High efficient power discretes for solar inverter

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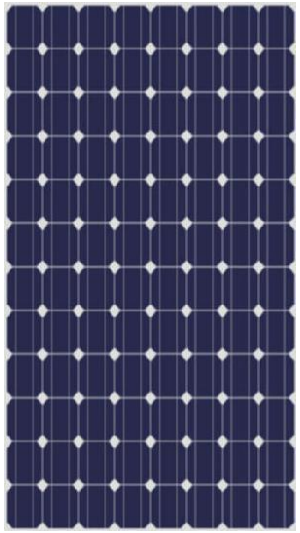
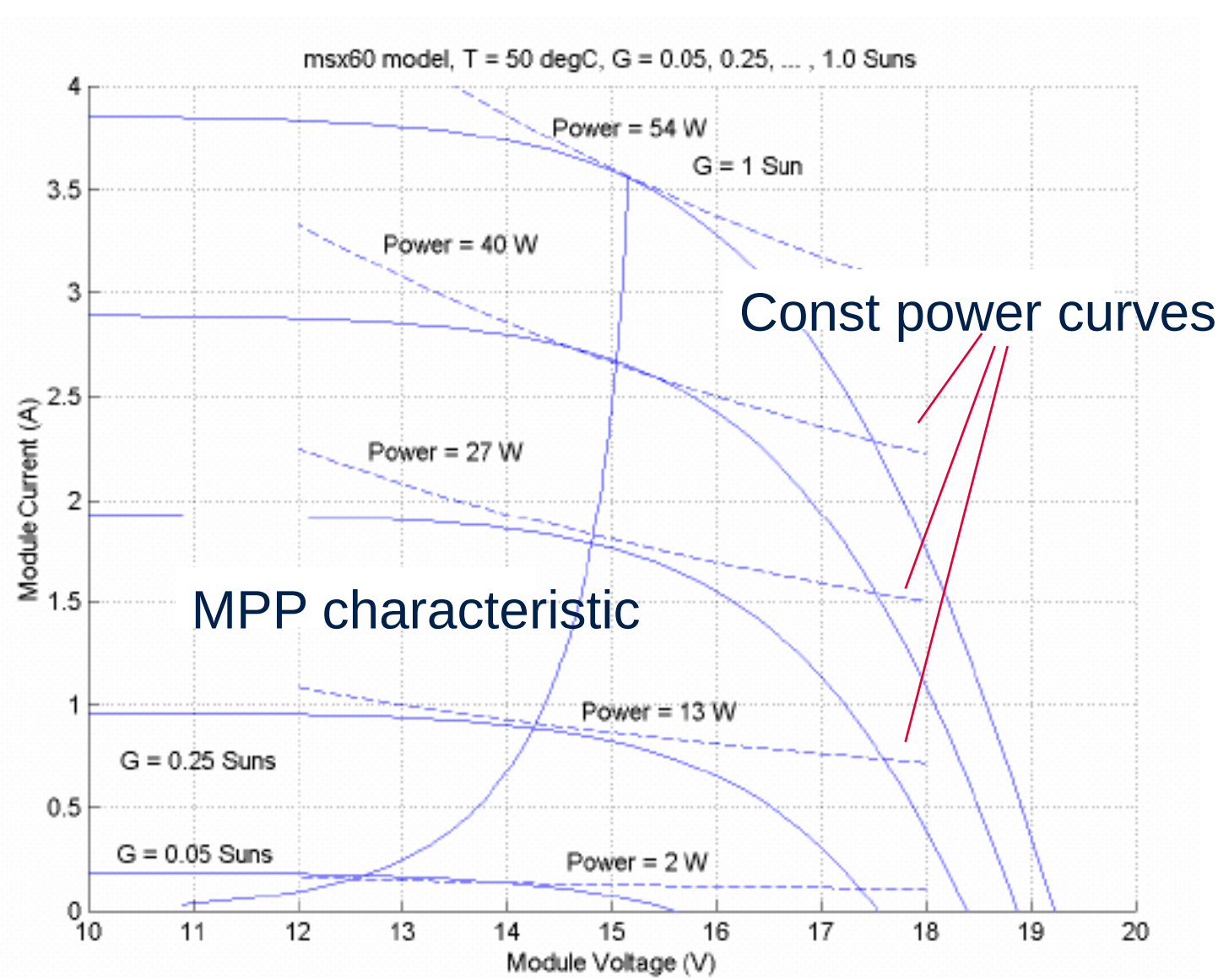
Content

Output power and I-V characteristic of a solar panel changes with sunlight and temperature

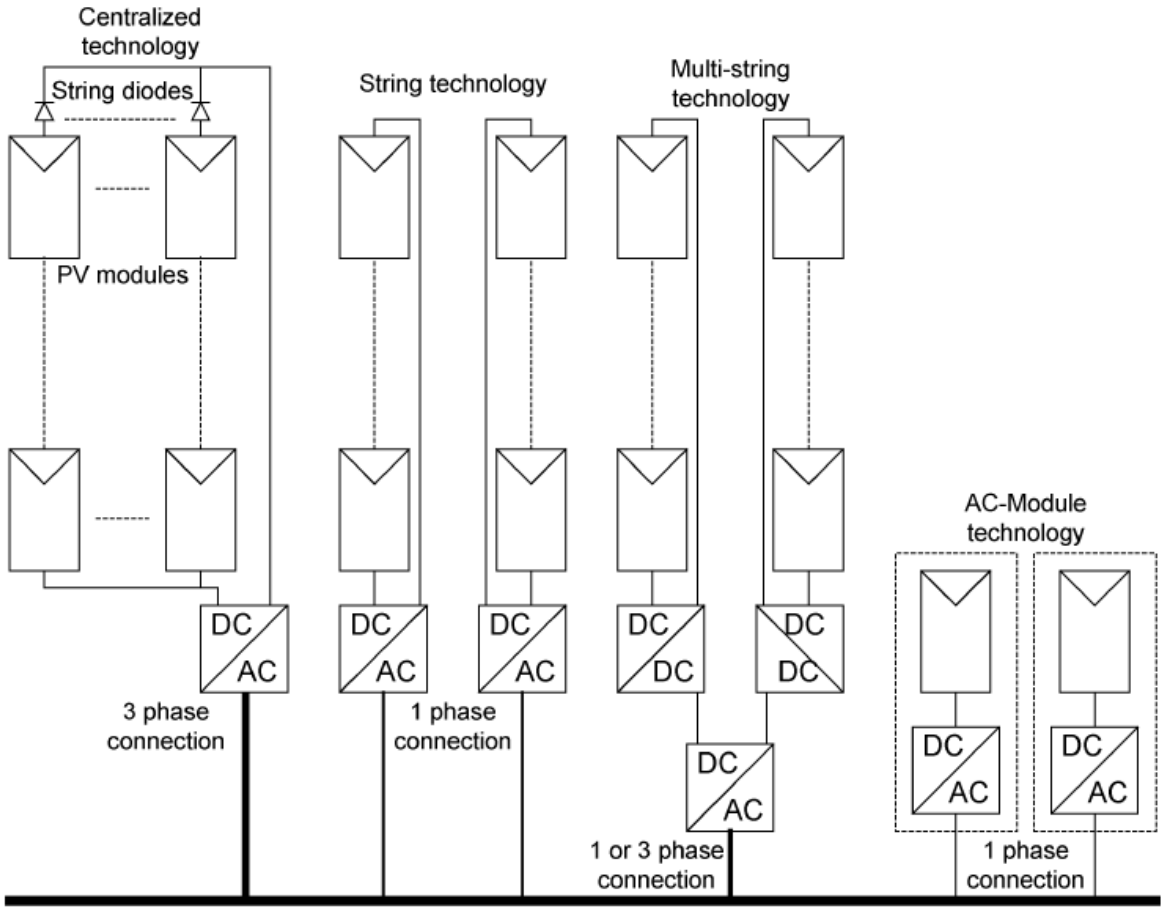




Const power curves

MPP characteristic

Solar system setup



* Source: Soeren Baekhoej Kjaer et al. A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules. IEEE 2005

Power classes and naming

- Central inverter (connects to a solar field)
  - 20..100 kW, large cabinets
  - Up to few MW in paralleled cabinets

- String / multi string inverter
  - 1 kW..8 kW string inverters (connects to one string of solar panels)
  - 8 kW..20 kW multi string inverters (several strings with individual MPP tracking can be connected)

- Microinverter (connects to one solar panel only)
  - 150W..600W

Requirement of solar inverter system

Differentiation

- **Highest efficiency**
- **Very high reliability**
- **Low cost**

IFX contribution

- **Leading edge technologies**
- **Proven quality with long field experience**
- **Best cost-performance**

DC side:

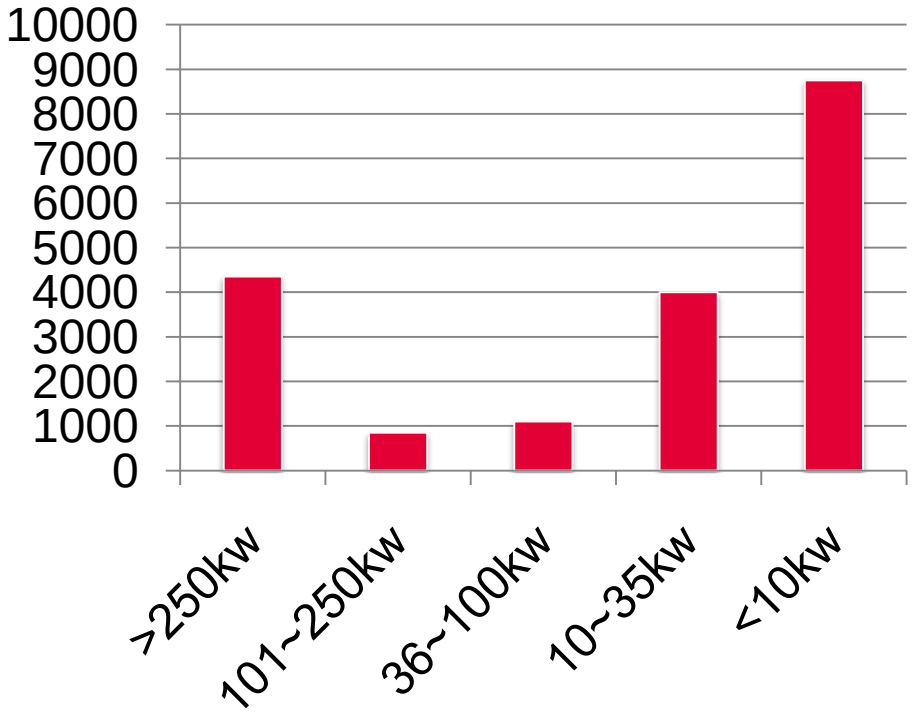
- **wide input voltage range**
- Maximum power point (MPP) tracking

