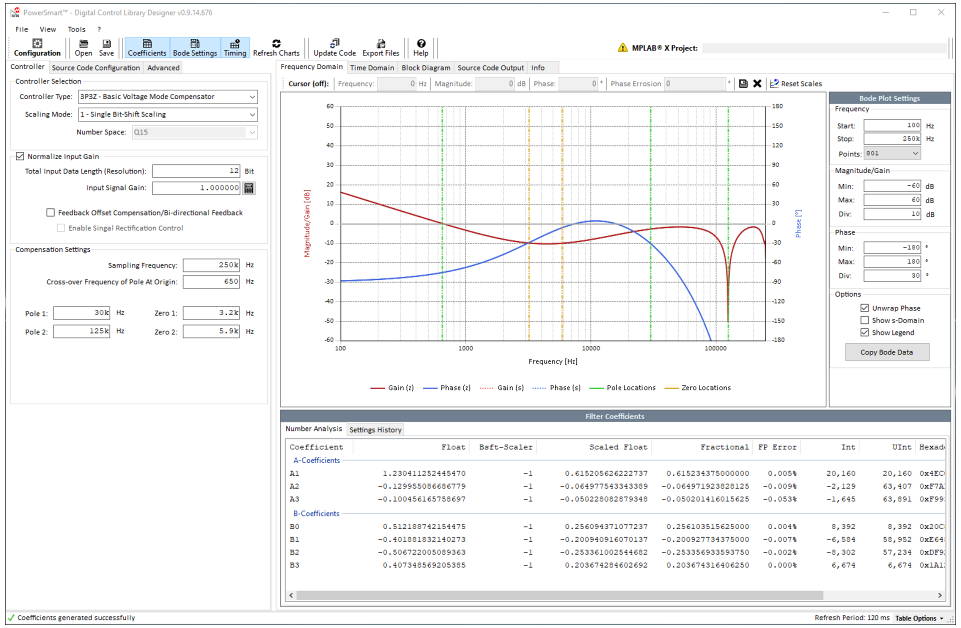
Datasheet:
[dsPIC33A Family Datasheet]

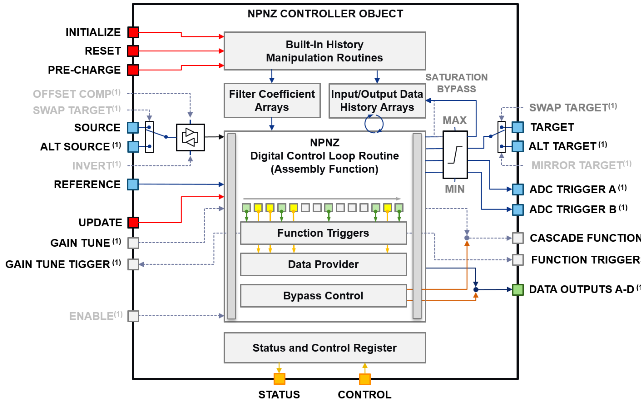
MICROCHIP

PowerSmart™ Development Suite

The Fast Way to a Working Power Supply

- **Create MPLAB X project**
  - Select device, compiler version, etc.
- **Configure device using MCC GUI**
  - Adds main.c to project, setup clocks and dividers
  - Configure ADC channel, pins, trigger source, interrupts
  - Configure PWMs including when to trigger ADC
- **Add example code snippets**
  - State machine, timing loop and soft start
- **Create P-Term loop measurement code using PowerSmart DCLD**
  - Use GUI to configure source code such as anti-windup clamping
- **Measure poles & zeros of plant**
- **Use PowerSmart DCLD to generate final compensator assembly code**



