Next-Gen Motor Drives : Exploring SiC

Didier Balocco, PSG EMEA Marketing, onsemi

Bodo's Wide Bandgap Event 2025

Making WBG Designs Happen

SiC

Next-Gen Motor Drives : Exploring SiC

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Motor Drive requirements and limiting factors

Requirements for a Drive and for Switches in Drives' Inverter

Drive requirements

- Low-cost solution
- Robust
- Long lifetime
- EMI compliant

Minor factors

- Efficiency
- Size

Electronic Switches requirements

- Short Circuit rated
- Peak current capability
- Easy implementation/design

Motor Limiting factors

- The motor winding is used as a low pass filter for the high frequency content generated by the switching inverter.
- Motor winding wires are isolated with a varnish.

- High dV/dt cannot be handle by the varnish.

Present Solution :

- Limit dV/dt by increasing the gate resistor.
- Integrated solutions (Switches+Drivers in one package) are less sensible to noise.

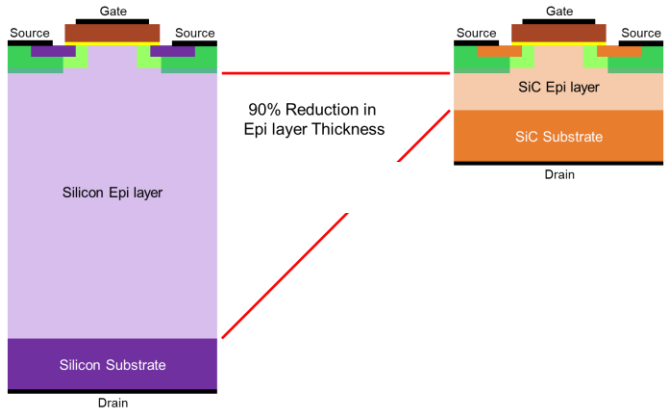
SiC performances vs IGBT

Comparison of Material Properties

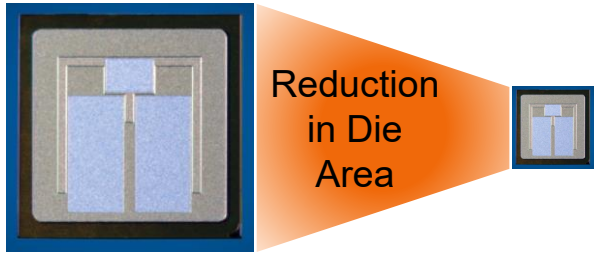
§ Critical Electric Field along c-axis for vertical power devices

Key Material Properties		
Electrical Property	**Silicon (Si)**	**Silicon Carbide (4H-SiC)**
Bandgap (eV)	1.12	3.26
Critical Electric Field (MV/cm)	0.3	3.0§
Saturated Electron Velocity (× 10^7 cm/s)	1	2
Thermal Conductivity (W/cm·K)	1.3	3.3

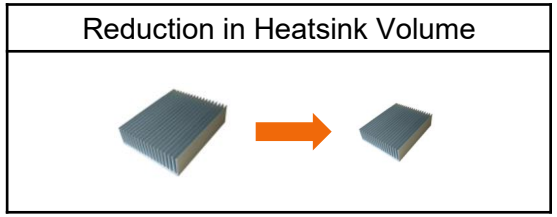
- 90% Lower Resistance
- Higher Voltage Devices



- Higher Current Density
- Faster Switching

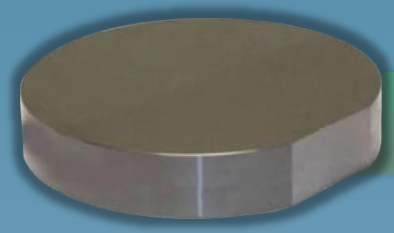


- Faster Heat Removal
- Less Complex Cooling



SiC Supply Assurance: From Substrate to Modules

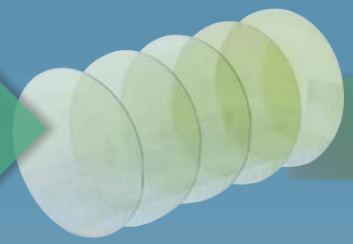
SiC Substrates



- 150/200mm SiC wafering internal in onsemi today

Hudson, NH, USA
(Roznov, CZ)

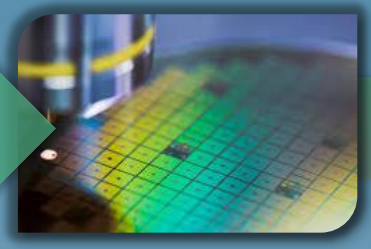
SiC Epi



- 150/200mm SiC epi internal in onsemi today

Bucheon, KR
Roznov, CZ

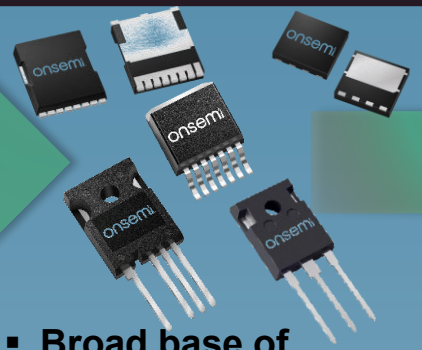
SiC Fab



- Fabs ready today for 150mm →200mm migration

Bucheon, KR
(Roznov, CZ)

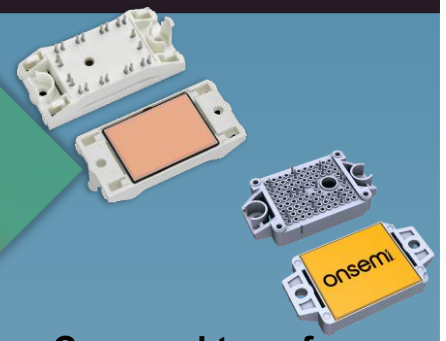
SiC Devices / Die



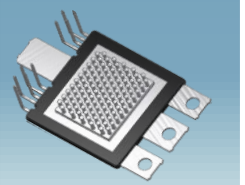
- Broad base of packages
- Die only & metal options
- Auto & Industrial devices

Binh Duong Province, VN
Suzhou, CN
Shenzhen, CN
Seremban, MY

SiC Modules



- Case and transfer molded options
- Full portfolio of half & full bridge modules
- Single & dual cooling, direct & indirect