AC side:

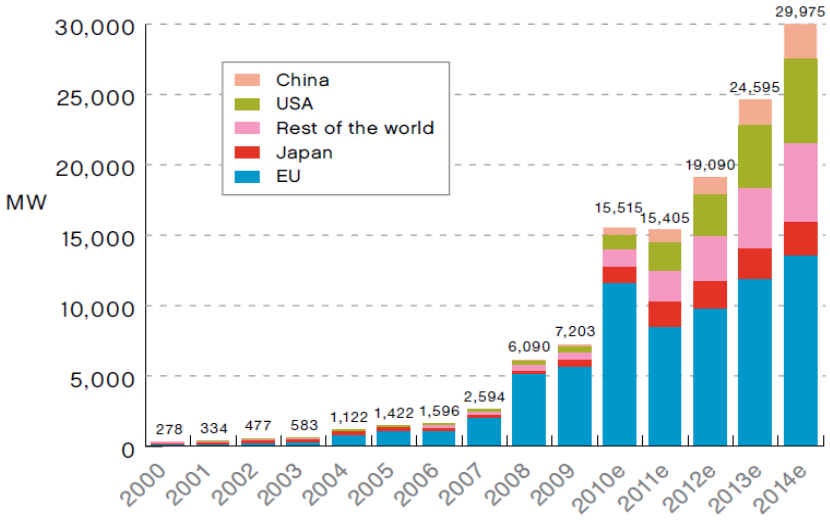
- Sinewave output current
- **Reactive power capability**
- **Fault ride through**

Solar market outlook

MW shipment in 2010 by IMS research



WW installation forecast by EPIA



Content

- Solar inverter overview and market outlook
- Topologies and power components
- Infineon best-in-class power discretes for solar inverter
- Summary

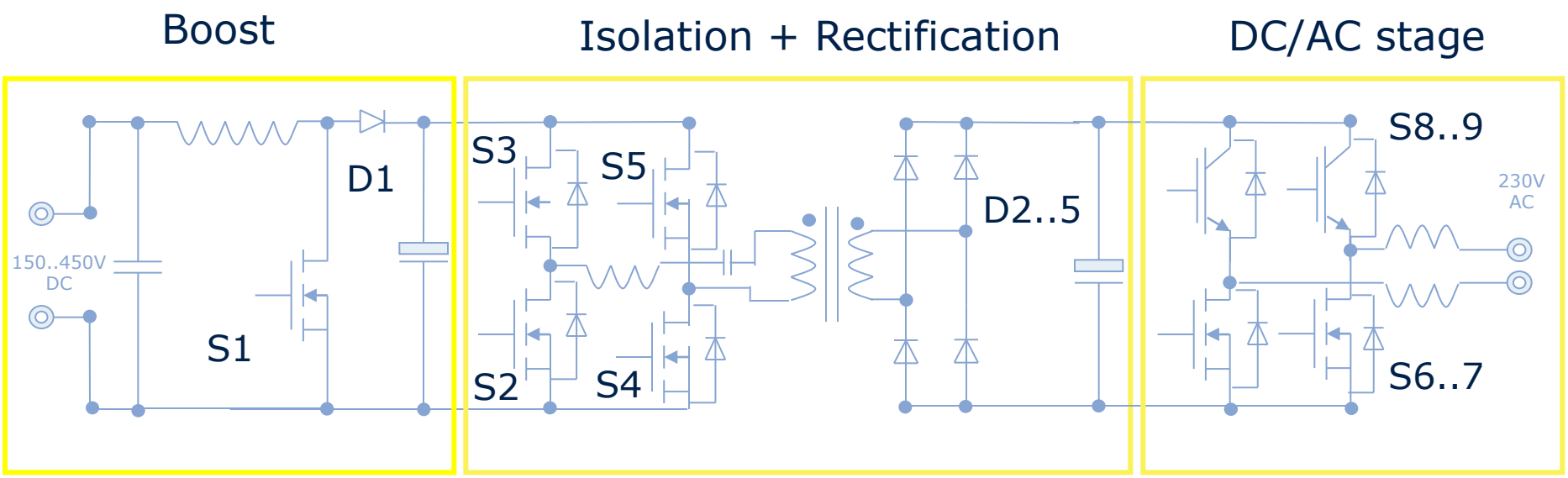
Non- isolated string inverter (Single phase)
Boost + 2-level DC/AC stage

DC/DC converter
(Boost)

DC/AC stage
(H4)

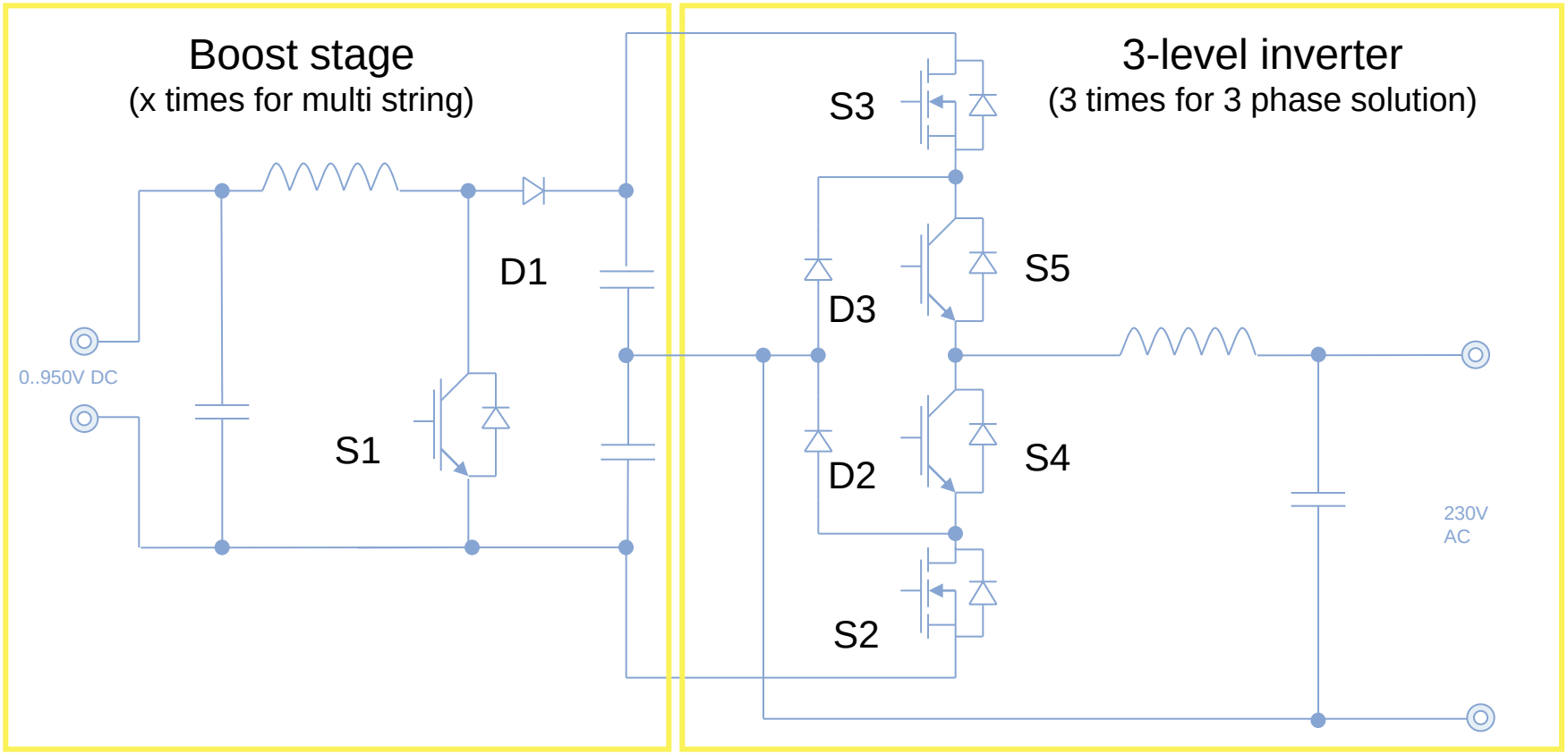
Devices	Function	Recommended IFX parts
S1	Boost switch	CoolMOS™ 650V C6
D1	Boost diode	SiC SBD 600V Gen 3
S2..S5	High frequency output switches	IGBT 600V HS3 + SiC SBD Gen 3

Isolated string inverter (Single phase)
Boost + LLC + isolation + unipolar PWM

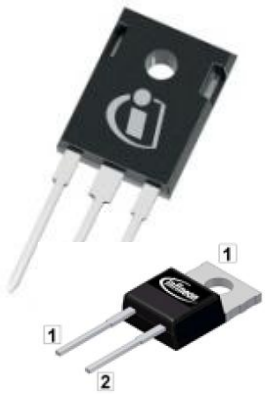


Devices	Function	Recommended IFX parts
S1	Boost switch	CoolMOS™ 650V C6
D1	Boost diode	SiC SBD 600V Gen 3
S2..S5	LLC FETs	CoolMOS™ 650V CFD2
D2..D5	Rectification diodes	SiC SBD 600V Gen 3
S6..S7	High frequency output switches	CoolMOS™ 650V CFD2
S8..S9	Polarity selection switches	IGBT 600V TrenchStop)

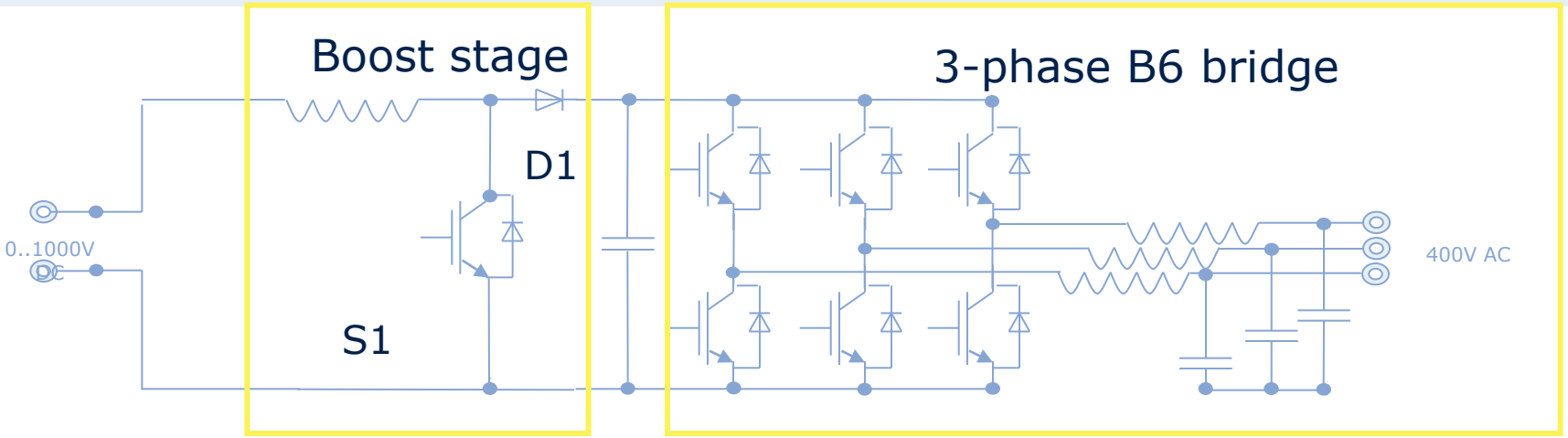
Three phase solution, transformerless
Boost + Neutral point clamp 3-level inverter



