SiC MOS Technology and Value Proposition

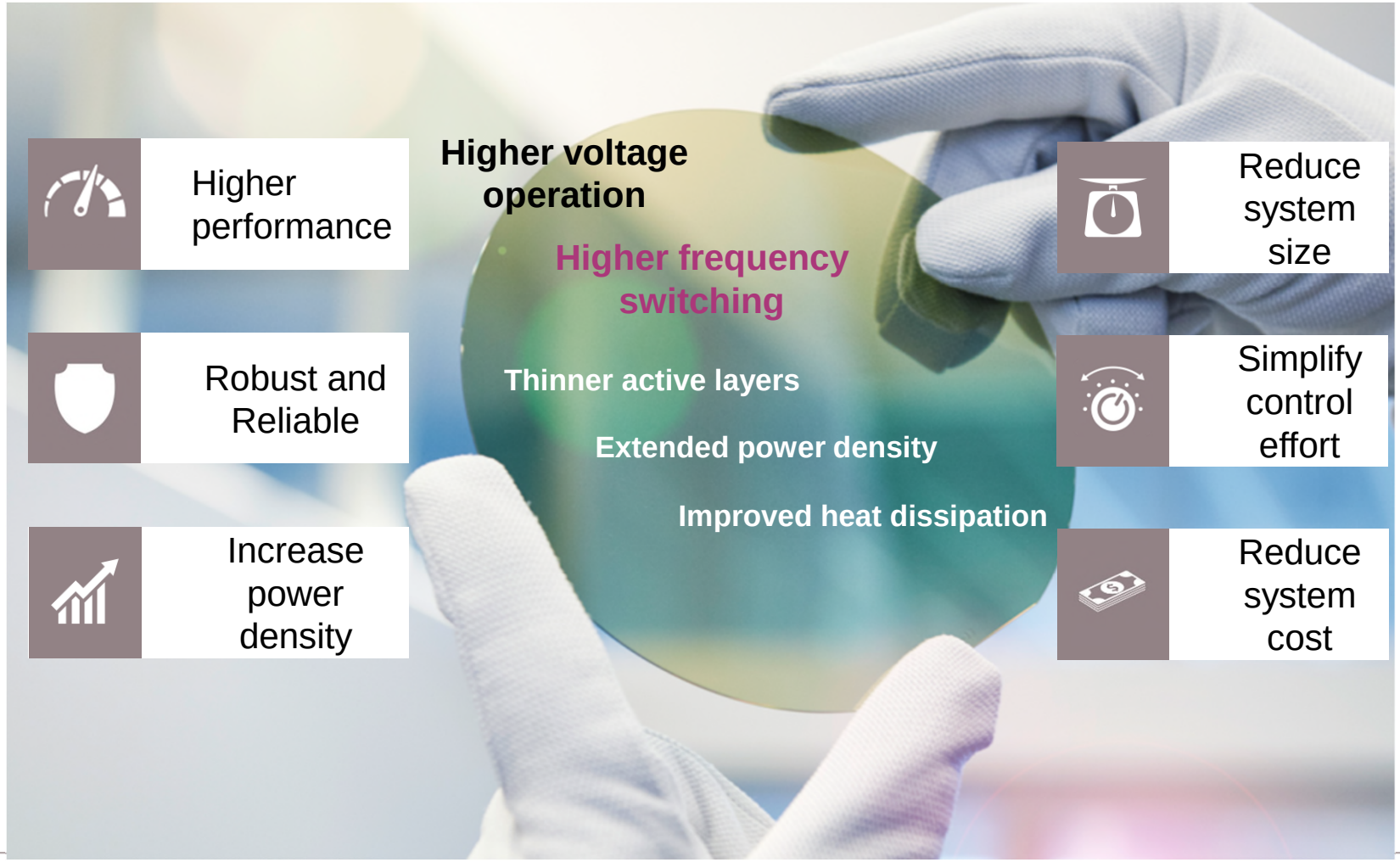
The Next Frontier for Semiconductor Devices – CoolSiC™ from Infineon