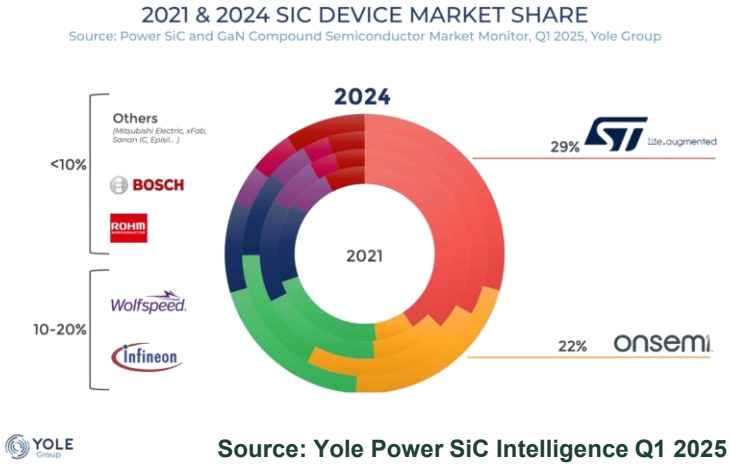


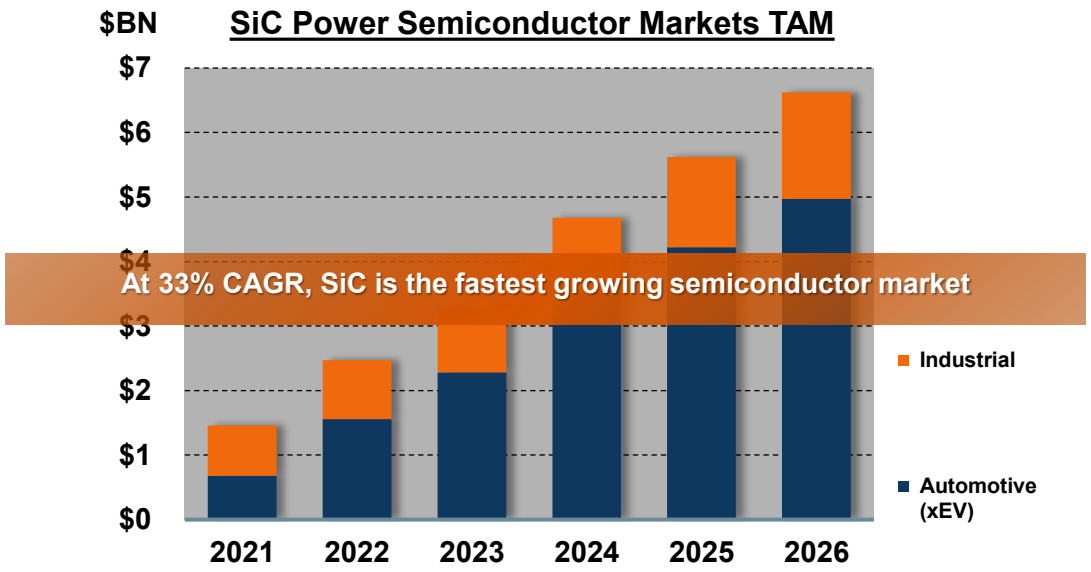
onsemi's end to end capabilities drive superior performance and quality

The Power Semiconductor Market Outlook :

EliteSiC

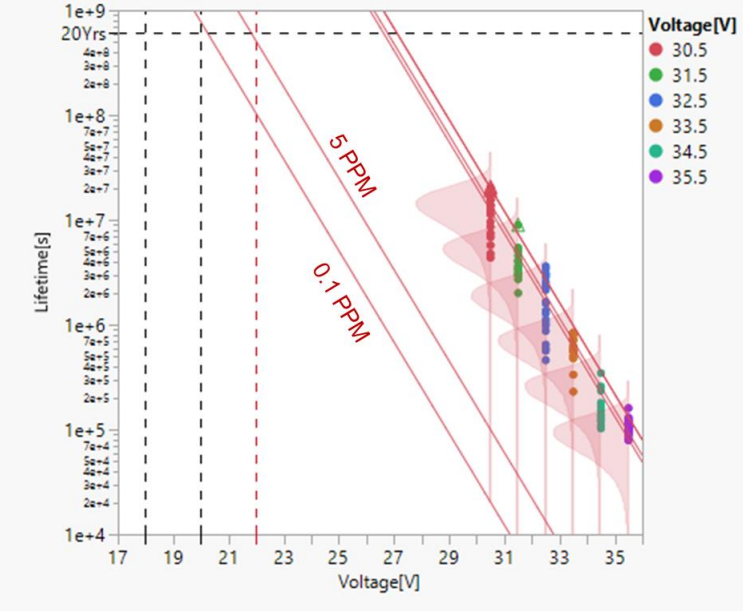
- **Power Semiconductor Market by 2028**
  - Total power marked forecasted to be $41B
  - SiC expected to be 23% or $9.4B
  - (Less than 20% is forecasted to be on 8inch..)
  - GaN is expected to be $2.2B
  - Parts of GaN market can be addressed with SiC Cascode
- **Automotive market ~70%**
  - eV Traction is KEY !
  - OBC, DCDC & BMS is significant
  - Adjacent such as Aircon
- **Industrial Market ~30%**
  - Renewables: Solar & Wind
  - Energy infrastructure ESS, UPS & EV Charging
  - + Servo Drives, Plasma cutting, Welding, Water Cookers, CT scanners +++



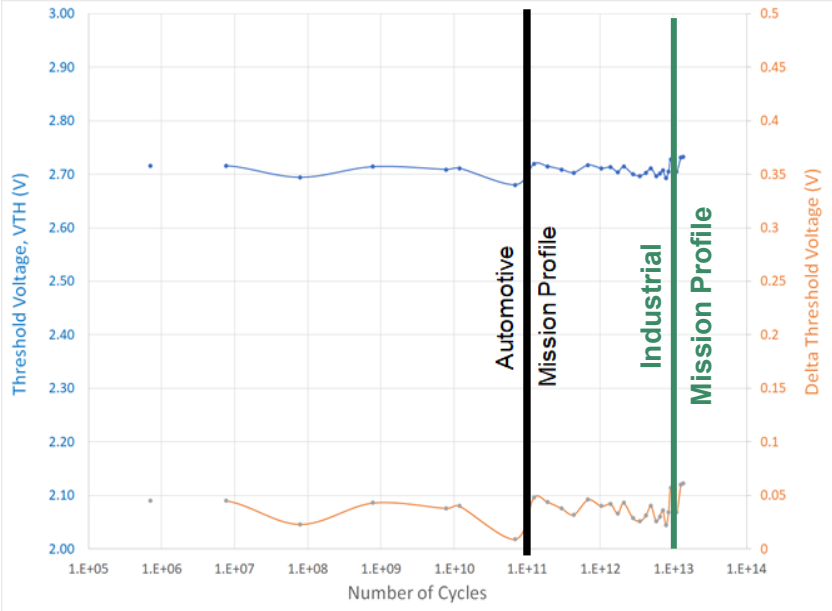


Generation M3S Reliability

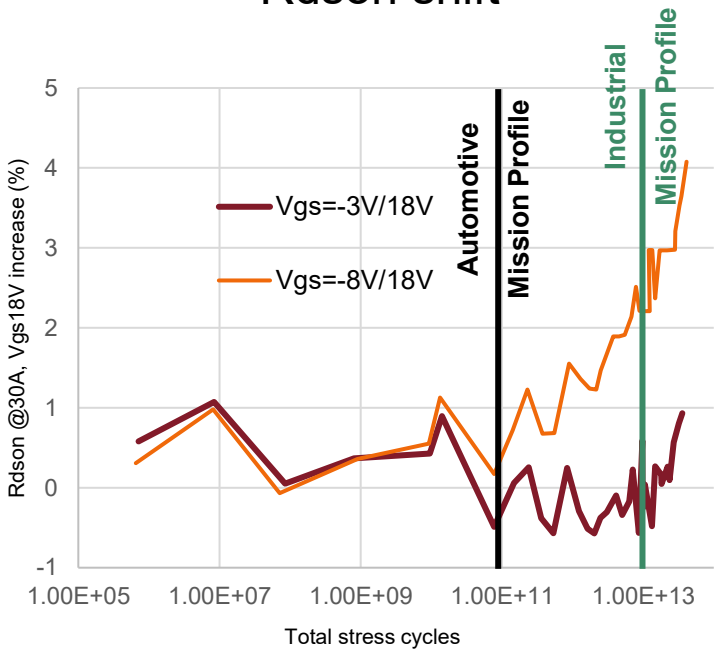
Intrinsic Gate Lifetime at 175°C



Gate Threshold, Vth



Rdson shift



At maximum operational V_{GS} = 18V, onsemi gate oxides demonstrate failure rates well below 1PPM achieved from optimized process and burn-in