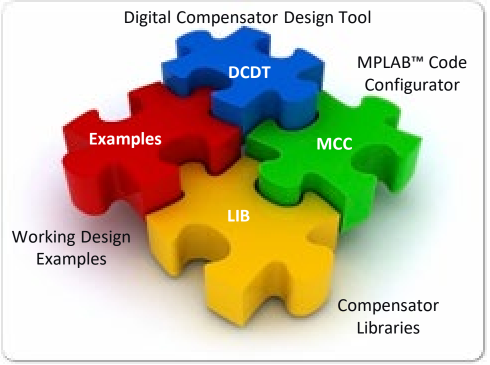


Digital Power Design Examples

Speed Development / Reduce Risk

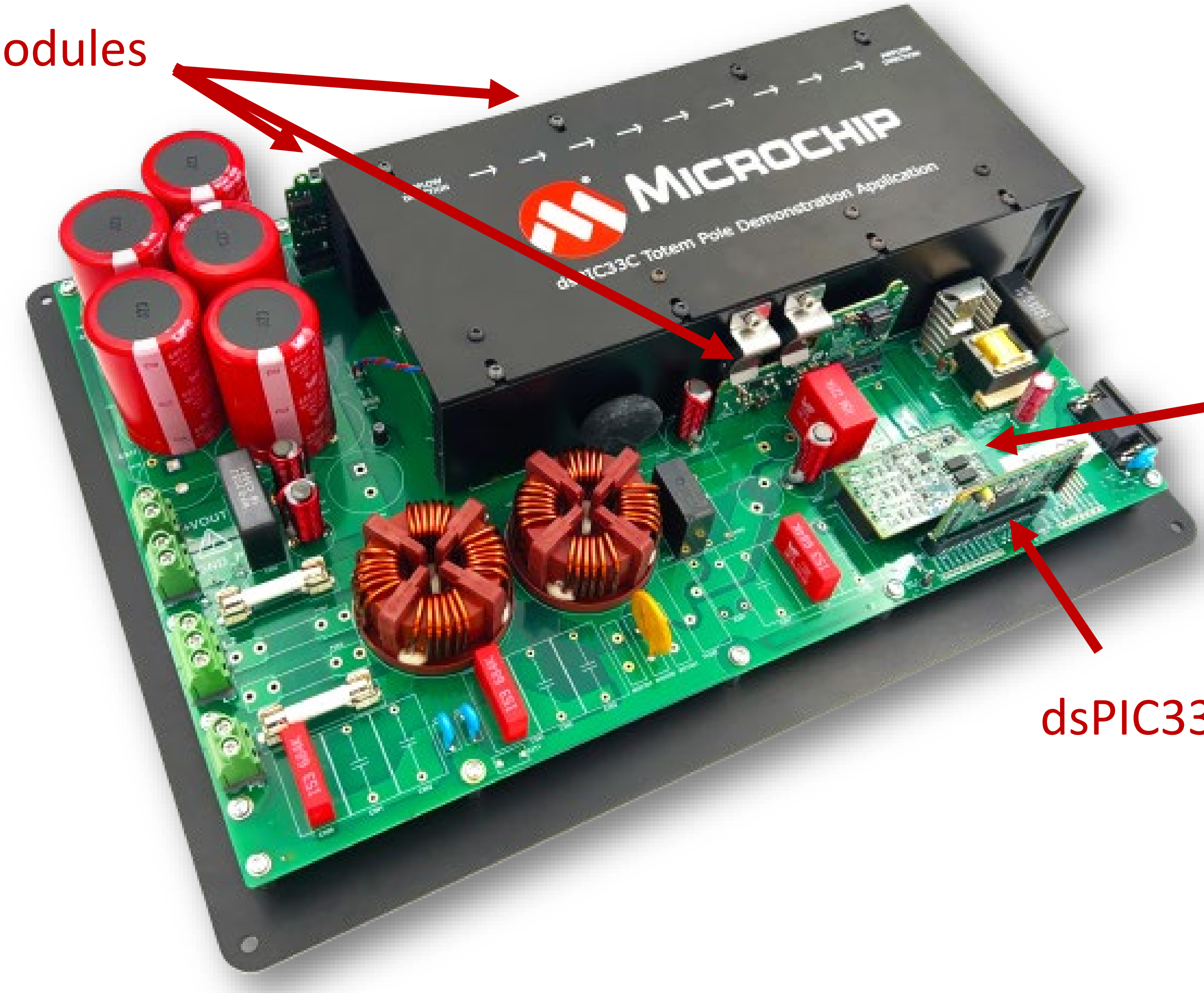
Royalty-free microcontroller and application-specific hardware and software designs

- Starter kits
- Development boards / EVBs
- Reference designs
- Code examples
- Application notes




```
_AltRegContext2Setup:

CTXTSWP #0x2   ; Swap to Alternate W-Reg #2

 ; w0 register used for compensator control reference

 mov #ADCBUF3,  w1   ; Address of ADCBUF3 register
 mov #CMP2DAC,  w2   ; Address of CMP2DAC register

 ; w3-w5 used for ACCAx and MAC/MPY instructions

 mov #BOOST_COMP_2P2Z_POSTSCALER, w6
 mov #BOOST_COMP_2P2Z_POSTSHIFT,    w7
 mov #_boostOptions,                w8
 mov #_boostABCoefficients,         w9
 mov #_boostErrorControlHistory,    w10
 mov #BOOST_COMP_2P2Z_MIN_CLAMP,    w11
 mov #BOOST_COMP_2P2Z_MAX_CLAMP,    w12

CTXTSWP #0x0  ; Swap back to main register set

return
```