Kwokwai Ma
Infineon Technologies Hong Kong Ltd

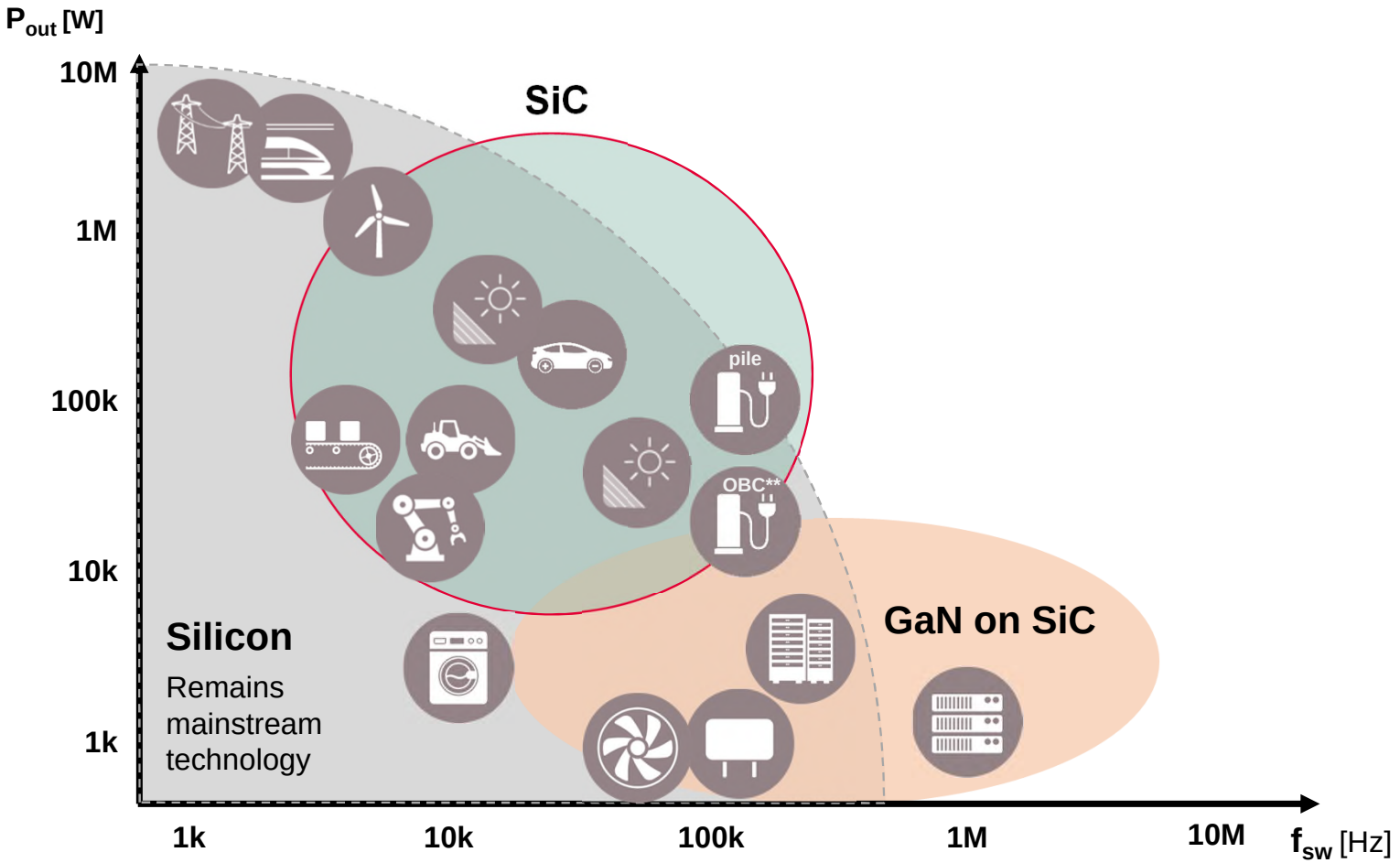
Agenda

1. Overview
2. Gate oxide reliability
3. dV/dt turn-on robustness
4. Diode robustness
5. Short-circuit robustness
6. Gate voltage range
7. Package

Wide bandgap power semiconductor (SiC and GaN) are the key to higher energy efficiency

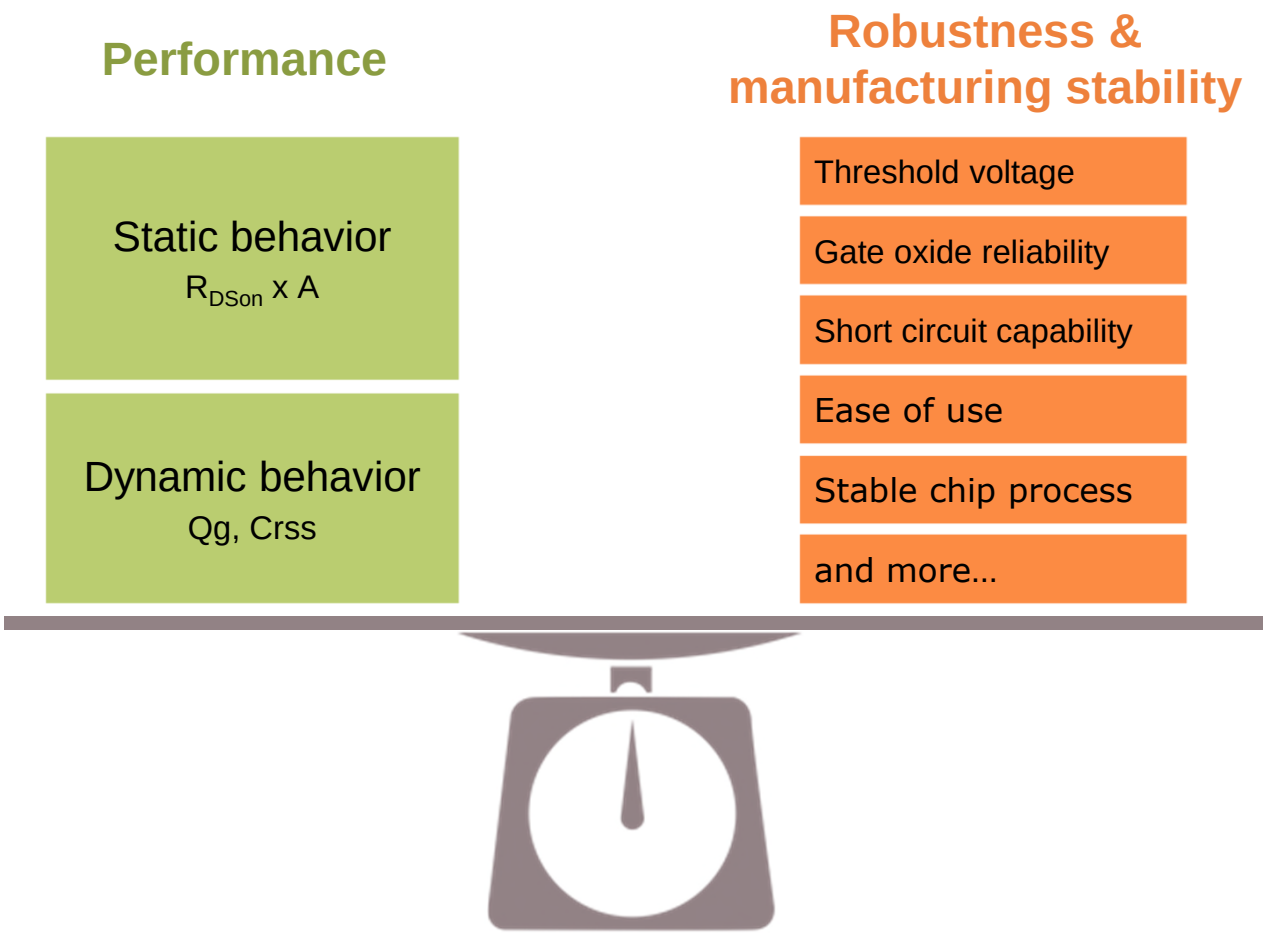


SiC and GaN enable higher efficiency through faster switching with lower losses than Si- devices



*OBC = onboard charger

Different performance parameters of SiC MOSFET must be matched



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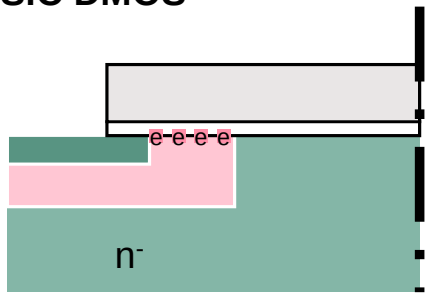
Trade-off between SiC MOS gate voltage and gate oxide reliability