Devices	Function	Recommended IFX part
S1	Boost IGBT	Highspeed3 IGBT 1200V
D1	Boost diode	SiC SBD 1200V
S2..S3	High frequency switches	CoolMOS CFD2 650V / Highspeed 3 IGBT 600V
D2..D3	Clamping diodes	SiC SBD 600V
S4..S5	Polarity switches	TrenchStop IGBT 600V



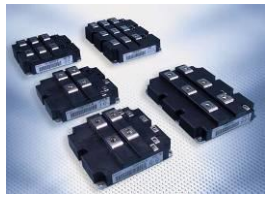
Central inverter: Boost + B6 bridge



Devices	Function	Recommended IFX part
S1	Boost MOSFET	IGBT 1200V T2
D1	Boost diode	Si-Diode EmitterControlled 1200V
B6	B6 switches	IGBT 1200V T2 + Si-Diode 1200V

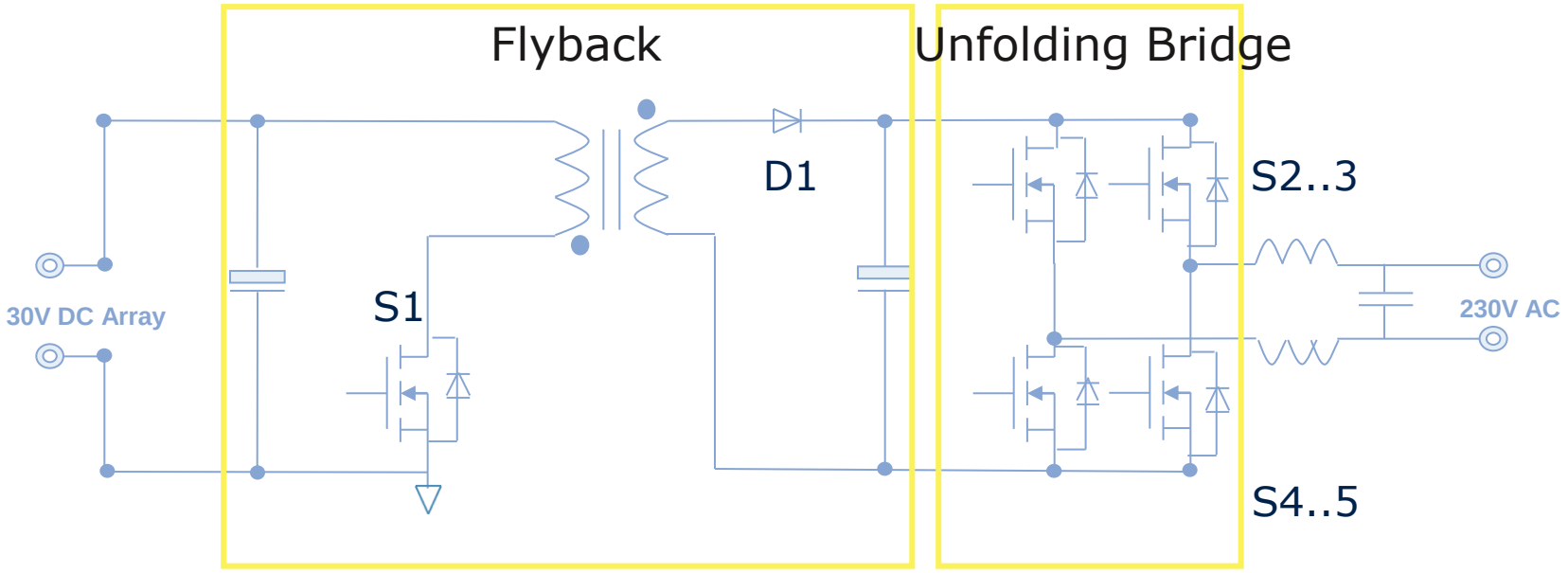







EconoPACK™ 4 62mm | EconoDUAL EconoPACK+ | PrimePACK | IHM IHV | Stacks

Micro-inverter



Devices	Function	Recommended IFX part
S1	High frequency flyback switch	OptiMOS 150V /60V (if double ends)
D1	Rectification diode	SiC SBD 1200V
S2..S5	50Hz unfolding switch	CoolMOS 800V/ 900V

What is the advantage of Microinverter?

- Less shading impact
- Individual panel MPPT
- Safety(low AC voltage)
- Easy installation
- Longer service life(warranty)

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Infineon offers a broad portfolio of Power Management Discretes

Discrete Power Semiconductors

Low Voltage MOSFETs

- **OptiMOS™**
  20V – 30V
- **OptiMOS™**
  40V, 60V, 75V, 80V
- **OptiMOS™**
  100V, 120V, 150V
- **OptiMOS™**
  200V, 250V
- **P-Channel**
- **Small Signal**

High Voltage MOSFETs

- **CoolMOS™ C3**
  500V, 600V, 650V, 800V , 900V
- **CoolMOS™ CP**
  500V, 600V
- **CoolMOS™ CFD**
  600V,650V
- **CoolMOS™ C6/E6**
  600V ,650V

IGBT

- **TRENCHSTOP™**
  600V, 1200V
- **RC Drives**
  600V
- **RC-H**
  900V, 1100V, 1200V, 1350V, 1600V
- **TRENCHSTOP™ 2**
  1200V
- **Fast/Highspeed 2**
  1200V
- **Highspeed 3**
  600V, 1200V

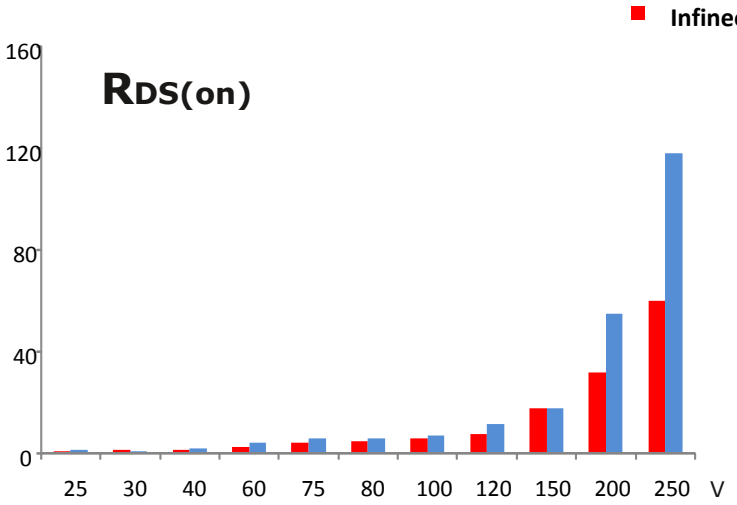
SIC Schottky Diodes

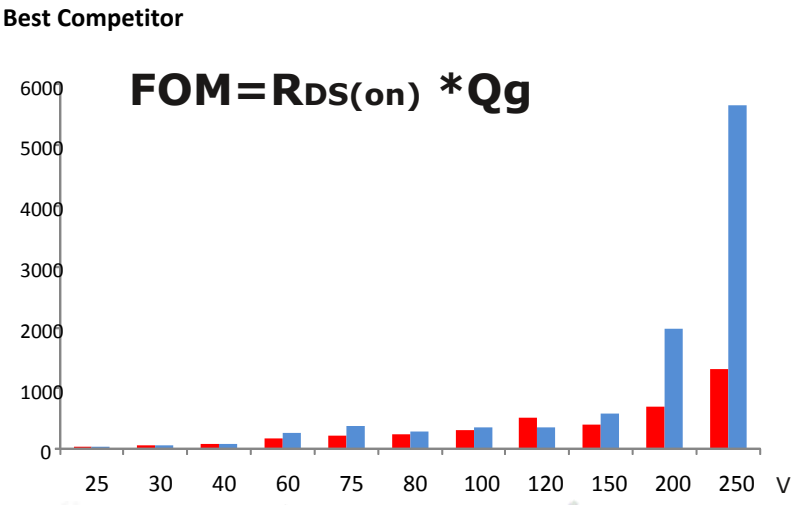
- **thinQ!™**
  600V, 1200V

- **Infineon SiC JFET is upcoming…**
- **Infineon provides Discretes well as Multi-Chip-Packaging solutions**