dsPIC33C 1PH 3.8 kW/7.6 kW PFC/Inverter



DP PIM- Controller Board

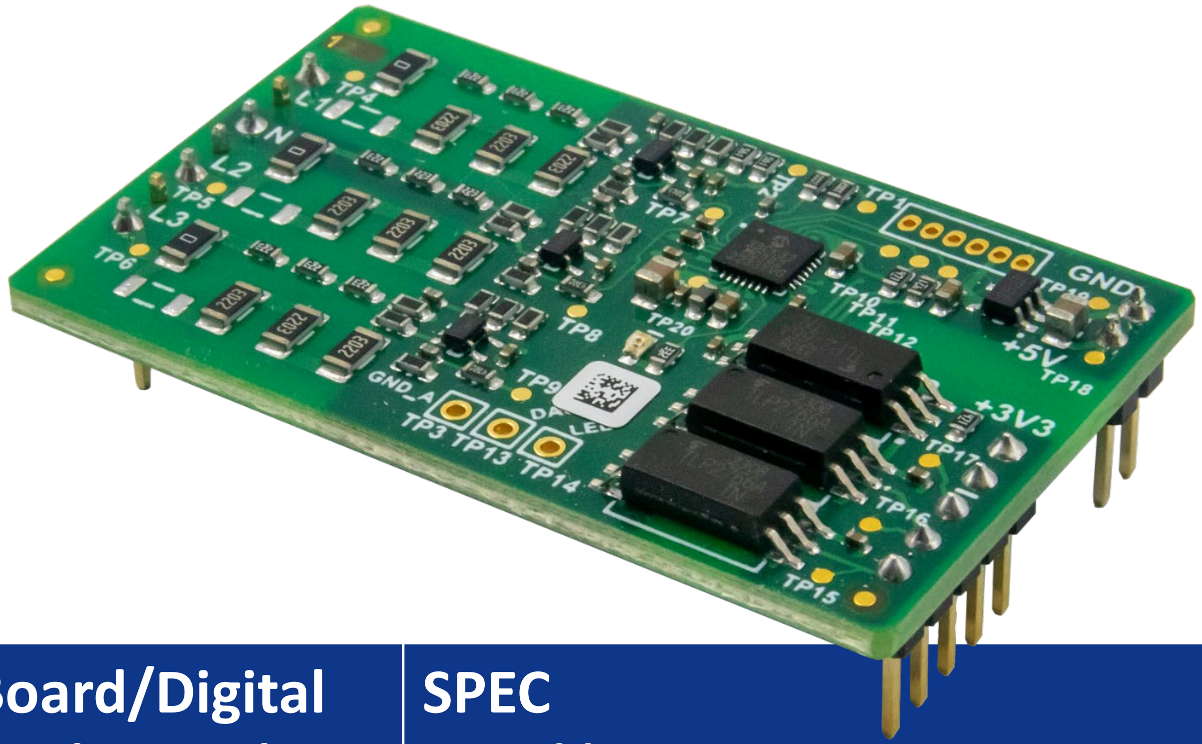
dsPIC33CH512MP506 Digital Power Plug-In Module
(Part # MA330049)

Digital Power Plug-In Module	SPEC
This board was used as a main power controller Firmware available for PFC/Inverter currently on CH device only	ADCs, PWMs, I2C, CAN 3 current loops at 100 kHz, voltage loop at 300 Hz Secondary core CPU load: 80%

Isolated Voltage Acquisition Board

https://www.l-tek.com/web-shop/ac-acquisition-board-mic0001/

Assembled for LV operation!