Technology solution - Trench-based structure

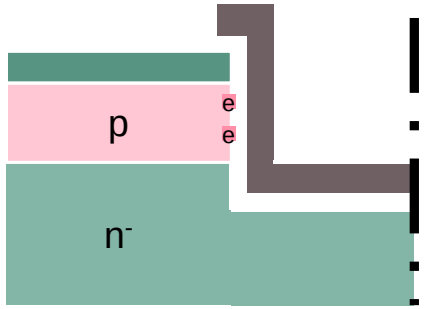
SiC DMOS



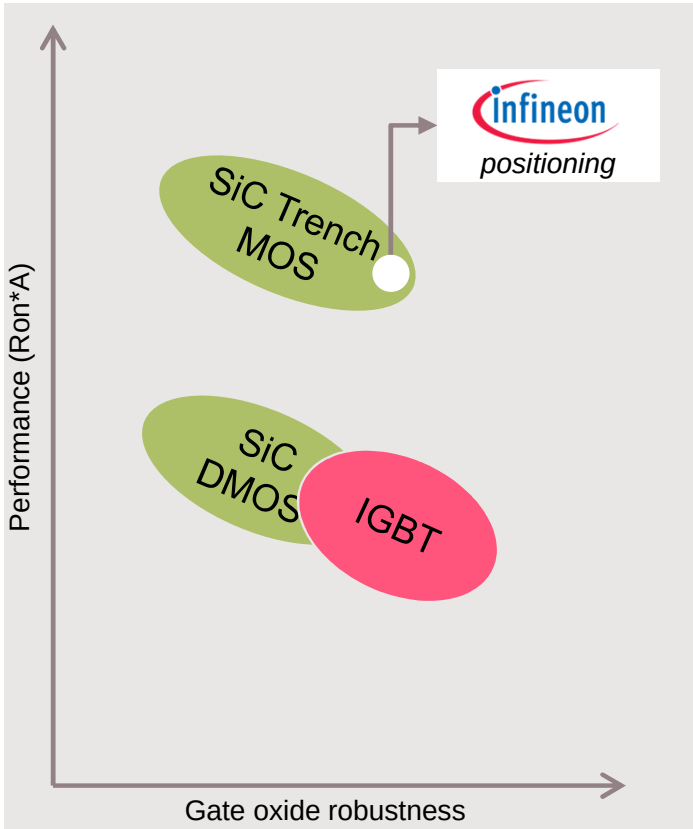
strong trade-off between performance and gate oxide robustness in on-state

vs

SiC Trench MOS



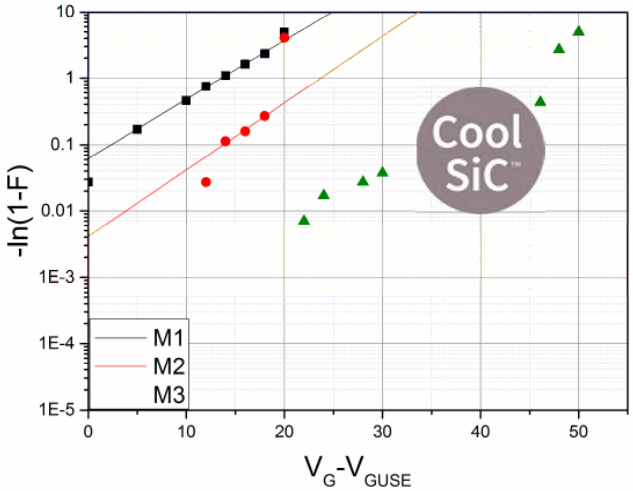
easier to reach performance without violating gate oxide safe conditions

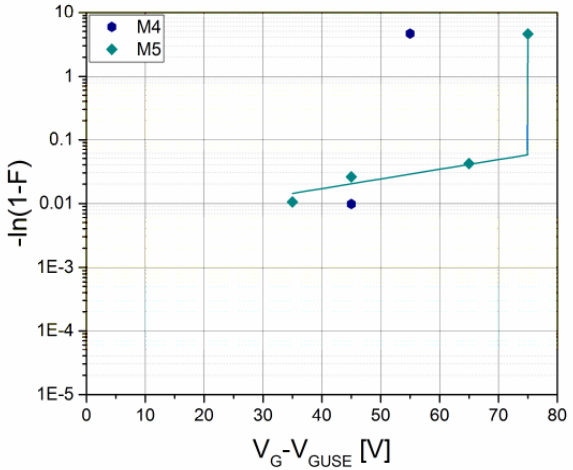


Best R_{dson} at gate oxide robustness level comparable to IGBT

CoolSiC™ MOSFET shows a gate oxide stability comparable to silicon IGBT's

Failure rates of SiC MOSFETs	Failure rates of Si-IGBT's





- Superior stability compared to available SiC MOSFETs
- Basic behavior approaches silicon IGBT performance