Infineon OptiMOS™ boost MPPT tracker/Micro-inverter efficiency

- Lowest $R_{DS(on)}$ and FOM against competitors





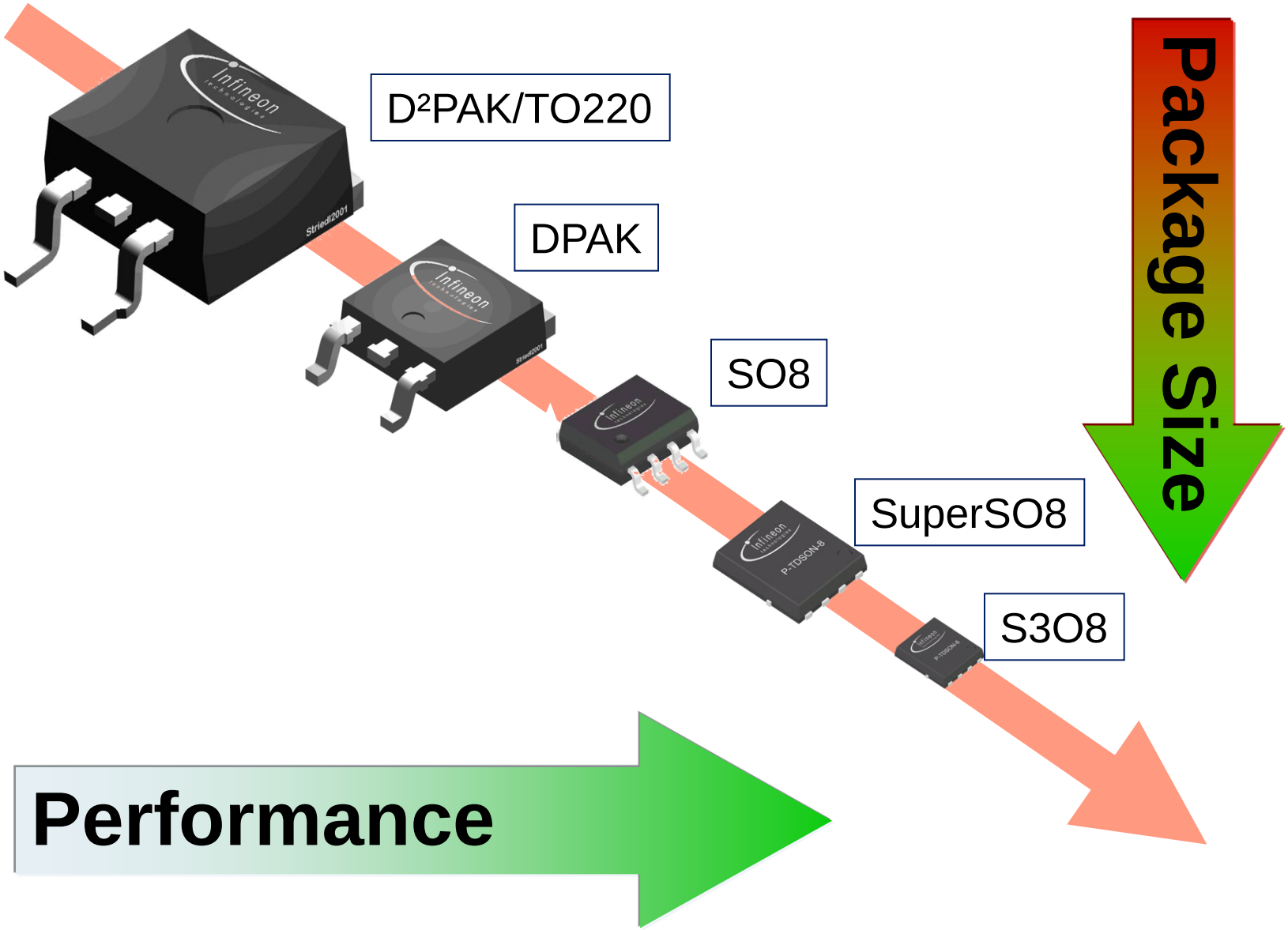




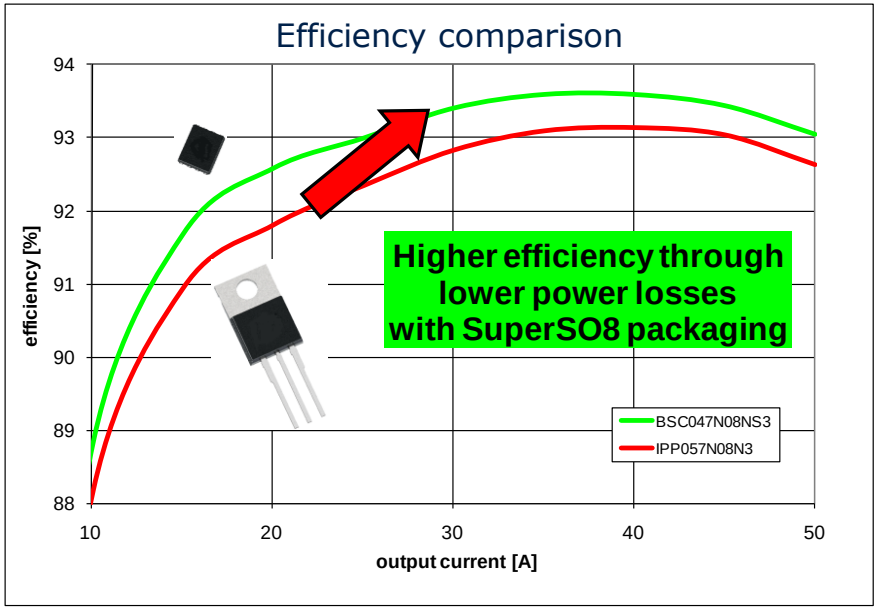
Best-in-class

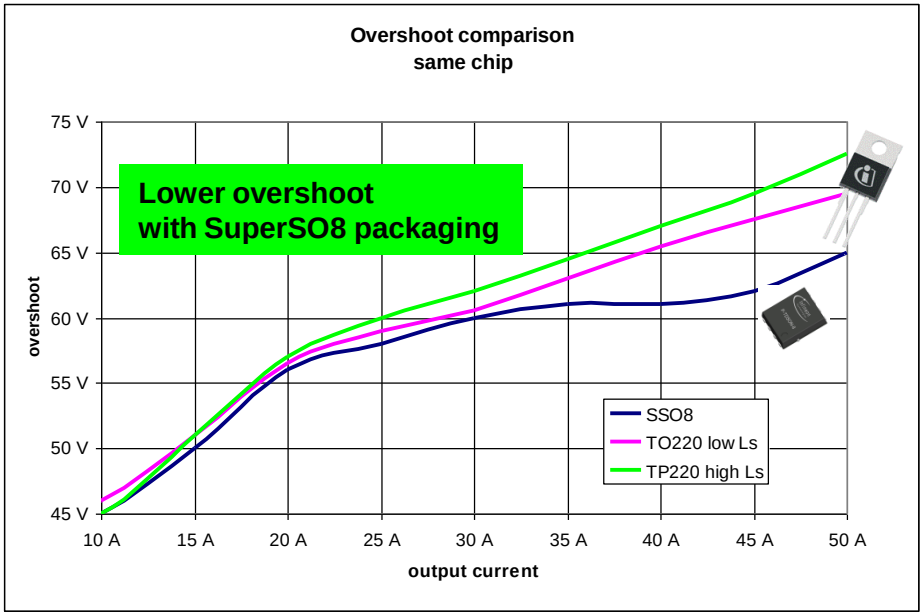
	CanPAK M	SuperSO8	D²PAK-7 pin	D²PAK	TO-220
80V	BSB044N08NN3 G 4.4 mOhm	BSC047N08NS3 G 4.7mOhm	IPB019N08N3 G 1.9mOhm	IPB025N08N3 G 2.5mOhm	IPP028N08N3 G 2.8mOhm
100V	BSB056N10NN3 G 5.6mOhm	BSC060N06NS3 G 6.0mOhm	IPB025N10N3 G 2.5mOhm	IPB027N10N3 G 2.7mOhm	IPP030N10N3 G 3.0mOhm
120V		BSC077N12NS3 G 7.7mOhm	IPB036N12N3 G 3.6mOhm	IPB038N12N3 G 3.8mOhm	IPP041N12N3 G 4.1mOhm
150V	BSB150N15NZ3 G 15mOhm	BSC190N15NS3 G 19mOhm	IPB065N15N3 G 6.5mOhm	IPB072N15N3 G 7.2mOhm	IPP075N15N3 G 7.5mOhm
200V		BSC320N20NS3 G 32mOhm		IPB107N20N3 G 10.7mOhm	IPP110N20N3 G 11.0mOhm
250V		BSC600N25NS3 G 60mOhm		IPB200N25N3 G 20.0mOhm	IPP200N25N3 G 20.0mOhm

Package revolution for low voltage MOSFET



OptiMOS™ in SMD leadless package achieve higher efficiency& less voltage overshoots

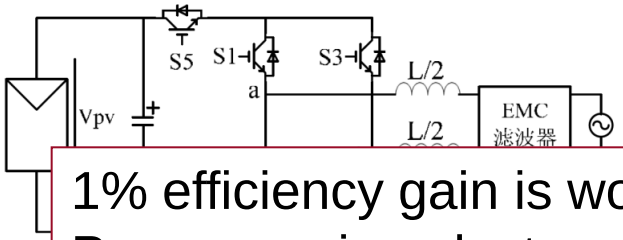




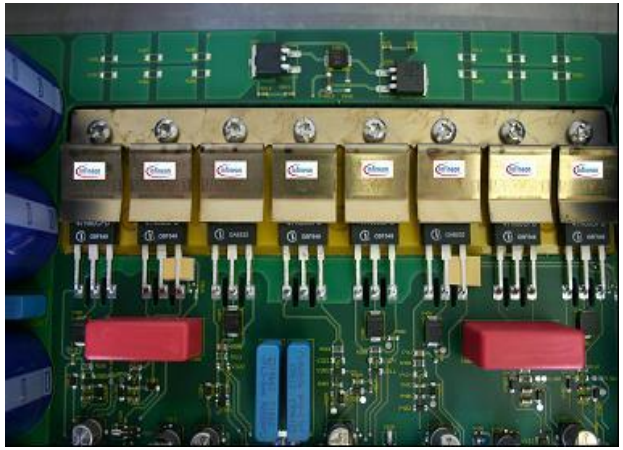
Tested in a 12V server power supply in the Sync Rec stage

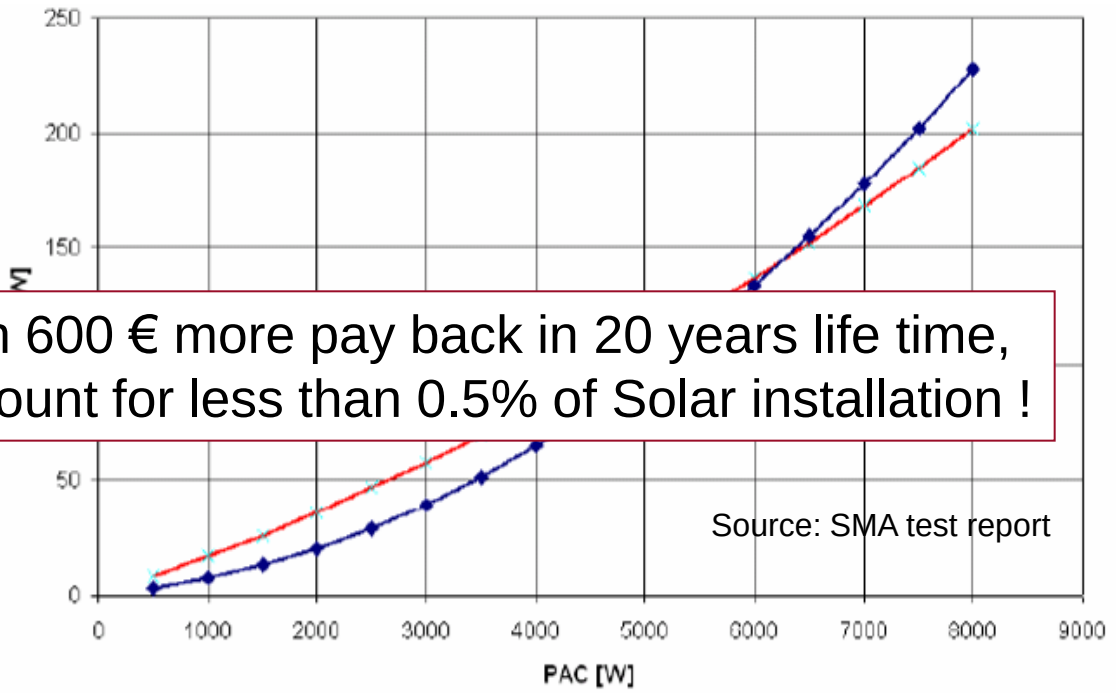
- Benefits of SMD leadless package (SuperSO8/S3O8)
  - Less parasitic inductances
  - Less space consumption
  - Less voltage overshoots, better switching behavior
  - Higher system efficiency & power density

How to achieve highest efficiency? CoolMOS or IGBT?