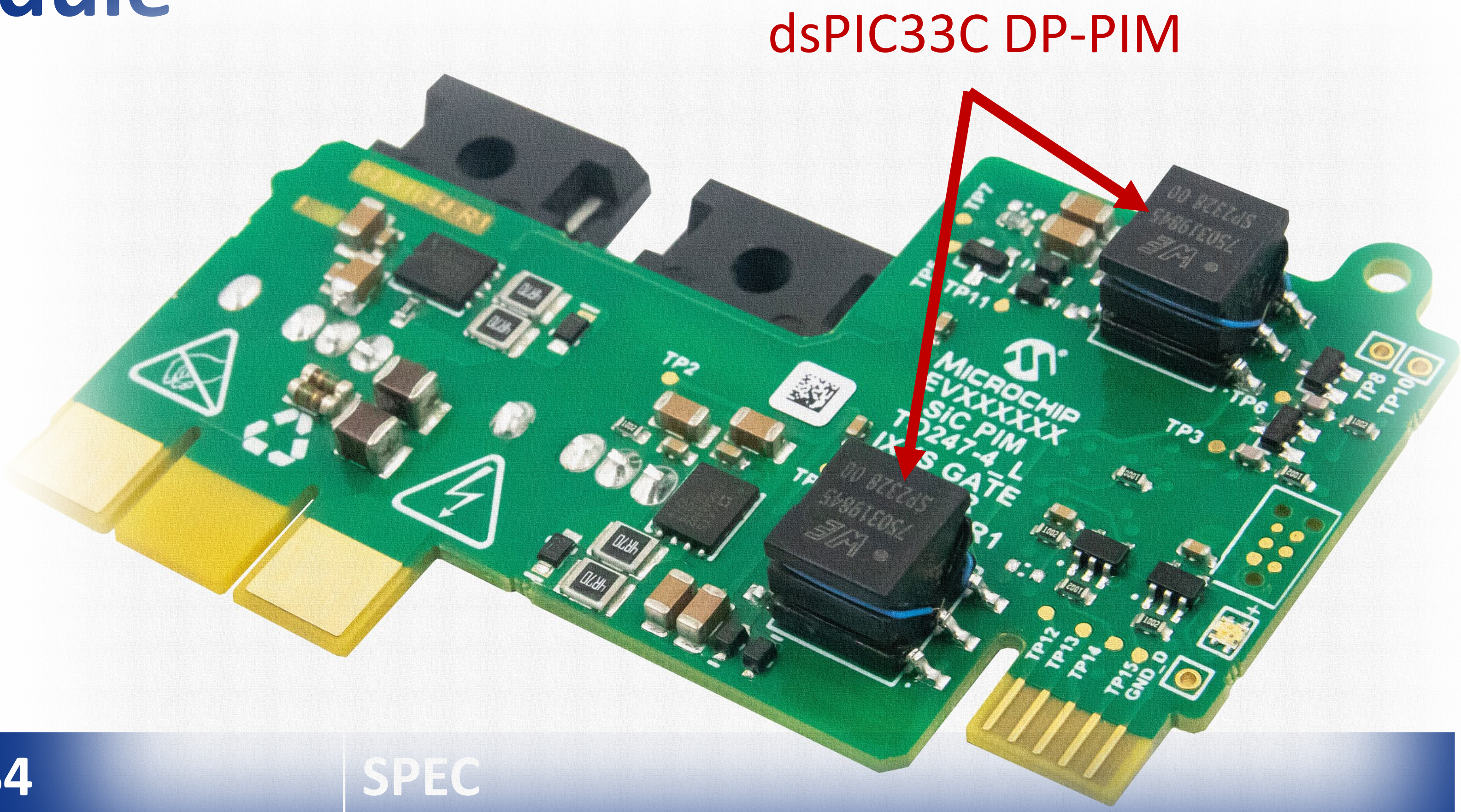


Isolated Voltage Acquisition Board/Digital	SPEC
This board is used to sense the three-phase AC line voltages with reference to neutral, digitalize and send this information to the main PFC controller over the SPI channel	4V<Vdd<10V, 100 mA$_{max}$ 270 Vac$_{max}$ 4 kV Isolation 100 kHz Vin sampling, 10 MHz SPI

MICROCHIP

SiC FET Plugin Module

MSC025SMA120B4
MSC040SMA120B4
MCHP Driver
4L PCB 1.65 mm
105 µm Copper outer
70 µm inner
70x55 mm