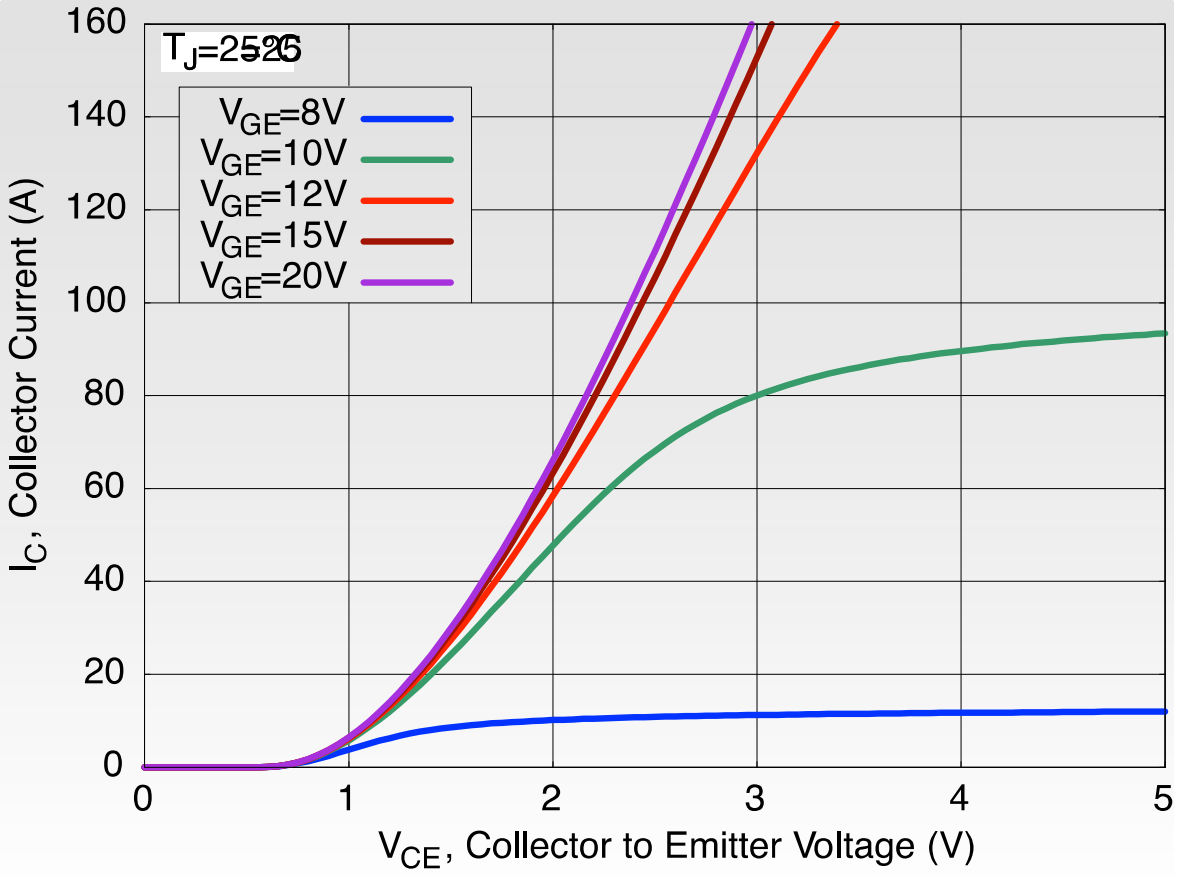
Only 50mV of threshold voltage shift observed after 1E11 cycles of gate switching (-3V to 18V) at 25°C.

Only 1% of Rdson shift observed after 1E13 cycles of gate switching (-3V to 18V) at 25°C.

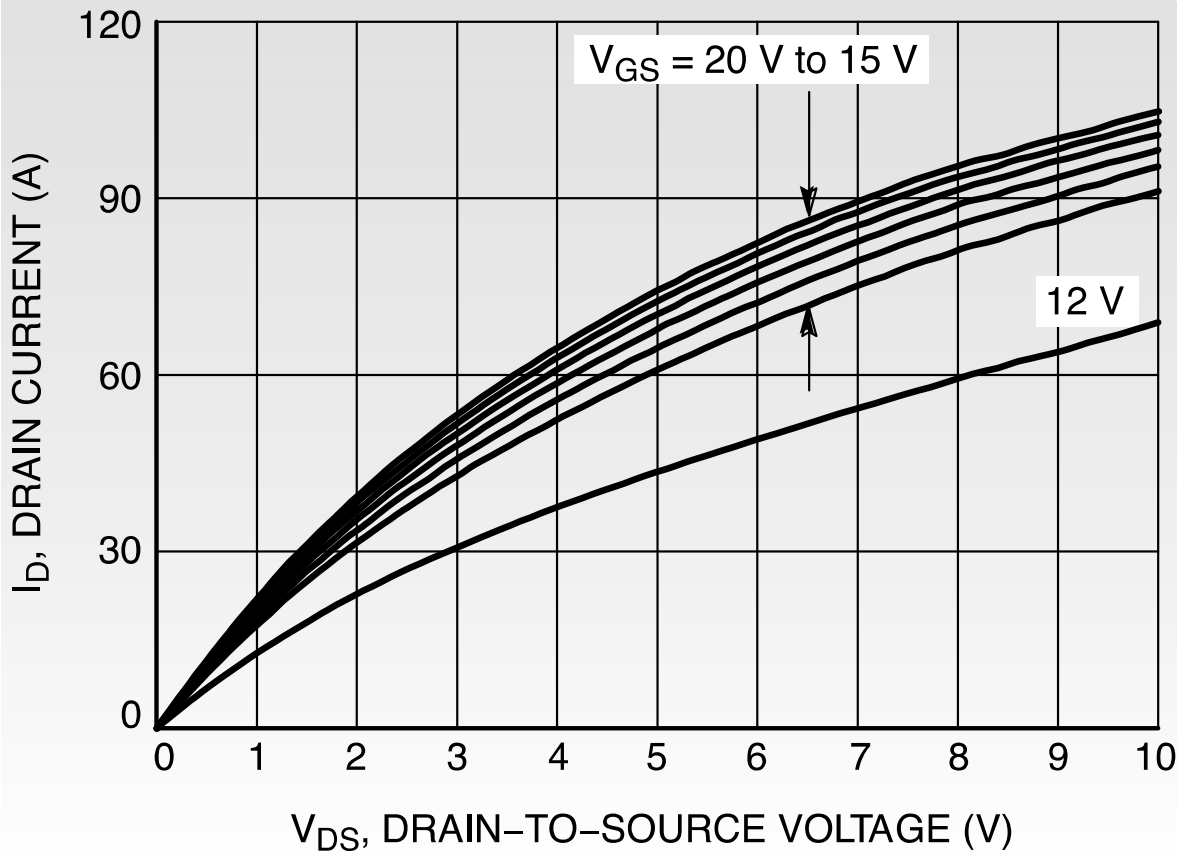
Why SiC in motor drives ?

On-Region comparison (for 40A device at 100°C)