Source : Beier-Möbius et al. PCIM 2017

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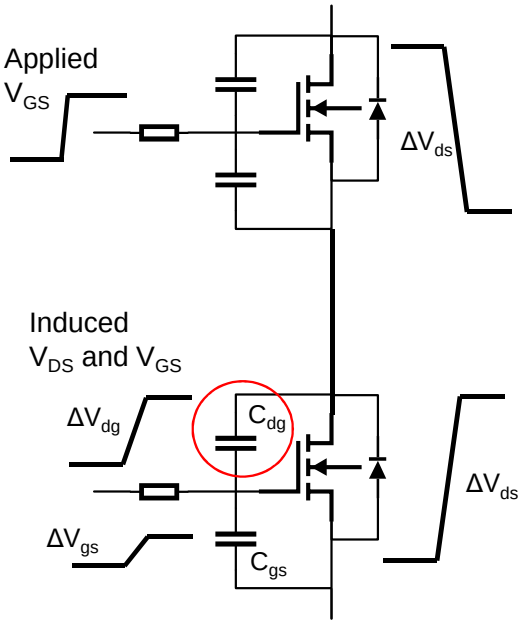
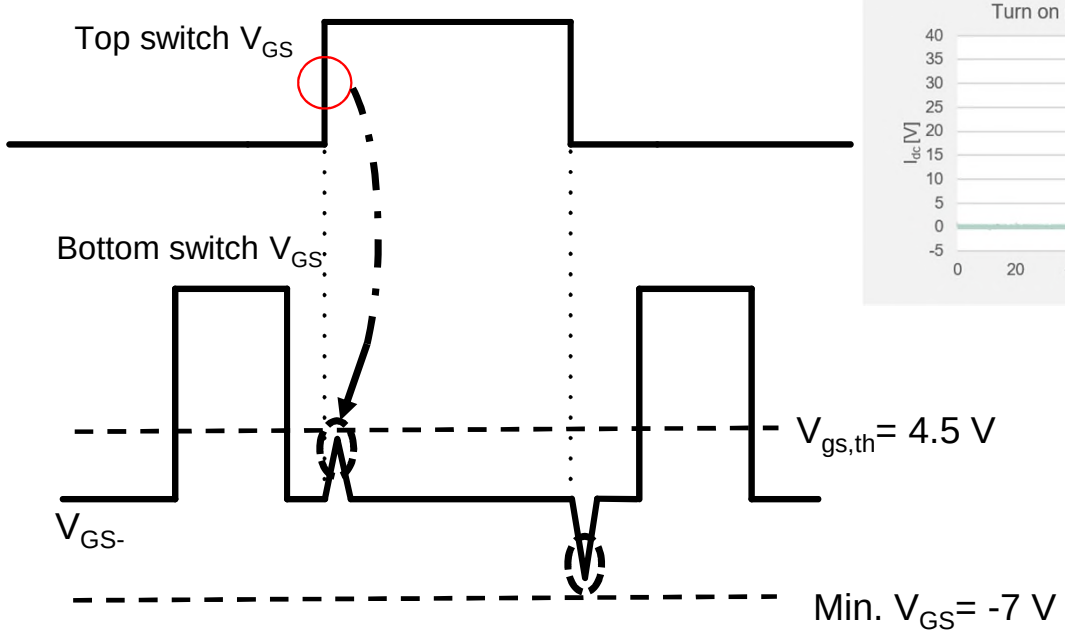
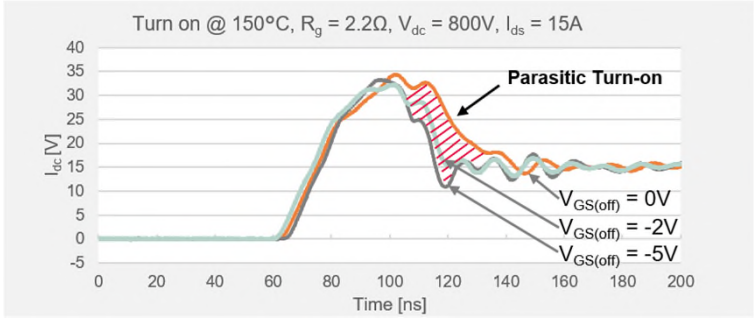
Parasitic dV/dt turn-on due to Miller capacitance C_{dg}





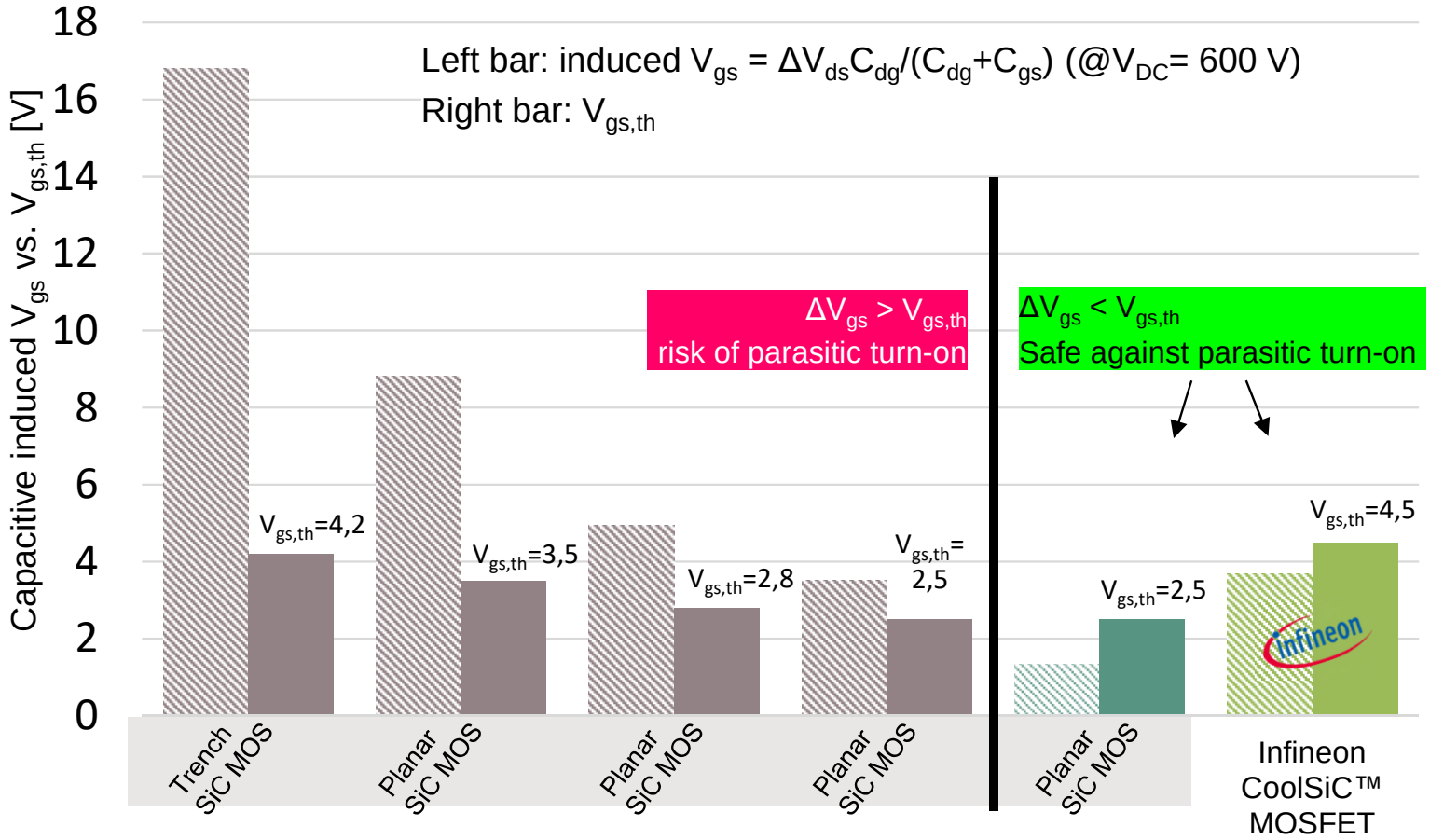


How to avoid parasitic dV/dt turn on ?