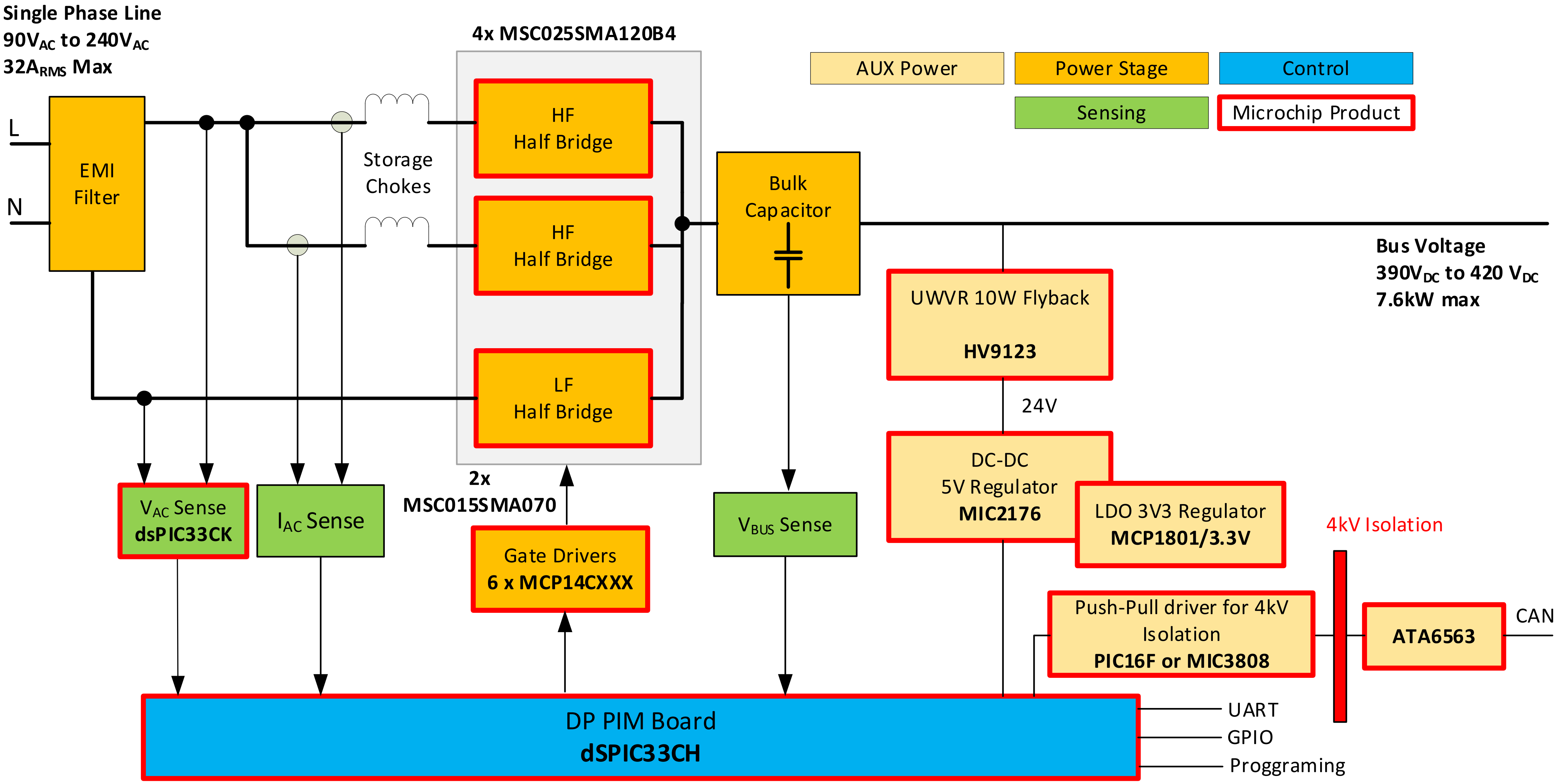
SiC FET PIM- MSC025SMA120B4

Generic half bridge board with SiC FETs, gate drivers, AUX supply, signal isolation, temp. sense, intelligence and more…
This board was used to provide switching legs for power conversion and rectifier leg.
Two are needed to operate PFC/Inverter in 1Ph Mode
Three are needed to operate 3Ph Mode

SPEC

4.5V<Vdd<5.5V
4 kV Isolation, 4 pF_{max}
Temp. Sense, I2C comunication
Microchip driver

Block Diagram



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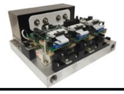
SiC Design Support - Hardware

Hardware Platform – Key Application		AC-DC	DC-DC	DC-AC	Available for Purchase
High-Voltage Auxiliary E-Fuse Technology Demonstrator					✓
SP6LI mSiC™ MOSFET Module Evaluation Board					✓
30 kW 3-Phase Vienna PFC Reference Design – EV Charging		✓			Design Files Available
11 kW 3-Phase Totem-Pole PFC Demonstrator – OBC		✓		✓	✓
3.8 kW/7.6 kW Totem Pole Demonstrator – OBC		✓		✓	✓
30 kW DC-DC Polymorphic Converter Ref Design – EV Charging			✓		Design Files Available
11 kW Dual Active Bridge DC-DC (OBC) Demonstration – OBC			✓		✓
250V - 1000V (63W) Auxiliary Power Supply Ref Design			✓		Design Files Available
Mersen 150 kVA 3-phase SiC Power Stack Evaluation Kit		✓	✓	✓	Design Files Available

mSiC™ Solutions Design Support

Software simulation tools

SiC Simulation Models

- mSiC SPICE and PLECS component models
- SiC Vienna PLECS models

MPLAB® SiC Power Simulator

- Free PLECS-based online MPLAB SiC power simulator
- Quickly evaluate Microchip's mSiC power devices and modules across various topologies