1% efficiency gain is worth 600 € more pay back in 20 years life time,
Power semiconductor account for less than 0.5% of Solar installation !





Efficiency measurements on 8kw PV inverter. 1) Red curve: Switch 1,2,3,4,5 are IGBT; 2) Blue curve: Switch 2, 4 and 5 are CoolMOS CFD, Switch 1 and 3 are IGBT

Highest efficiency in photovoltaic system using CoolMOS!

CoolMOS vs IGBT: 8 kW photovoltaic DC/AC converter, **98.1% peak efficient**

The evolution on CoolMOS is never end

Vds=600V
Rds=70mOhm

Vds=600V
Rds=70mOhm

Vds=600V
Rds=83mOhm

Vds=650V
Rds=80mOhm

CoolMOS C6/CFD2 is the new generation
Super- Junction MOSFET

CoolMOS™ C6 & CFD2 650V
Latest generation SJ MOSFET

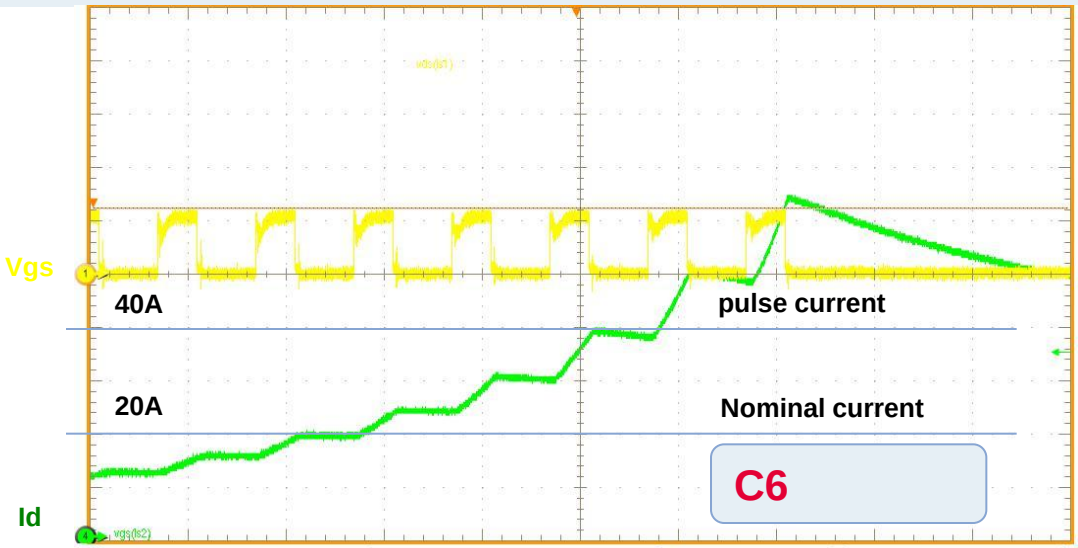
CoolMOS™ C6 650V

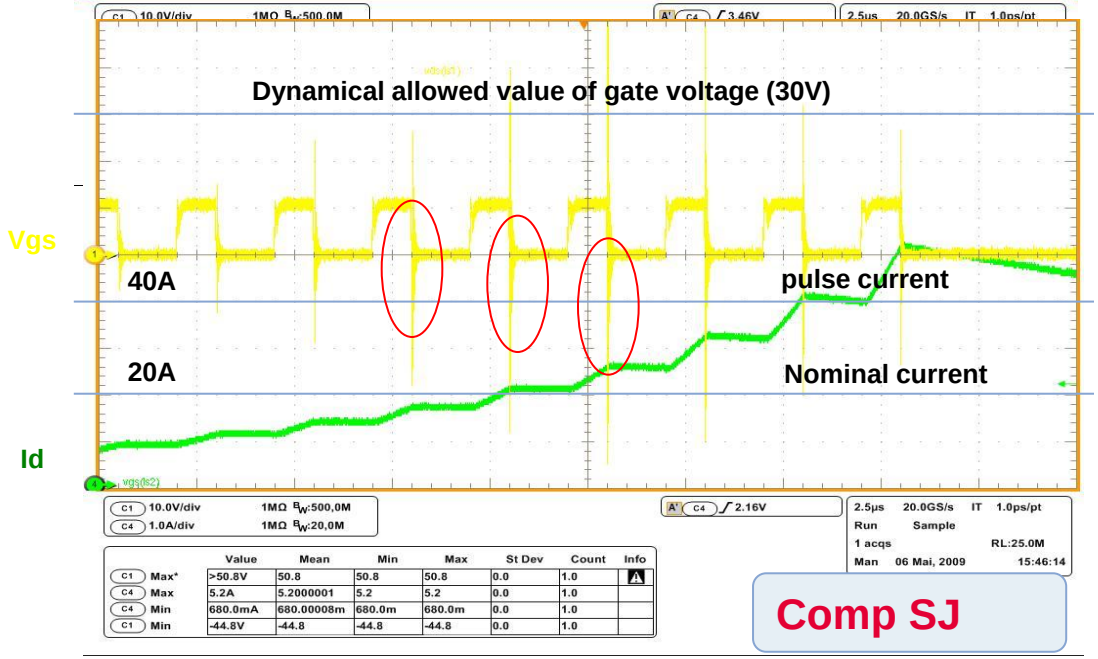
- **True 650V technology enables open circuit voltage of up to 600V**
- Best combination of efficiency and ease-of-use
- Reduction of capacitive losses vs previous generation and competitors
- Proven CoolMOS™ quality since 1998
- Large volume manufacturing in two independent frontends & backends
- BIC device IPW60R037C6, Rdson=37mOhm

CoolMOS™ CFD2 650V

- **First 650V technology with integrated fast body diode on the market**
- **Very low voltage overshoot during hard commutation**
- **Lowest reverse recovery charge of all inhouse and competing technologies**
- Reduction of capacitive losses vs previous generation and competitors
- Proven CoolMOS™ quality since 1998
- BIC device IPW65R041CFD, Rdson=41mOhm

CoolMOS C6 gate switching behavior
Under high conduction current



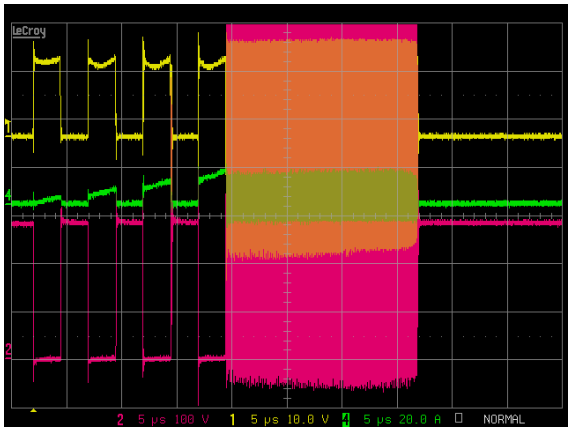


C6 shows **no gate spikes** up to pulse currents beyond 2 times rated current

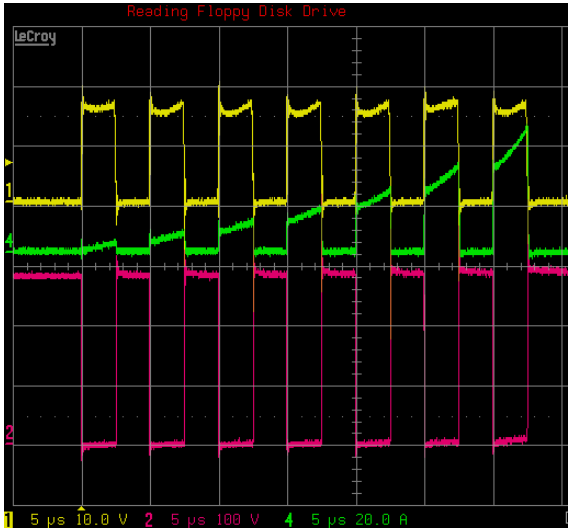
Competitor part shows turn off gate spikes even below nominal current.

How to cope with high switching frequency CoolMOS?