- Use MOSFET with high $V_{GS,TH}$
- Use MOSFET with low capacitance ratio C_{DG} / C_{GS}
- *Increased negative V_{GS}*
- *Use driver IC with Miller clamp*

Comparison of induced Vgs and threshold voltage Vgs,th as parasitic turn-on risk indicator

Datasheet comparison:



1200 V SiC MOSFET latest generation devices having a nominal on-state resistance of 60-80 mΩ, as per datasheets on supplier web pages September 2019

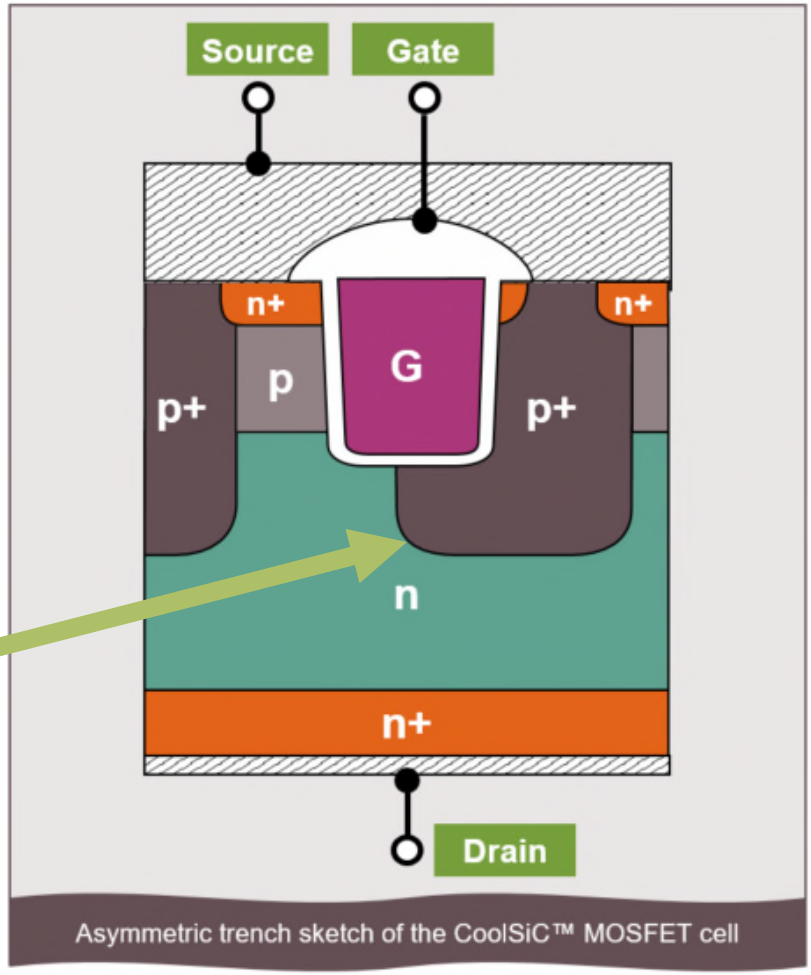
Infineon SiC MOSFET technology solution

- Trench-based structure with P+-well shielding gate-to-drain capacitance

- Turn-off at 0V Vgs to eliminate $V_{GS,TH}$ drift
- No parasitic turn-on due to
  - high threshold voltage V_{GSTH}, AND
  - low capacitance ratio C_{DG} / C_{GS}

Robust body-diode

- Trench bottom embedded into a p+ region
- Enhances the body diode area
- Shielding of gate-to-drain capacitance



Asymmetric trench sketch of the CoolSiC™ MOSFET cell

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4. **Diode robustness**
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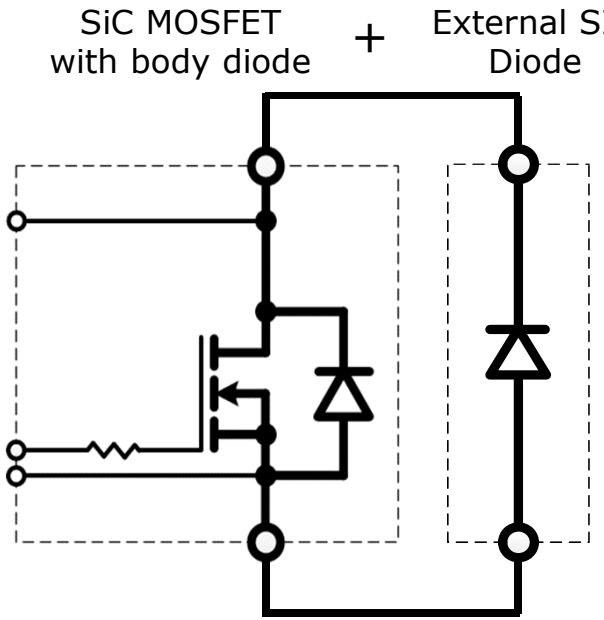
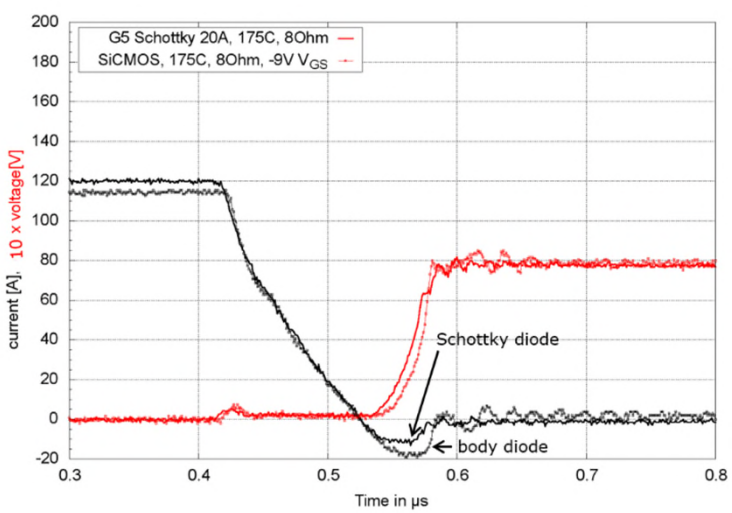
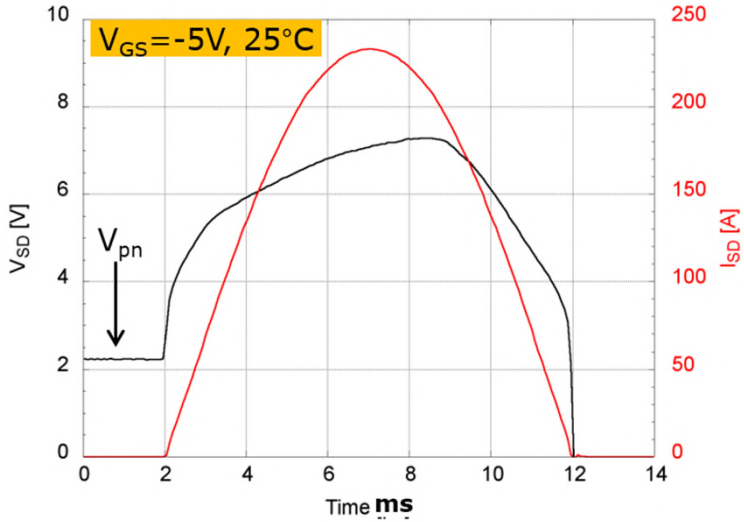
Can the body diode of SiC MOS be used for hard commutation?