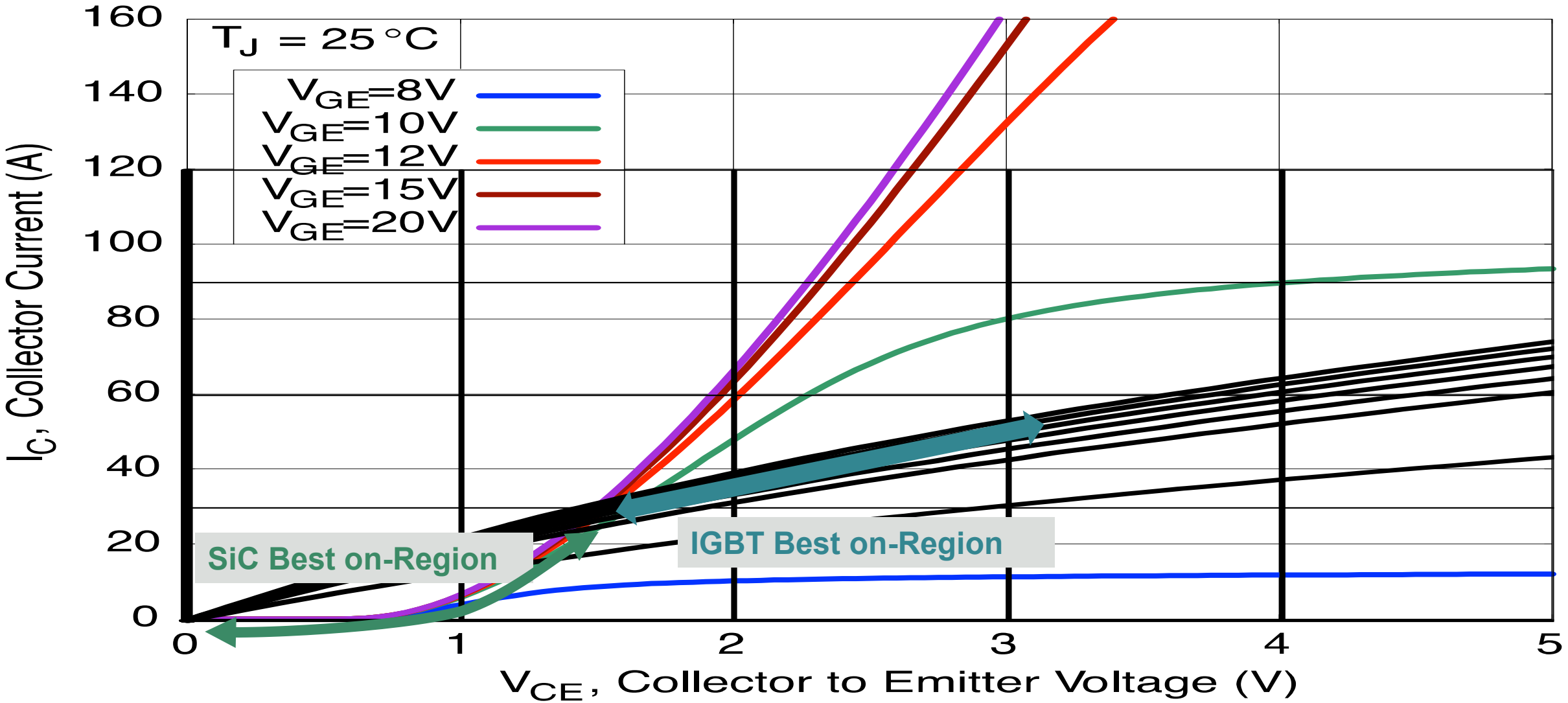
IGBT 40A @ 100°C



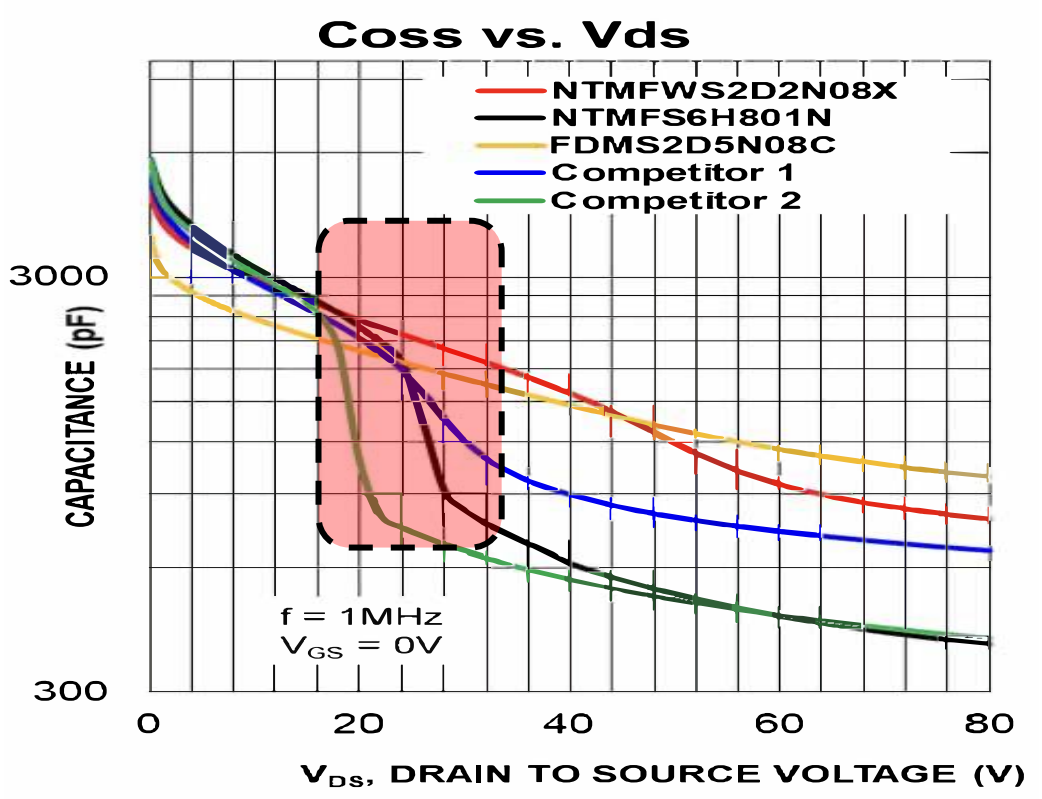
SiC 40mΩ => 40A max @ 100°C

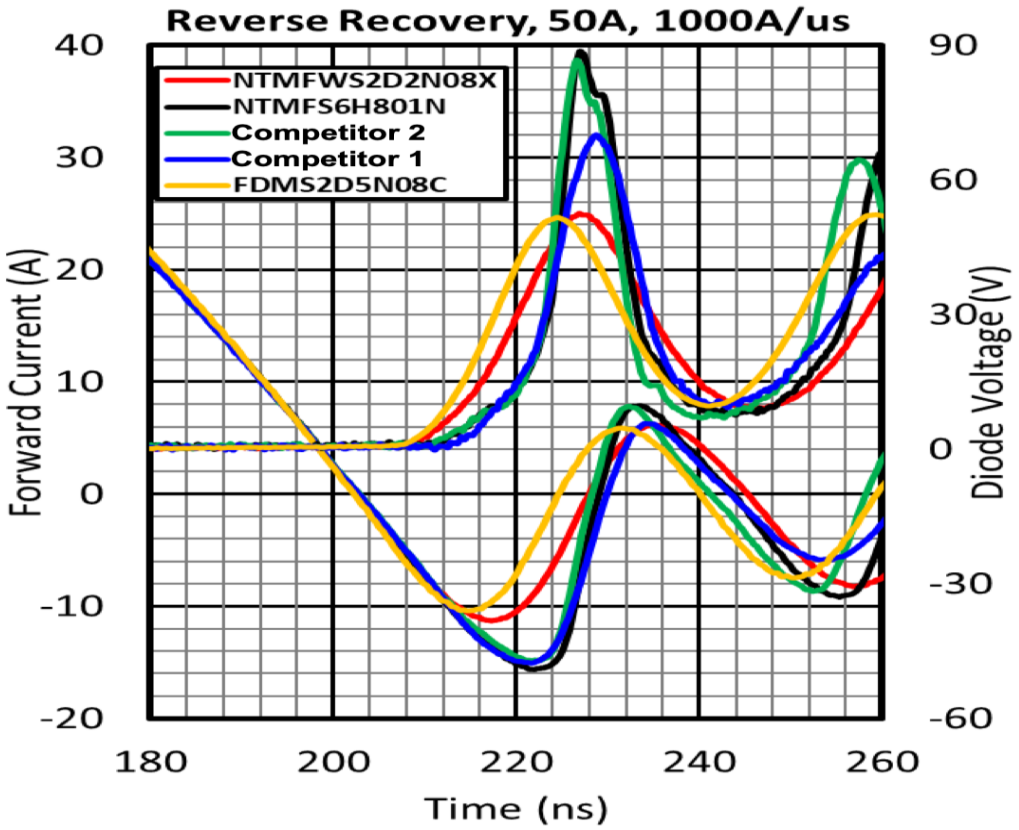


On-Region comparison (for 40A device at 100°C)



Coss and Qrr optimization - T10 80V (NTMFWS2D2N08X)