MPLAB® Mindi™ Analog Simulator

- Microchip's free circuit simulation software available for download at www.microchip.com/Mindi
- Uses SIMetrix and SIMPLIS simulation environment for SPICE and piecewise-linear modeling, respectively

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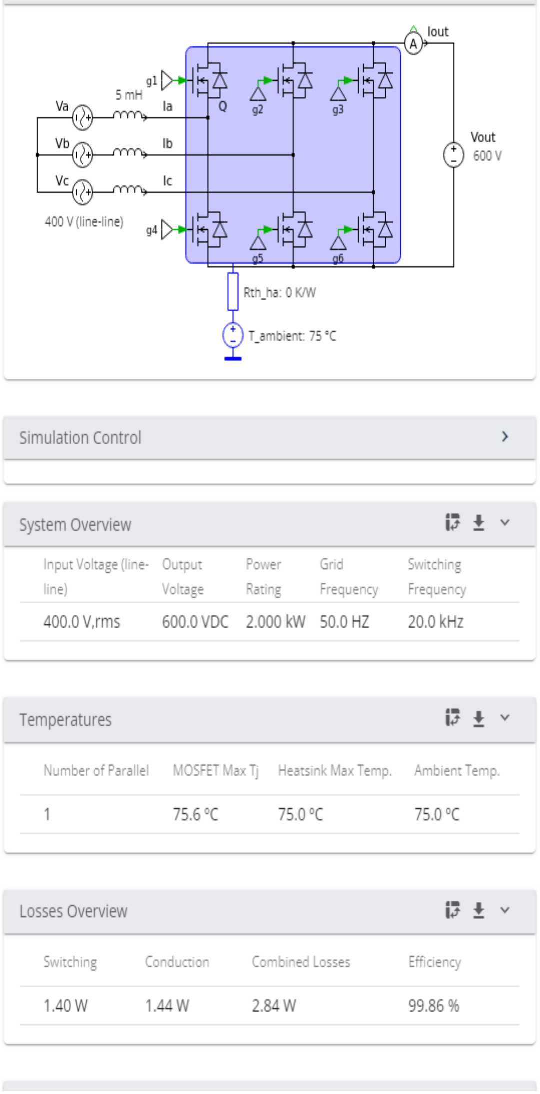
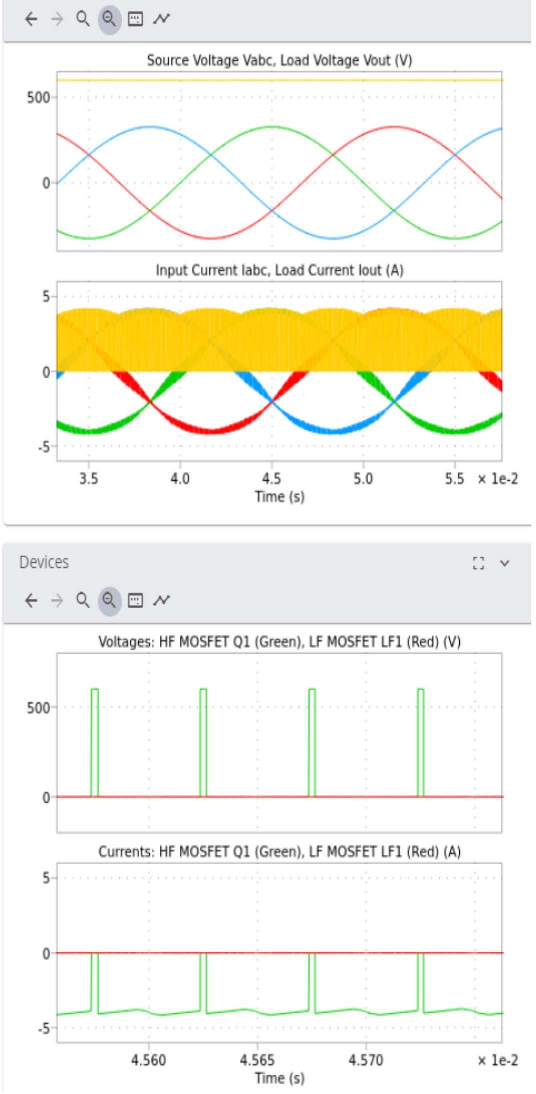
MPLAB® SiC Power Simulator