- If the SiC MOSFET body diode does not have the required dynamic switching performance, a separate external SiC diode **is** required
- Infineon CoolSiC™ MOSFET **does not** requires use of external SiC diode



Diode commutation during reverse recovery



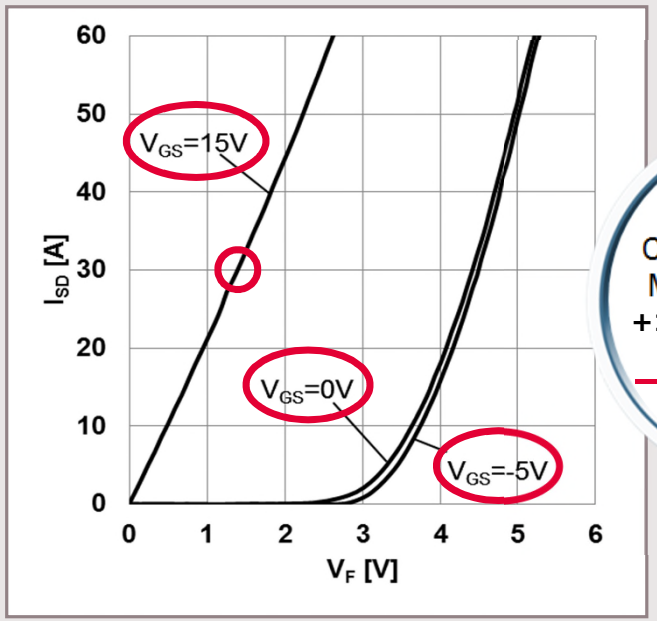
Body diode non-repetitive surge current behavior

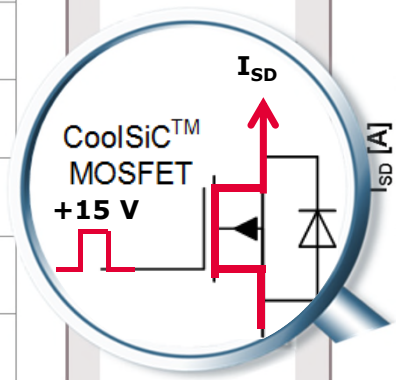
- Bipolar degradatiom of body diode is eliminated by quality assurance processes in production

Body diode and synchronous rectifier mode

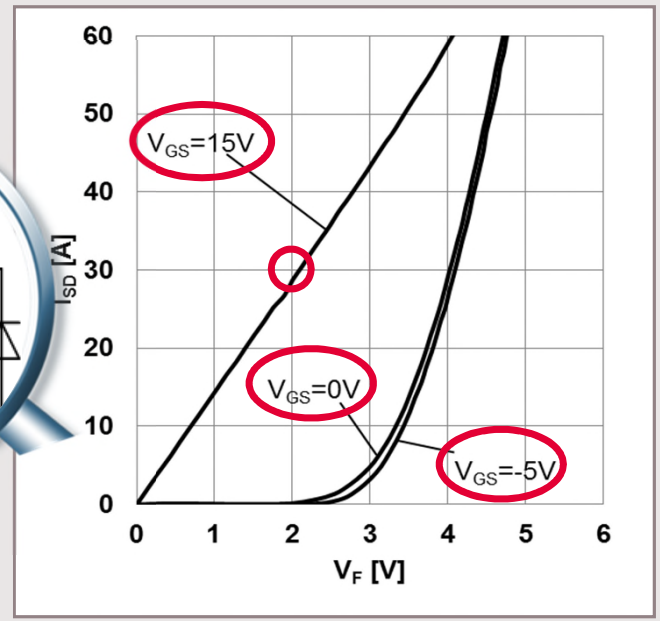
Reverse current V_{SD} as function of voltage at different gate voltages and temperature