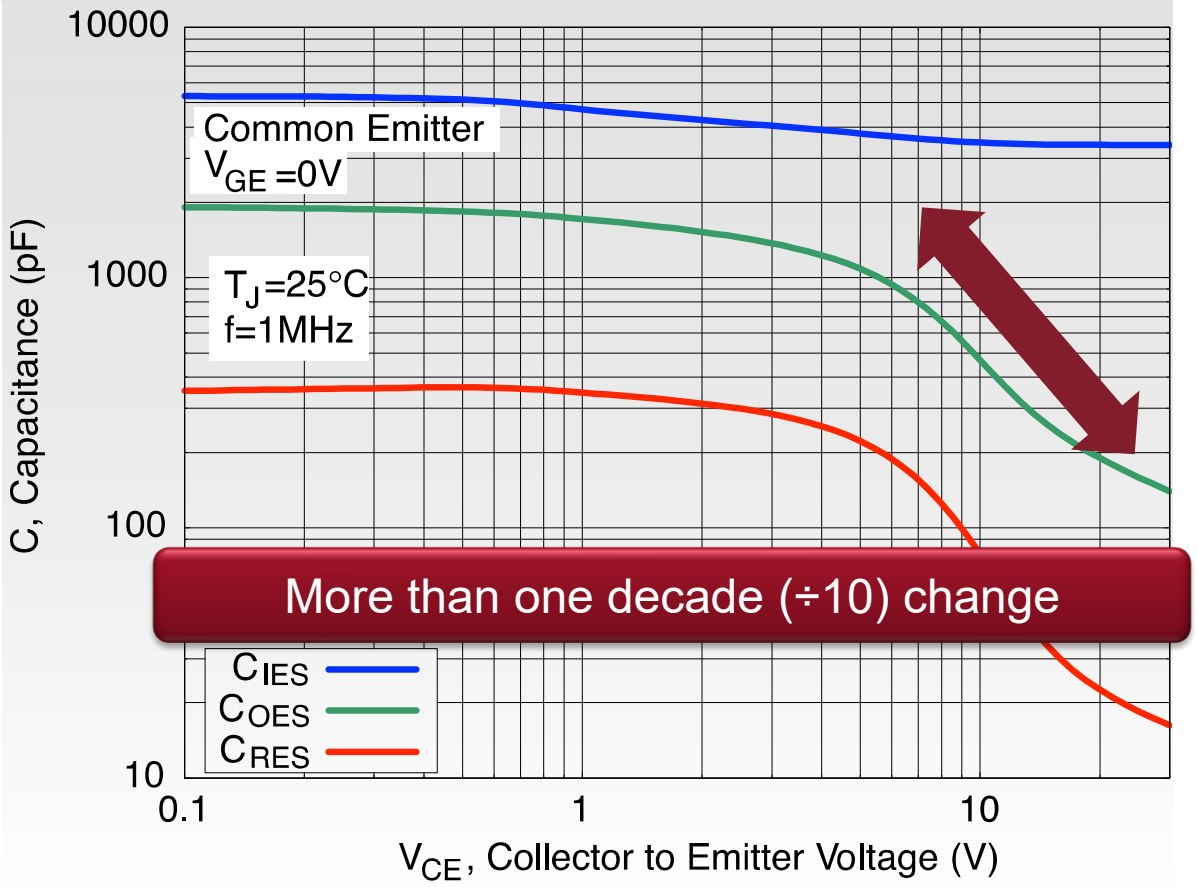




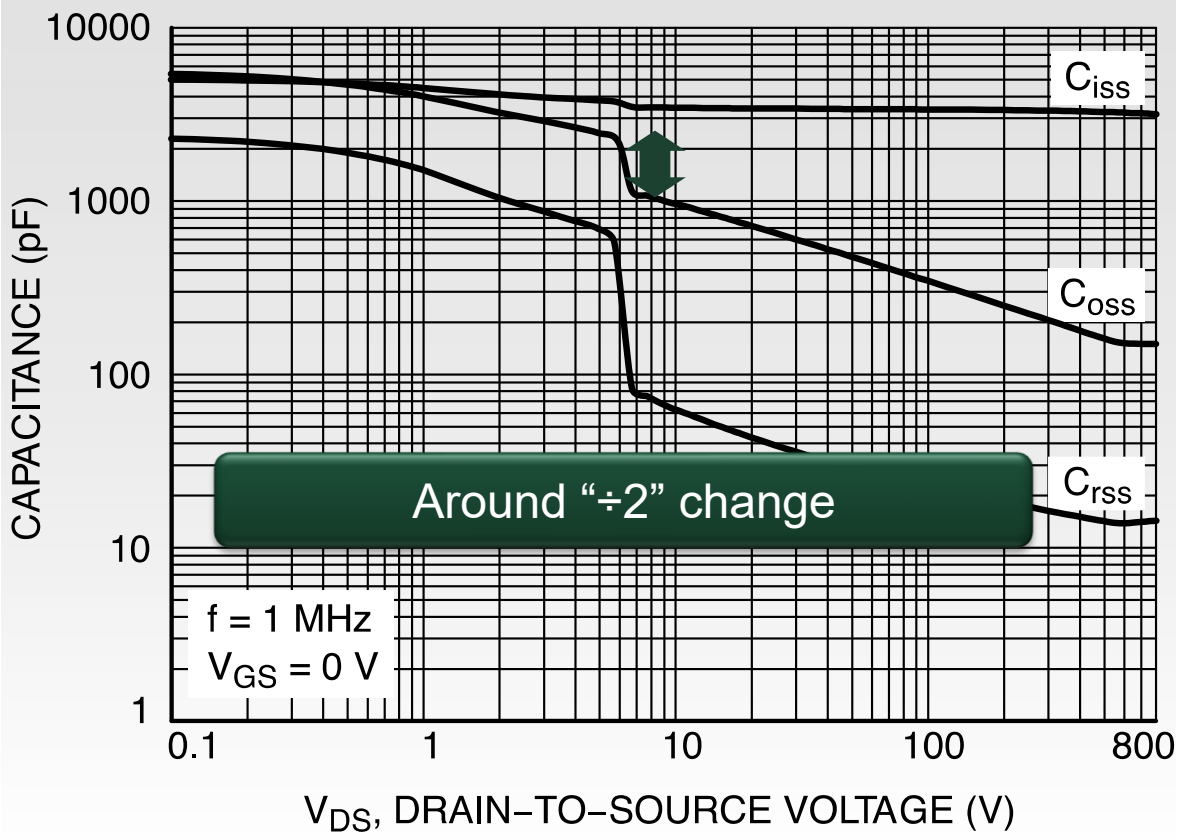
The larger the step in Output Capacitor, the higher overvoltage and steeper the reverse recovery