License-free online SiC power simulator





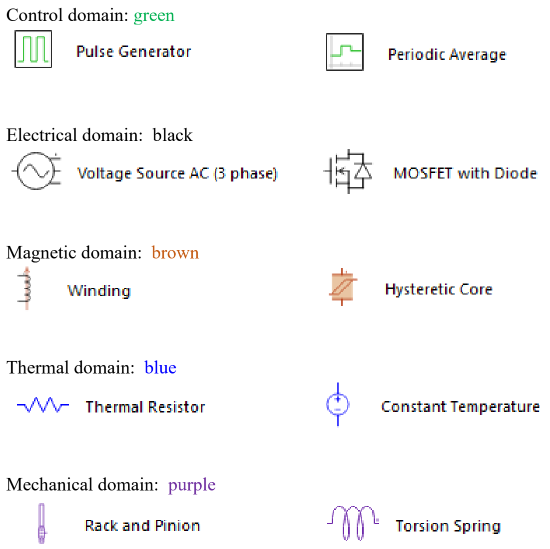
- **Open online access to customers**
  - Test Microchip mSiC device and power module performance, and more
- **Evaluate Microchip mSiC models risk-free**
  - Web-based model for anywhere access
  - No software license required
- **Multiple topologies and over 45 device and power module models**
  - Component level details

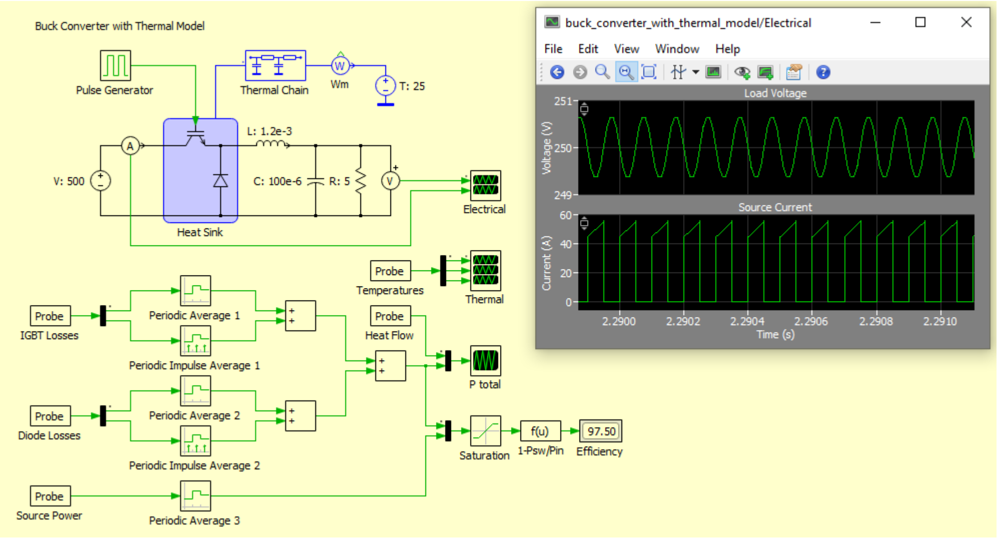
PLECS Software

- Piecewise-Linear Electrical Circuit Simulation (PLECS) by Plexim
- Power electronics circuits and systems simulation tool
- Uses ideal switches to quickly and efficiently simulate dynamic behavior of complex systems
- Multi-domain approach to simultaneously simulate the control, electrical, magnetic, thermal, and mechanical domains
- Supports Processor-In-the-Loop (PIL) and Hardware-In-the-Loop (HIL)
- Similar tools: Matlab/Simulink, PSIM, Opal RT, SaberRD
- SiC competitors providing reference designs and component models in PLECS