T_j= 25ºC





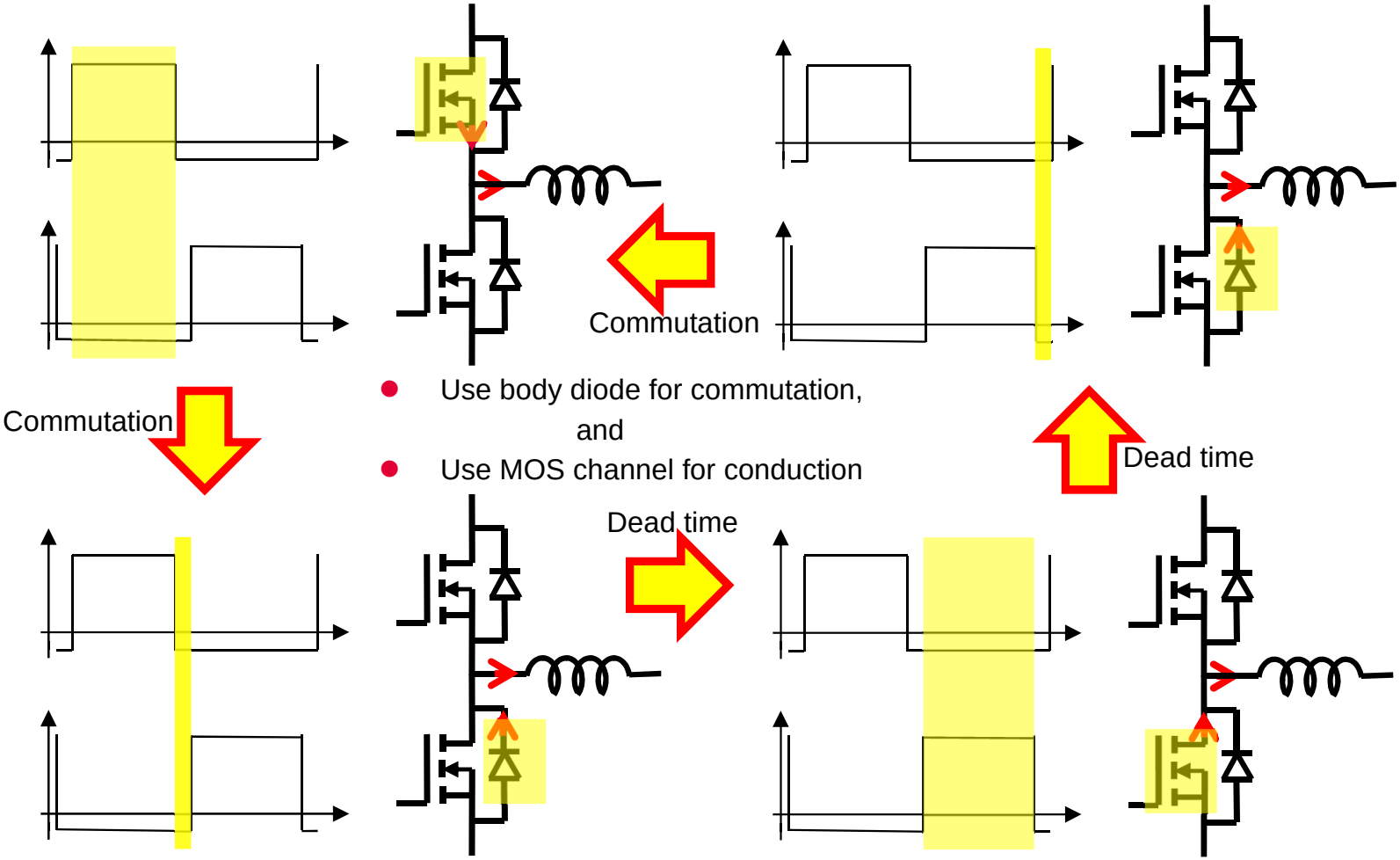
T_j= 175ºC



Sync Rect benefit: ease of devices' paralleling operation

Body diode and synchronous rectifier mode

- 3rd quadrant operation principle



- Use body diode for commutation, and
- Use MOS channel for conduction

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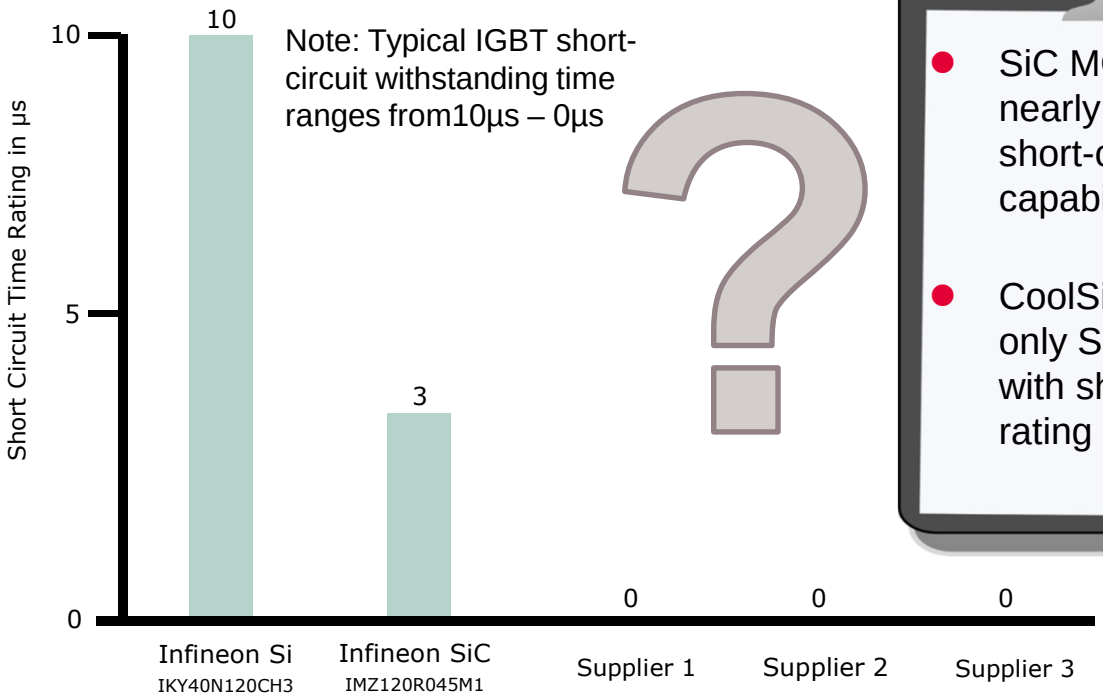
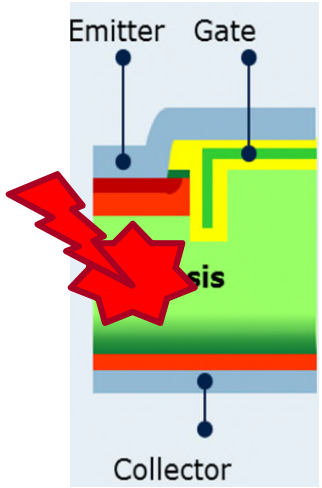
Compare short-circuit capabilities of Si IGBT vs SiC MOS



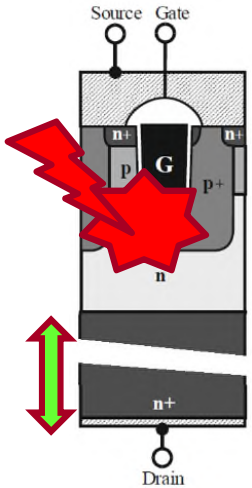
Note: Typical IGBT short-circuit withstanding time ranges from10µs – 0µs