Output Capacitor comparison

IGBT

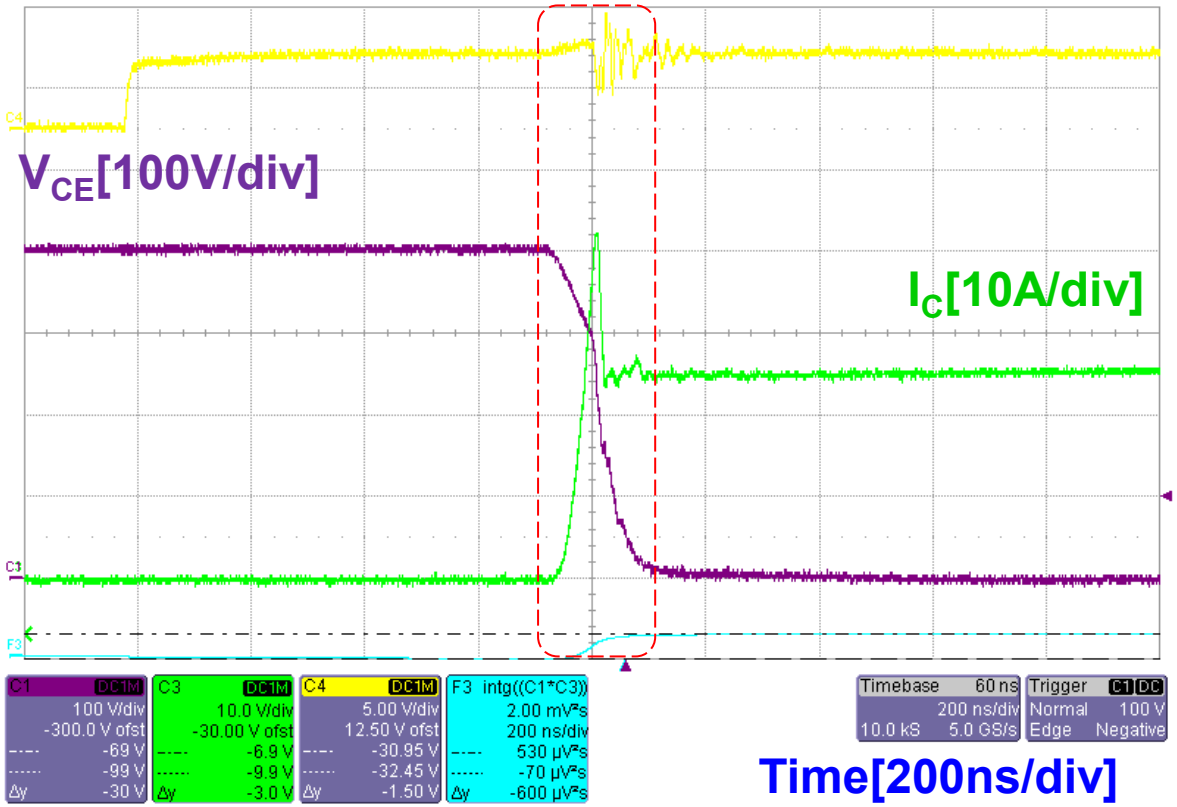


SiC MOSFET

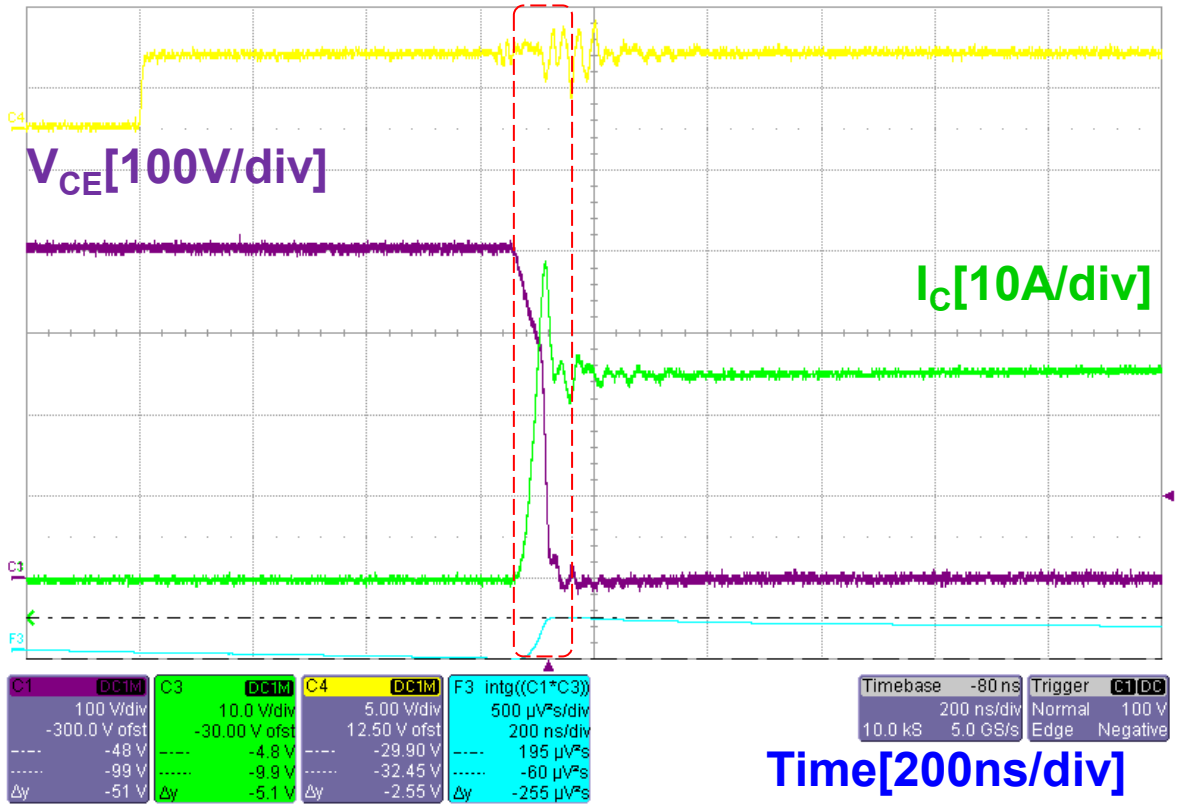


Switching Performances (@ same maximum dV/dt)

IGBT



SiC



- Lower peak current or lower reverse current
- No tail current
- Lower transition duration ➢ Lower losses

onsemi proposal

onsemi IPM All in One Technology

Substrate

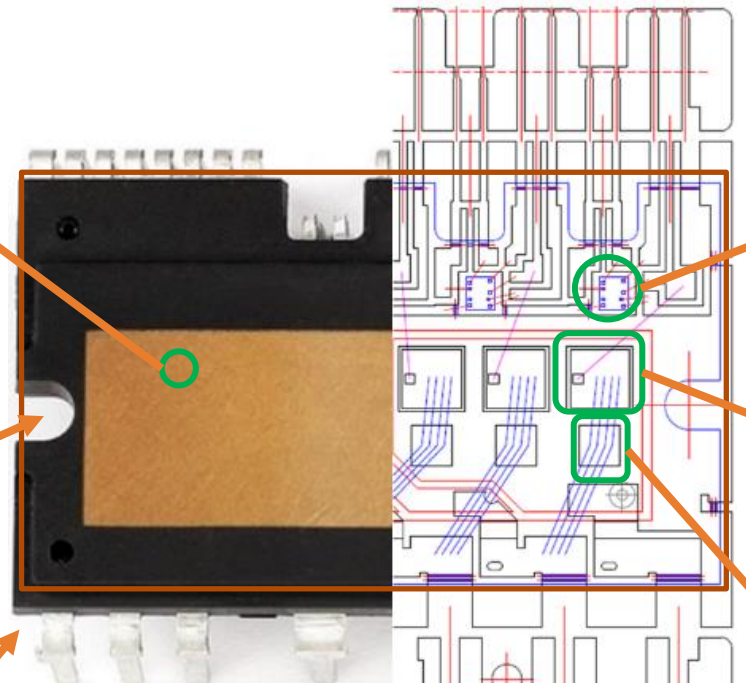
DBC substrate (AIN/Al2O3)
IMST substrate
Ceramic substrate
Full Mold PKG

Passive Component

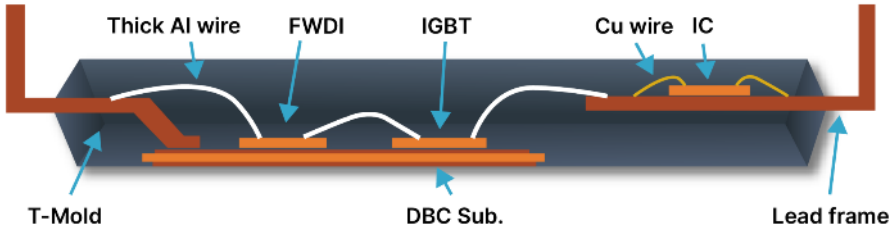
Shunt resistor
NTC thermistor
Ceramic capacitors / Resistors

Variety Topology

3-phase topology
PFC : Interleaved / Bridge-less / Boost



Exterior outline *Internal Structure*



Gate Driver Unit

IGBT/MOSFET control
Protection function

Power Switch

650V FS3/4 Trench SCR IGBT
1200V FSII Trench SCR IGBT
Super Junction SF2/3 MOSFET
Planar UniFET MOSFET
650V FS4 RC IGBT 1200V FS7 IGBT
1200V SiC MOSFET

Power Diode

800V/1600V Hyper Fast Diode
650V /1200V Extreme Fast Diode
650V SiC Diode
1200V Gen7 Diode

IGBT SPM®31 (Mini)