- Oscillation appears 20A turn off current

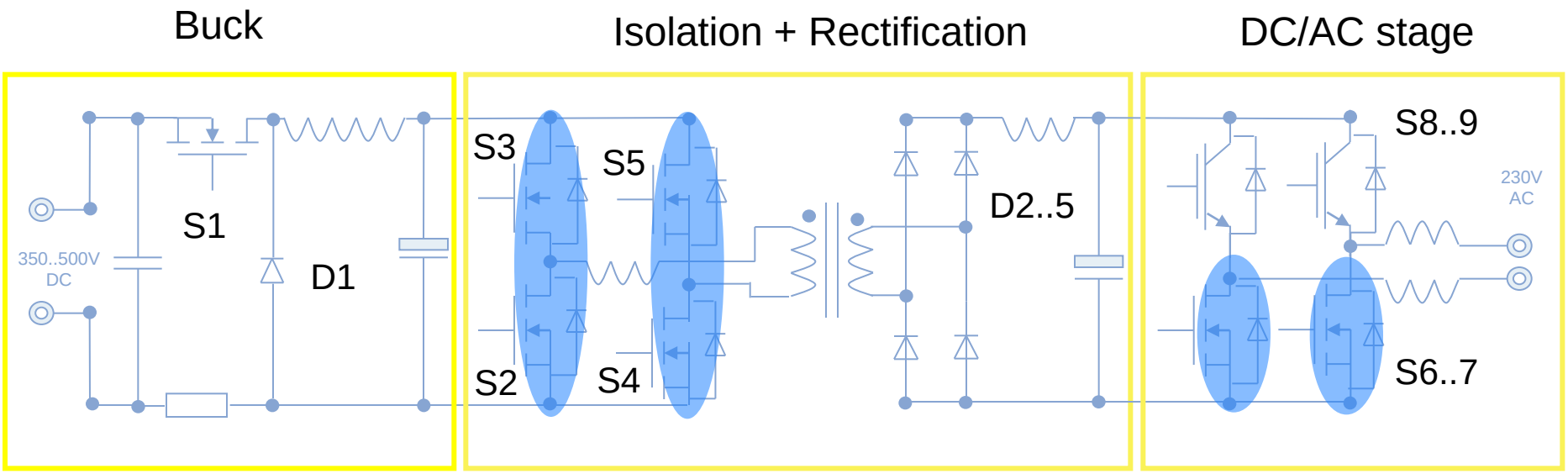


- Clean up to 50A turn off current with a ferrite bead



- Control dv/dt and di/dt by proper selection of gate resistor
- Minimize parasitic gate-drain capacitance on board
- Use gate ferrite beads
- Locate gate drivers and gate turn-off components as close as possible to the gate
- Use symmetrical layout for paralleling

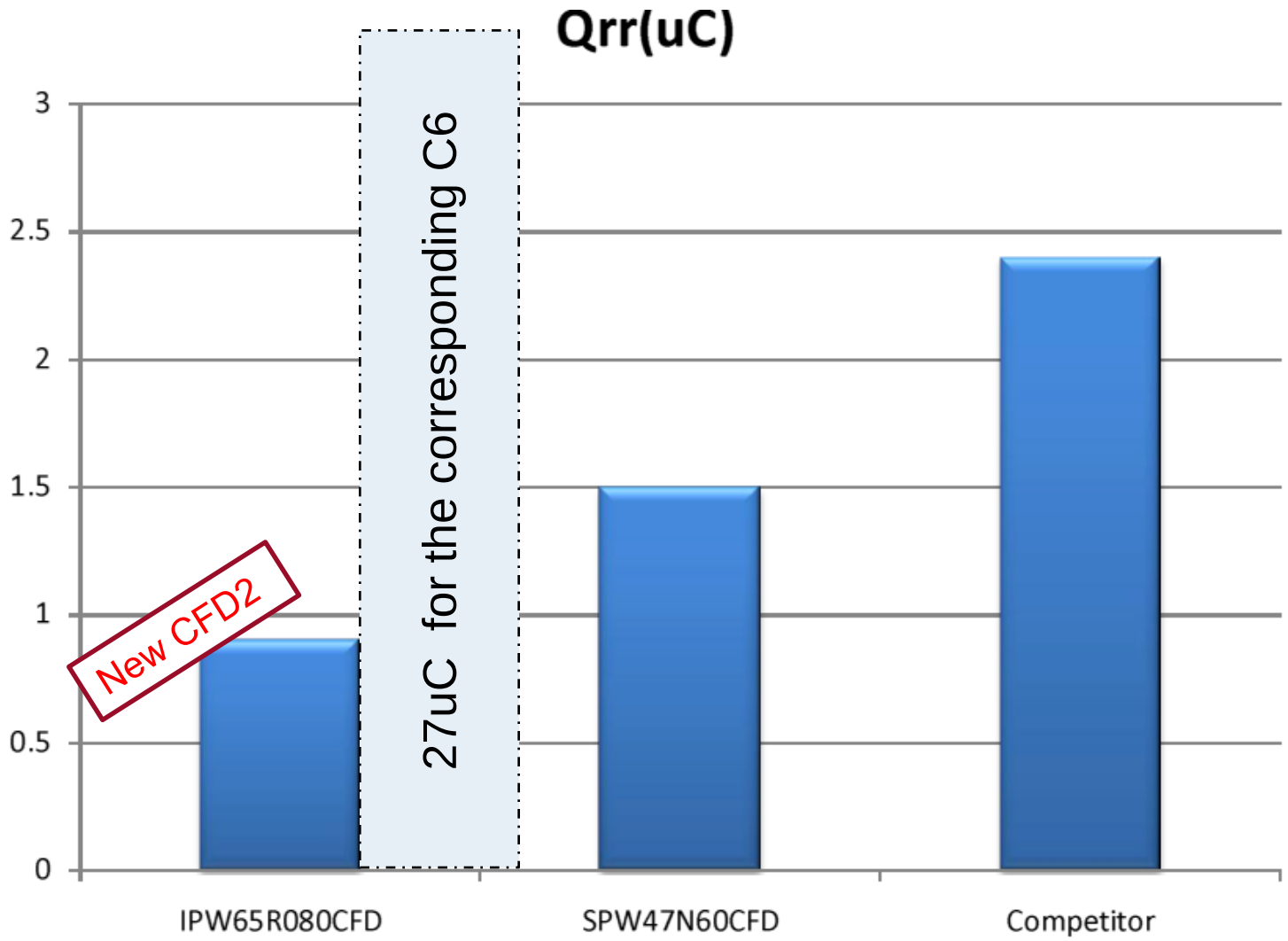
But, a MOSFET with integrated fast body diode is required in some design…



- ZVS topology
  - S2..S5 require the MOSFET has low reverse recovery charge Qrr and robustness body diode for hard-commutation
- Reactive power operation
  - S6,S7 switches to hard commutation of body diodes

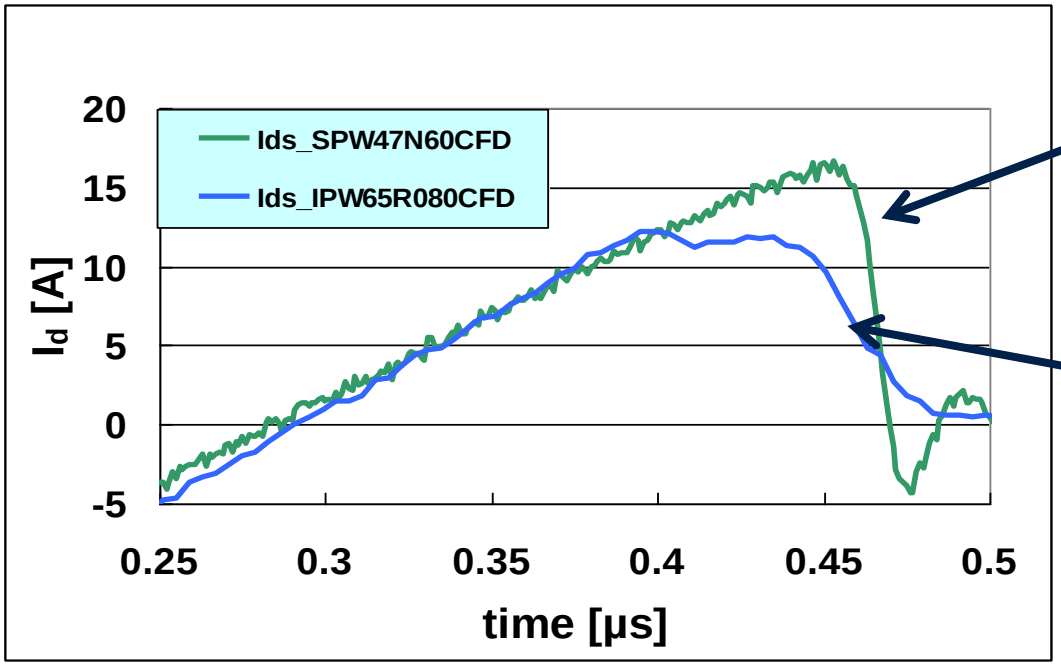
…Infineon has officially launched CoolMOS CFD2

CFD2 offers lowest reverse recovery charge
80 mOhm types at rated nominal current



Main differences between CFD and CFD2

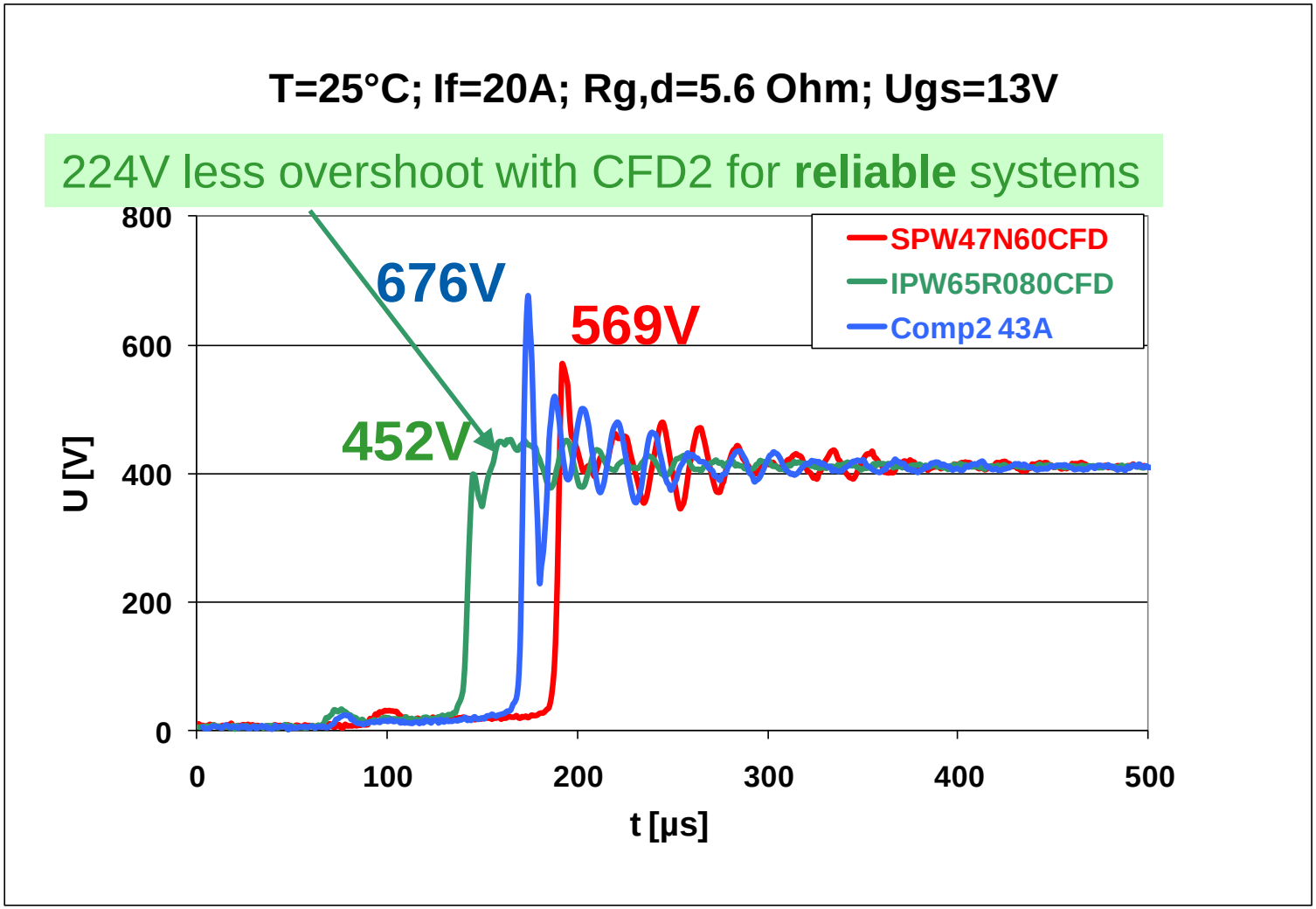
- CFD2 is a 650V class MOSFET (CFD is 600V)
- Better light load efficiency due to reduced gate charge
- Softer commutation behavior and therefore better EMI behavior
- CFD2 offers customers a new cost down roadmap