- SiC MOSFETs nearly do not have short-circuit capability
- CoolSiC™ is the only SiC MOSFET with short-circuit rating (2~3 µs max)

IGBT heat location during S/C - bulk



SiC MOSFET heat location during S/C – epitaxial layer



Infineon's CoolSiC™ SiC MOSFET with flexible gate voltage range and exclusive short-circuit rating

M1H series:

IMW120R030M1H

IMW120R030M1H

CoolSiC™ 1200V SiC Trench MOSFET
Silicon Carbide MOSFET

Features

- Very low switching losses
- Threshold-free on state characteristic
- Wide gate-source voltage range
- Benchmark gate threshold voltage, $V_{GS(th)}$ = 4.5V
- 0V turn-off gate voltage for easy and simple gate drive
- Fully controllable dV/dt
- Robust body diode for hard commutation
- Temperature independent turn-off switching losses

Benefits

- Efficiency improvement
- Enabling higher frequency
- Increased power density
- Cooling effort reduction
- Reduction of system complexity and cost

Potential applications

- Energy generation
  - Solar string inverter and solar optimizer
- Industrial power supplies
  - Industrial UPS
  - Industrial SMPS
- Infrastructure – Charge
  - Charger

Green
RoHS

Product validation

Qualified for industrial applications according to the relevant tests of JEDEC 47/20/22

Table 1 Key Performance and Package Parameters

Type	V_{DS}	I_D	$R_{DS(on)}$	$T_{vj,max}$	Marking	Package
IMW120R030M1H	1200V	56A	30mΩ	175°C	12M1H030	PG-TO247-3

Datasheet Please read the important Notice and Warnings at the end of this document 2.0
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Typ and Max $R_{DS(on)}$ @ $V_{gs,on}$ = 15, 18 V

- **$V_{gs,on}$ = 18 V**
  - Highest power handling capability through lower R_{DSon}
- **$V_{gs,on}$ = 15 V**
  - Short-circuit capability 3µs specified under Maximum ratings:

Short-circuit withstand time V_{DD} = 800V, $V_{DS,peak}$ < 1200V, $V_{GS,on}$ = 15V, $T_{j,start}$ = 25°C	t_{SC}	3	µs

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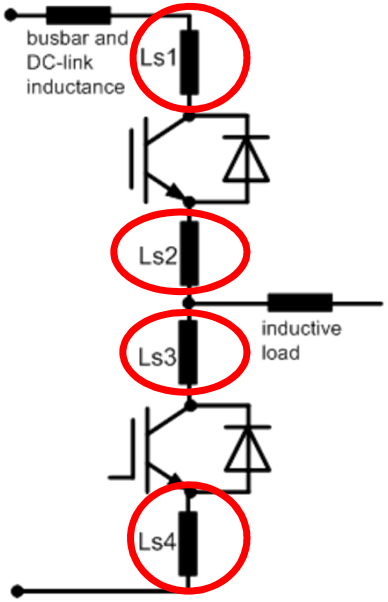
High-speed SiC MOS requires high-speed package

- Turn-off voltage overshoot peak $V_p = L_S$ di/dt
- Most IGBT module packages today have stray inductance L_S too high for SiC MOS

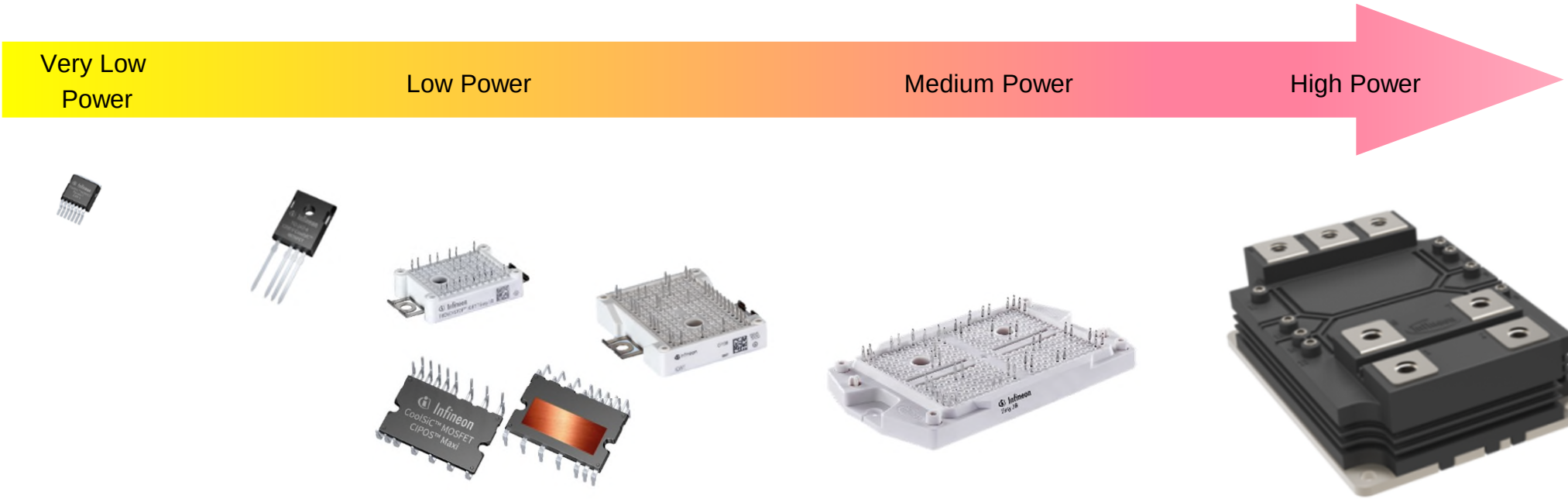
Ls too high

Ls ~OK



High-speed SiC MOS requires high-speed package

- The fast di/dt of SiC MOS requires package stray inductance be substantially reduced across all power levels



Summary

		Reliability	Robustness	Performance
1	Gate oxide reliability	√		
2	dV/dt turn-on robustness		√	
2	Diode robustness	√	√	√
4	Short-circuit rating		√	
5	Gate voltage range			√
6	Package			√

Part of your life. Part of tomorrow.

Infineon