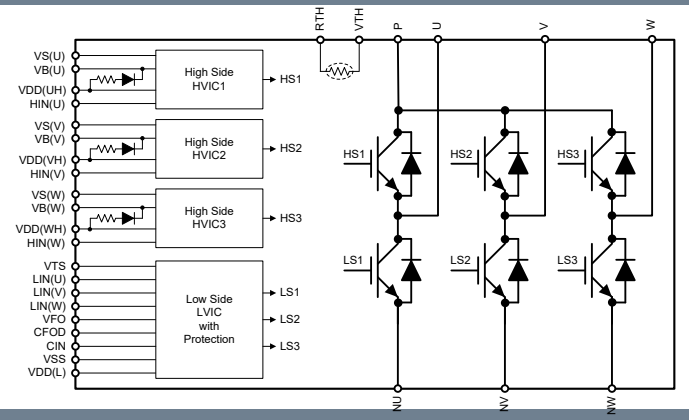
Features

- Pin compatible with ‘M’ Competitor Mini DIP
- Advanced Trench SC rated IGBT
- Very low thermal resistance with DBC substrate
- Built-in real NTC on DBC(Option), bootstrap diodes
- No side dummy for more creepage

Benefits

- All these part is pin-compatible
- Wide product coverage ; 20A~50A/650V, 15~35A/1200V
- Superior thermal performance and low loss

Block Diagram



Specifications

1200V Line up

Product	Voltage	Current	$V_{CE(SAT)}$ typ.	IGBT	Substrate	Remark
NFAM1512L7B	1200V	15A	1.50V	FS7	DBC(Al2O3)	MP
NFAM2512L7B	1200V	25A	1.50V	FS7	DBC(Al2O3)	
NFAM3512L7B	1200V	35A	1.60V	FS7	DBC(Al2O3)	

650V Line up

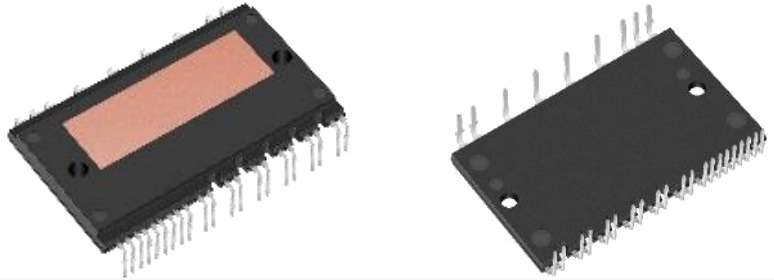
Product	Voltage	Current	$V_{CE(SAT)}$ typ.	Substrate	Status
NFAM2065L4B(T)	650V	20A	1.6V	DBC(Al2O3)	MP
NFAM3065L4B(T)	650V	30A	1.6V	DBC(Al2O3)	MP
NFAM5065L4B(T)	650V	50A	1.65V	DBC(Al2O3)	MP

T: NTC option

Target Applications

- HVAC, Heat Pumps, Commercial Air conditioner
- Industrial Pumps
- Variable frequency drive
- Servo drive, Robotics
- Industrial Fans

Package ; 54.5 mm × 31 mm × 5.6 mm



SiC SPM®31 (Mini)

Features

- 1200V M3P SiC MOSFET (Vgs : 0V ~ 18V)
- Miller Clamp function into gate drivers
- Pin compatible with ‘M’ Competitor Mini DIP & onsemi IGBT SPM31
- Low thermal resistance with DBC substrate
- Built in bootstrap circuit
- NTC thermistor for junction temperature monitoring
- Temperature sensing and output voltage function in LVIC
- No side dummy for more creepage
- High power density, High efficiency, Fast switching capability

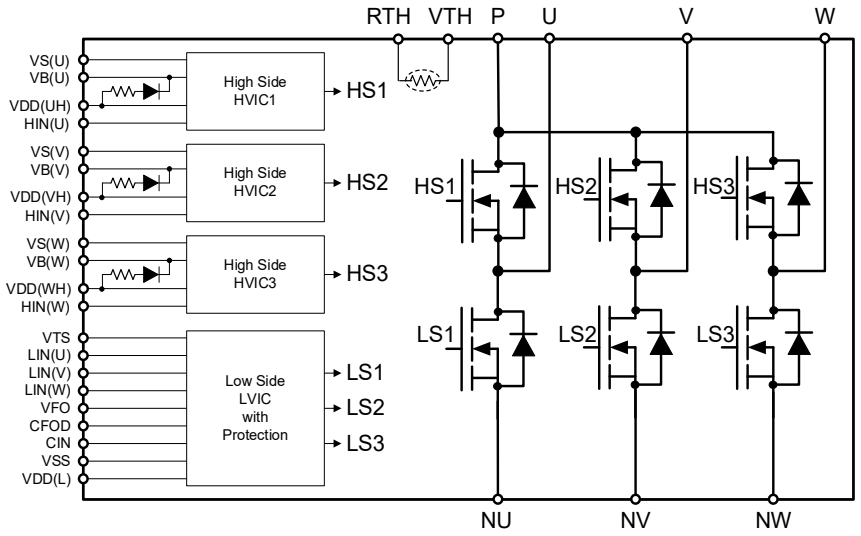
1200V Line-up

Product	Voltage	Rds(on)	Substrate	Remark
NFAM5312SCBUT	1200V	53 mΩ (40A)	DBC	MP
NFAM3812SCBUT	1200V	38 mΩ (50A)	DBC	
NFAM2512SCBUT	1200V	25 mΩ (70A)	DBC	