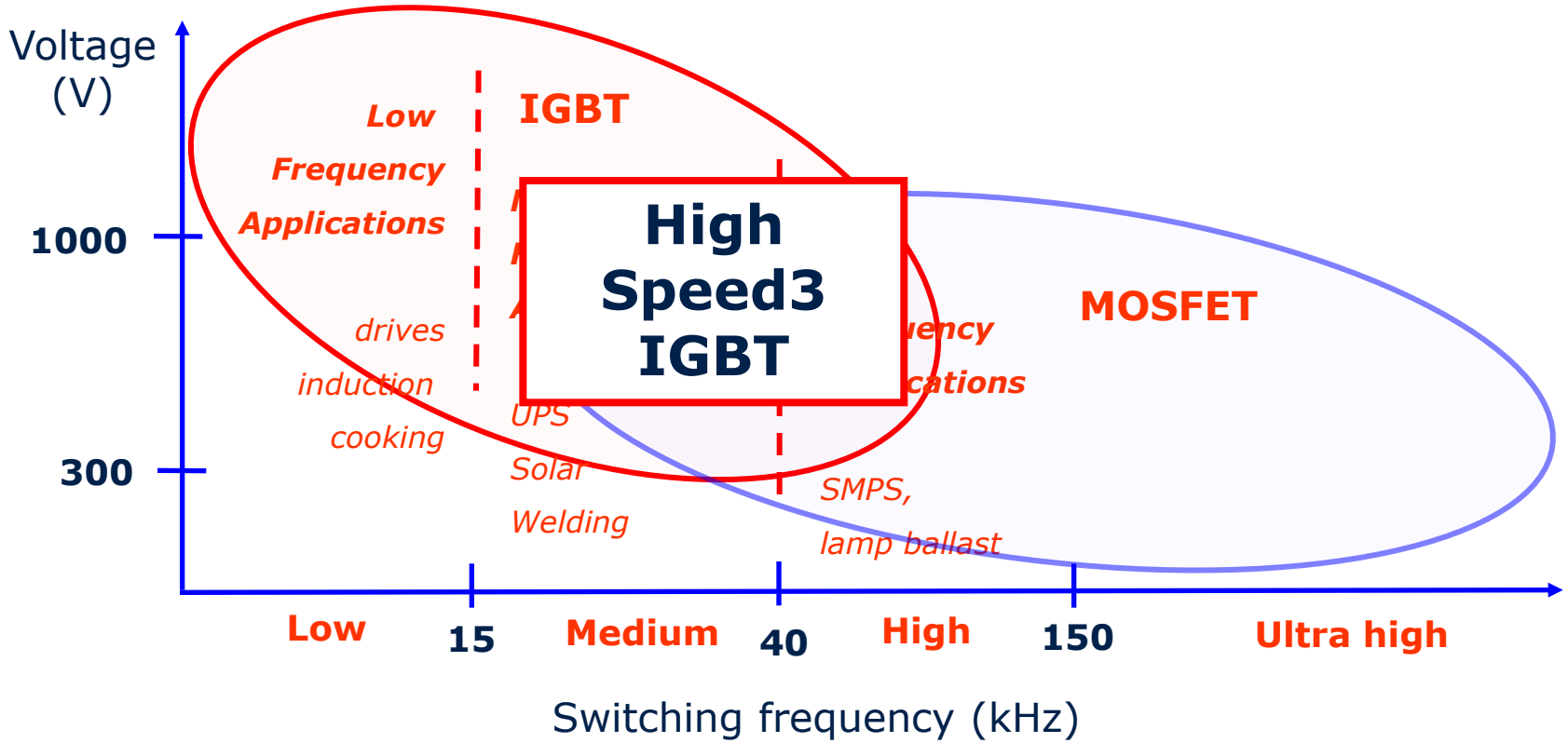
CFD: fast switching of voltage or current i.e. di/dt or dv/dt (main causes of EMI)

CFD2: softer commutation reduces this problem saving customer time and money in designing in the part

Voltage overshoot CFD2 vs. CFD vs. Competition



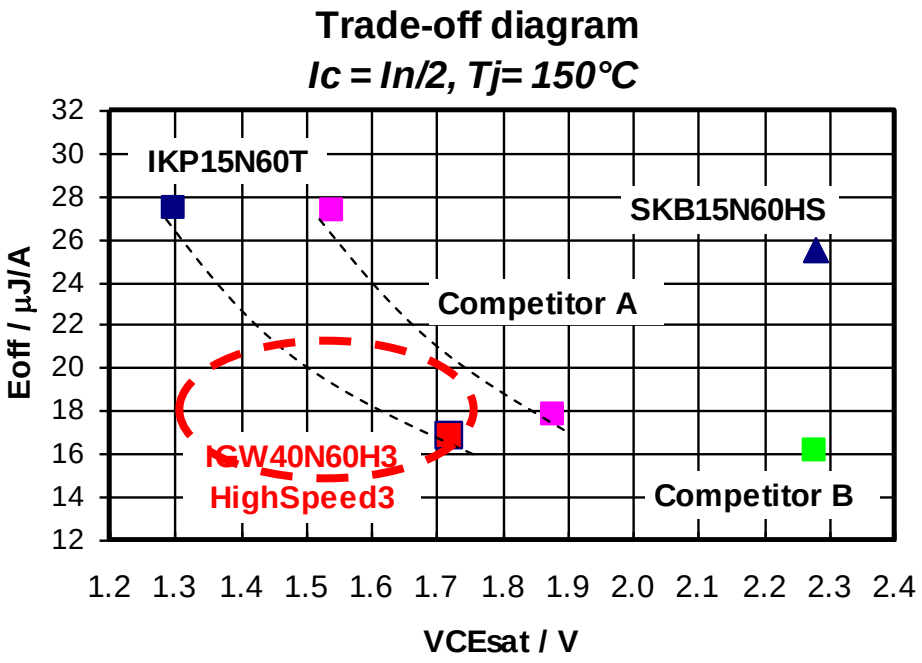
Is IGBT still working at low switching frequency?



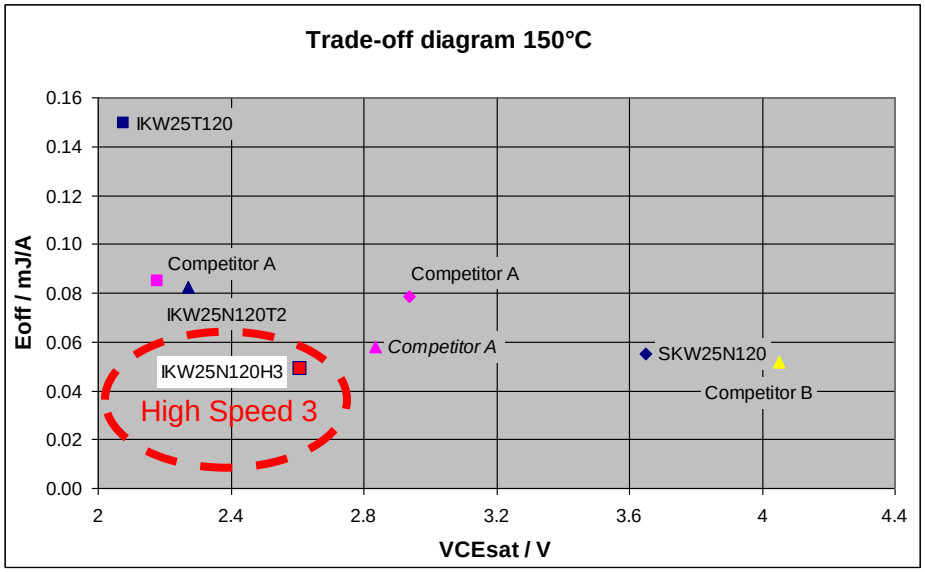
- High Speed IGBT was developed to brige the gap between IGBT and mosfets in mid-high frequency hard-switching applications