- Demo mode available, allows users to build and simulate models

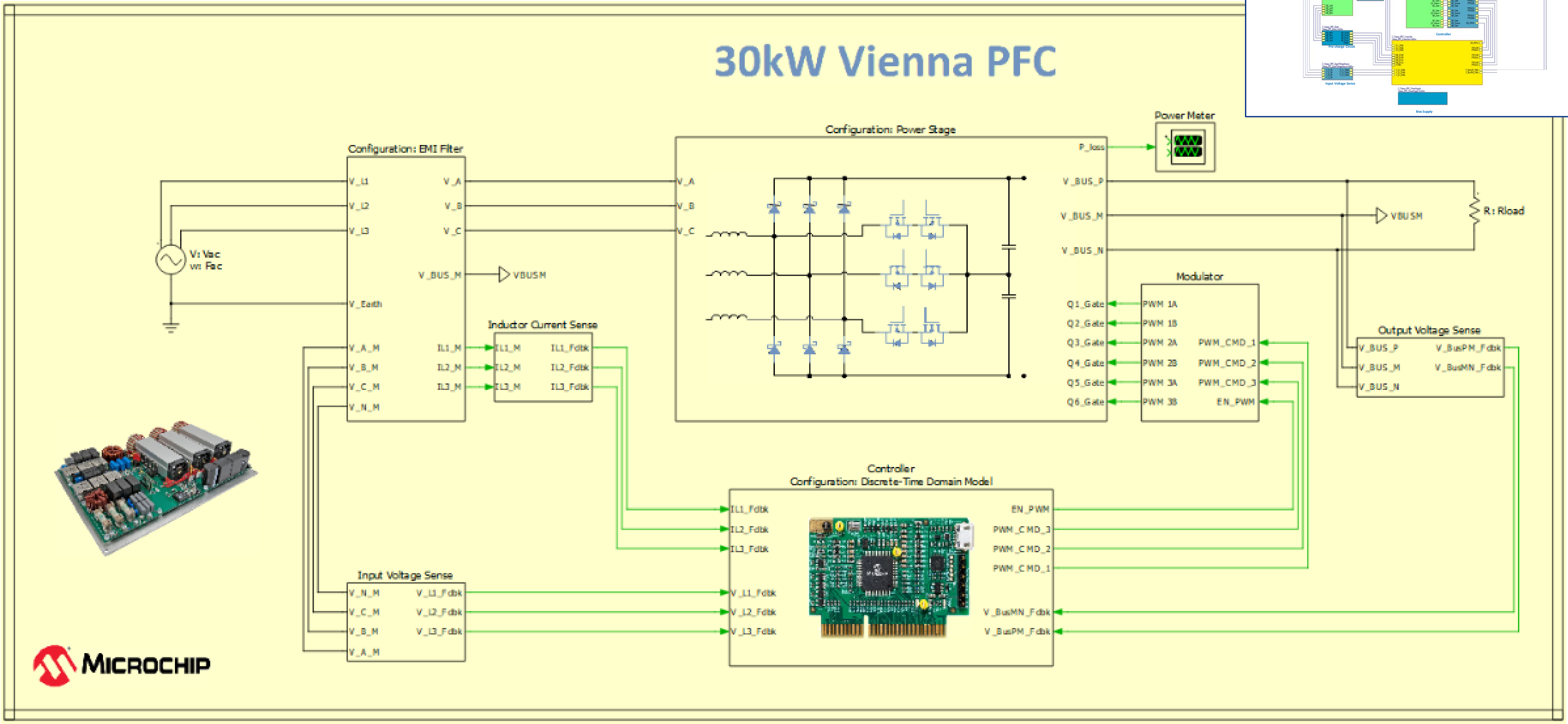
- Plexim currently offering 90-day trial license (Video walk-through of PLECS Standalone installation)
  - Windows: https://www.plexim.com/support/videos/installing-standalone-win
  - Mac: https://www.plexim.com/support/videos/installing-standalone-mac
  - When requesting license, select PLECS Standalone and PIL





Top-Level Model

Reference Design Schematic



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mSiC™ Product Portfolio | 700V, 1200V, 1700V, 3.3 kV

Products	Packages	Portfolio
Bare Die		• 700V – 3.3 kV, 15 – 750 mΩ SiC MOSFETs • 700V – 3.3 kV, 10 – 90A SiC Schottky Barrier Diodes (SBDs)
Discretes		• 700V – 3.3 kV, 15 – 750 mΩ SiC MOSFETs • 700V – 3.3 kV, 10 – 100A SiC Schottky Barrier Diodes
Modules		• 700V – 1700V, 1.5 – 40 mΩ SiC MOSFETs • 700V – 1700V, 50 – 600A SiC Schottky Barrier Diodes • 650V – 1200V, 25 – 100A Hybrid (Si IGBT + SiC SBD) • Custom Power Modules
Gate Drivers		• 1200V – 3.3 kV Plug-and-Play Gate Drivers • Augmented Switching™ Technology • Isolated 5A Gate Driver

MICROCHIP

Microchip SiC Portal

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- SiC Discretes
- SiC Modules
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  - Reference Designs and Application Notes
  - Models and Simulation Tools
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