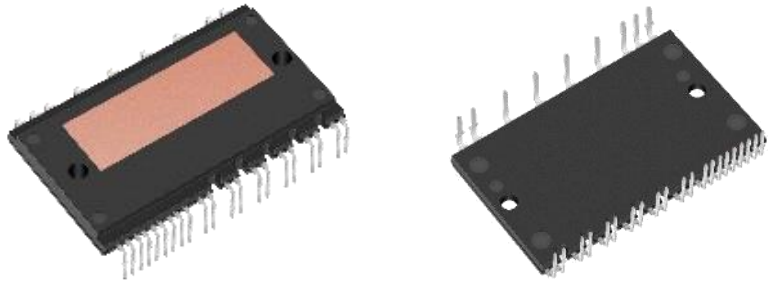
Target Application

- Servo Motor
- Industrial Inverter
- HVAC, EC Fan

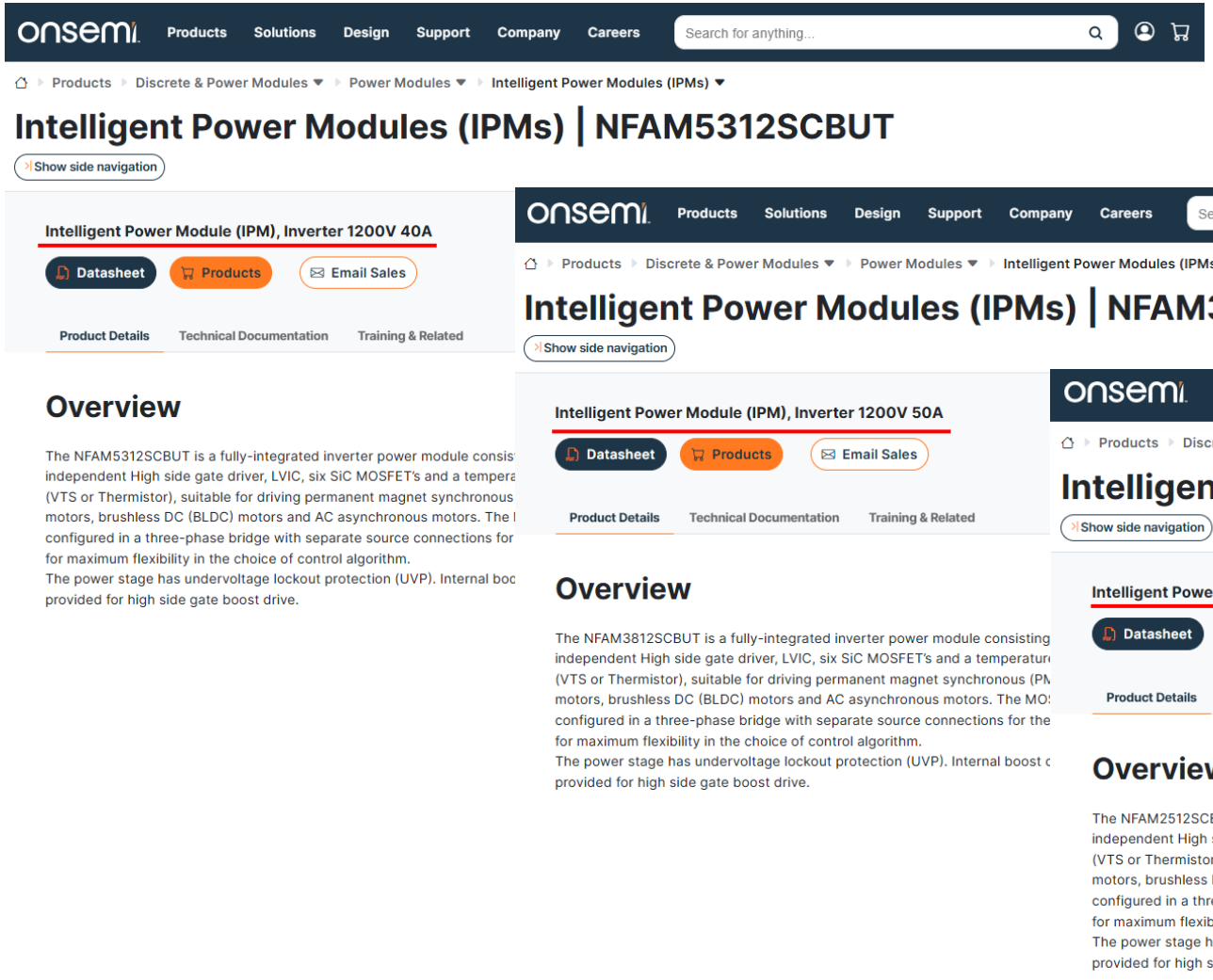
Block Diagram



Package: 54.5 mm × 31 mm × 5.6 mm



SiC SPM31 Released



Tool to compare IGBT vs SiC in motor drive applications

Ask onsemi support for assistance to use it.

SPM SiC Power saving

onsemi

BLDC Motor

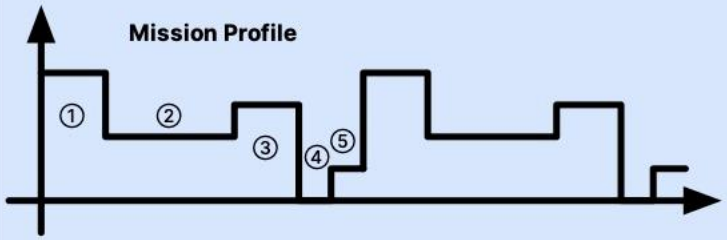
RPM (tr/min)	1800
P (kW)	6
PF / Cos Φ	95%
I (A rms)	18
R (Ohms)	0,5

Motor Drive

Bus voltage (V) :	600
Junction Temperature (°C) :	150
Life Time (Years) :	10

IGBT SPM : FSBB20CH120D	
Switching Frequency (kHz) :	5
SiC SPM : NFAM5812SCBUT	
Switching Frequency (kHz) :	20

Mission Profile



OK	Motor Power (kW)	RPM (tr/min)	I (A)	Duration
Step 1	6	1700	18	50,0%
Step 2	1	1800	3	10,0%
Step 3	3	1750	10	15,0%
Step 4	2	1775	6	25,0%
Step 5				0,0%

Price Adder ($)	26,85
Electricity Price ($/kWh)	0,3500
kg of CO2 / kWh	0,45

Losses Saving (W)	**10,42**
Total Power Saving (kWh)	**914**

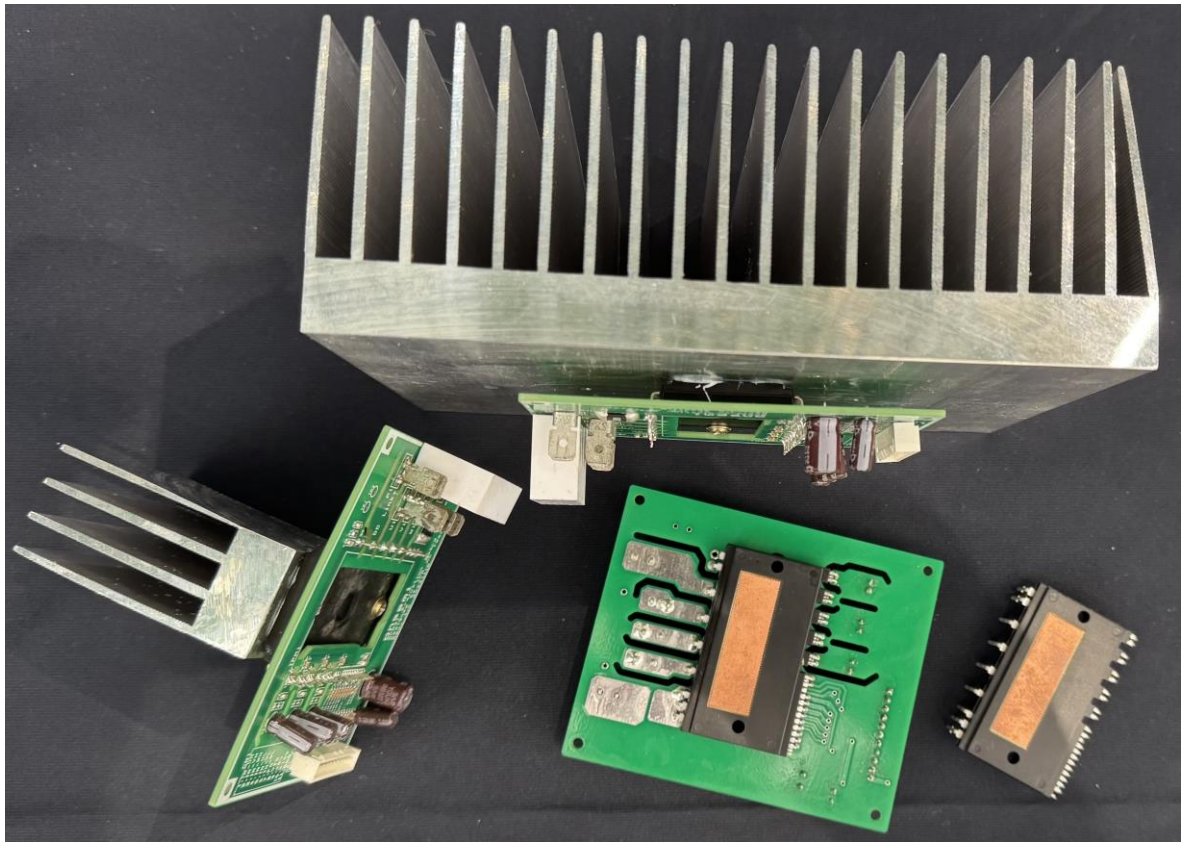
Profitable after : 0 Years 11 Months

Lifetime $ Saving $ 293

CO2 saving (kg)	**411**

Conclusion

Industrial Motor Drive



- SPM31 IGBT vs SiC
  - For Heat Pump application : 7kW motor
  - Same Junction Temperature
  - Same conditions

➢ Heatsink ratio between IGBT and SiC

12

Conclusion

- **onsemi** provides IGBT solutions for motor drive applications in discrete and modules with or without drivers included.
- In **onsemi**, we believe in SiC for medium- and high-power drive applications
- We have proven and reliable solutions for SiC Discrete and Module
- SiC MOSFETs will remain more expensive than Silicon IGBTs

For motor drive, Cost and dV/dt are critical. SiC modules have same dV/dt as IGBT ones.

- Even if SiC Motor Drives modules will be more expensive, **onsemi** demonstrates :
  - The cost of ownership will be lower with SiC
  - SiC Drives Return On Investment is positive rapidly…

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