New Highspeed 3 IGBT technology

600V IGBT



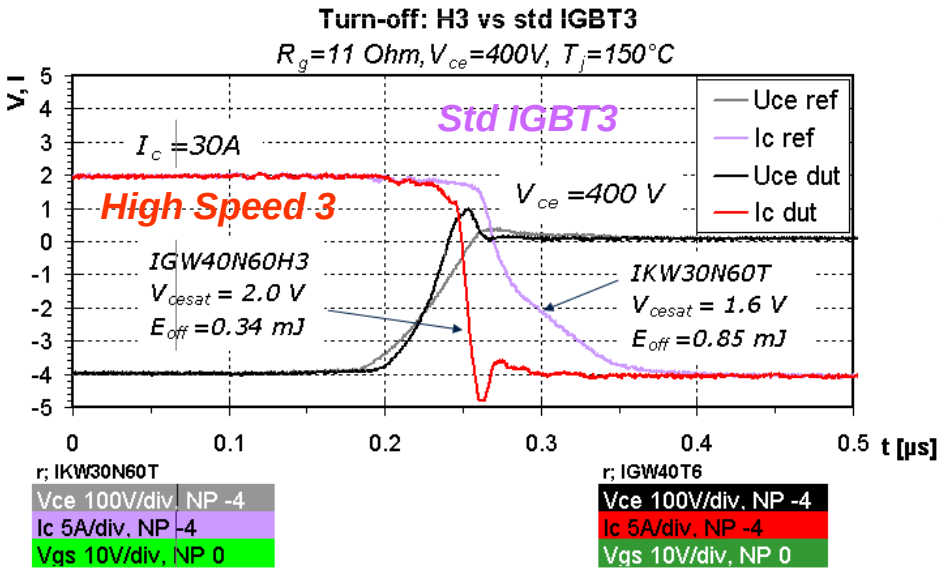
1200V IGBT

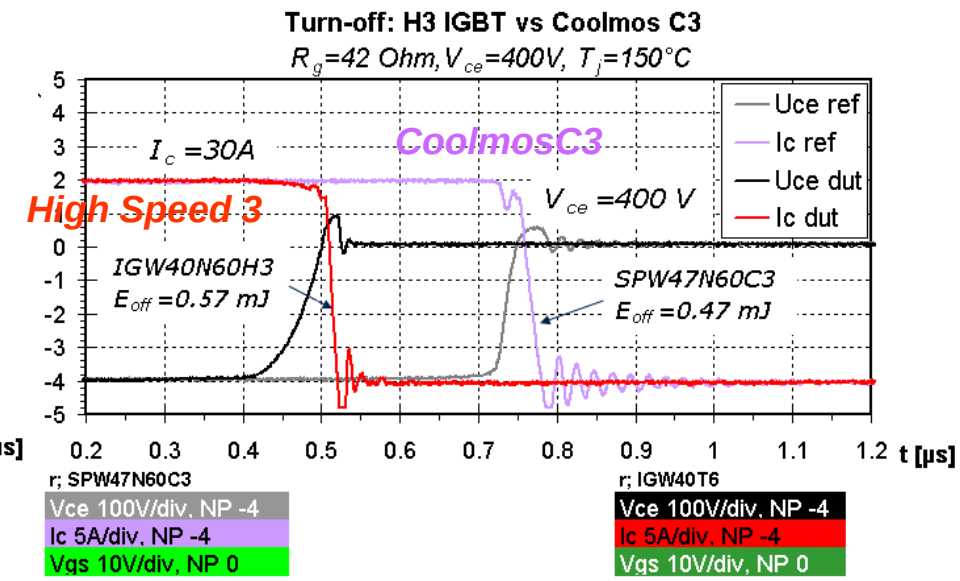


- Trench gate+ Field Stop offers superior trade-off
  - Reduced switching losses for switching Frequencies above 20 kHz
  - Soft switching behaviour
  - Optimized diode for target applications

New highspeed 3 IGBT switching behavior

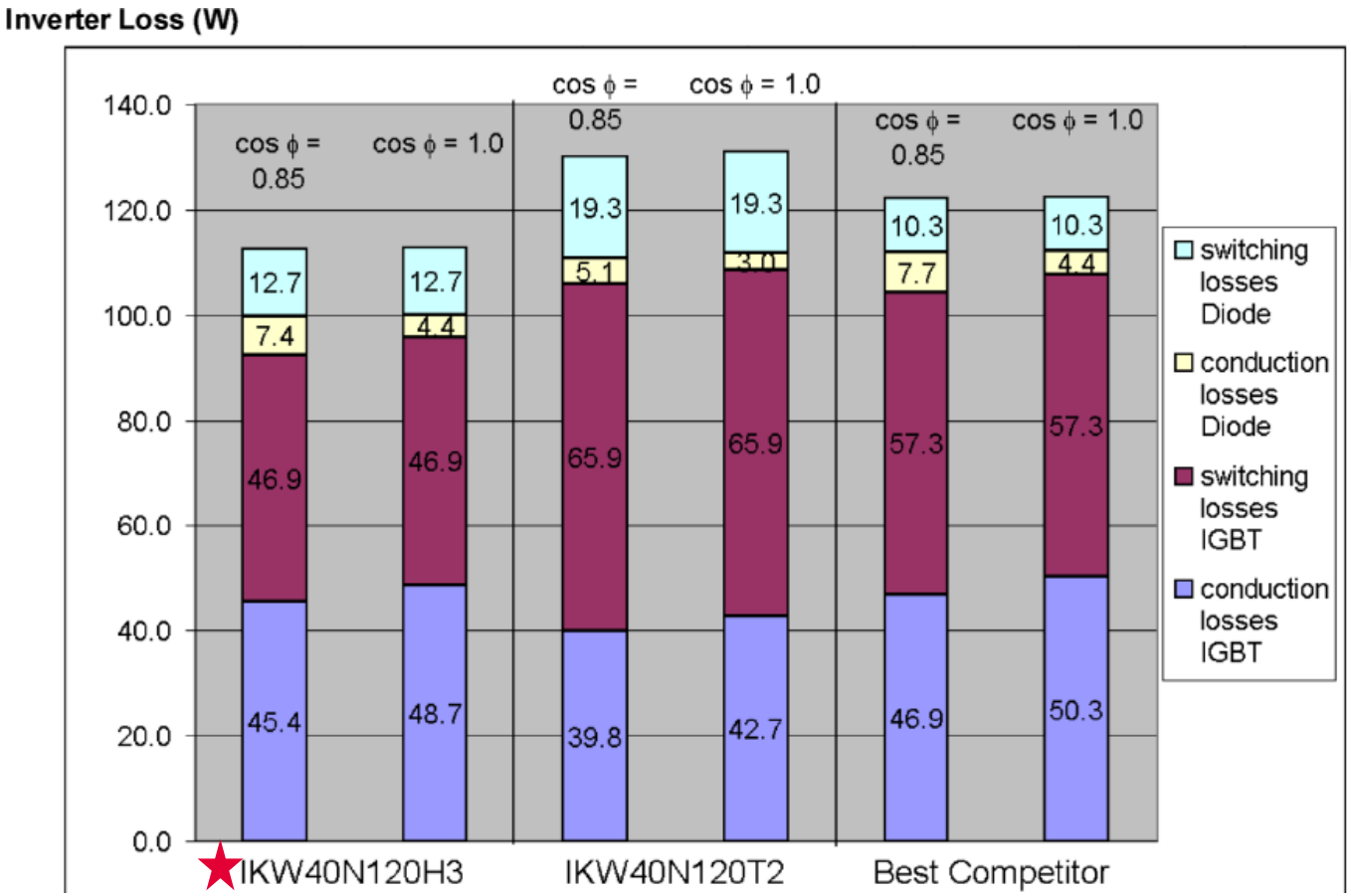
Elimination of tail current at high temperature…





…for **MOSFET-like** switching behavior

Powerloss comparison
Simulation with IPOSIM™

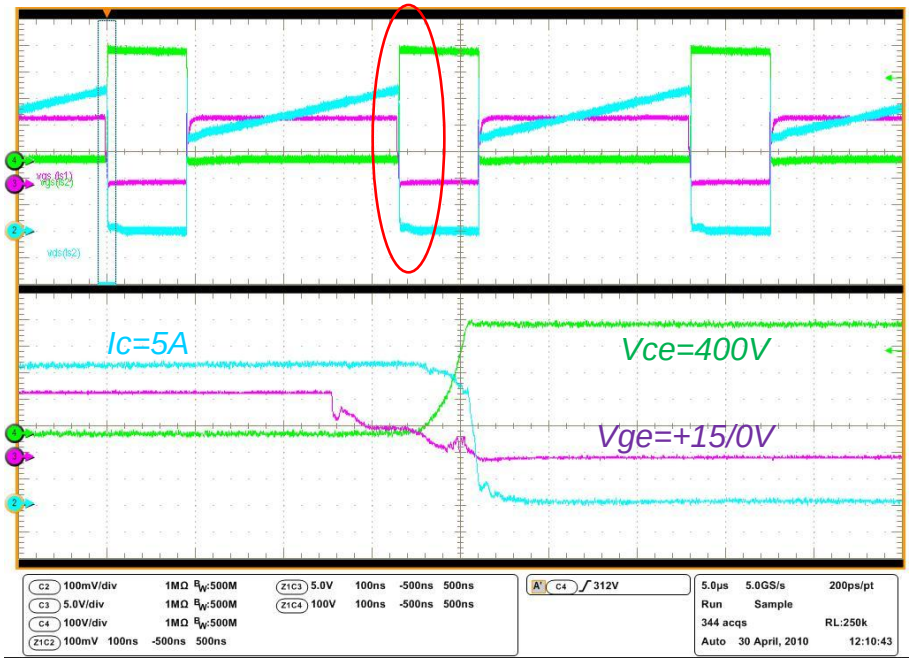


3-phase inverter
Vbus=600V
Fsw=20kHz
Iload=40A

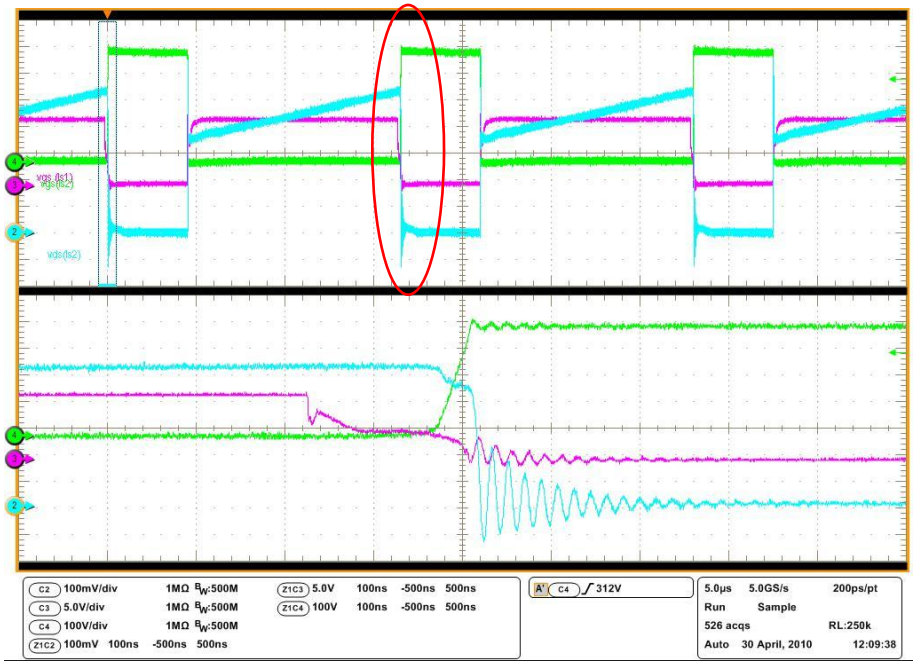
- In comparison with the previous generation TrenchStop2, the HighSpeed 3 shows 30% reduction in switching losses and only 16% increase in conduction losses.
- The HighSpeed 3 shows approx 10% lower losses than the best competitor, setting benchmark performance.

Turn-off Waveform comparison

IKW30N60H3



IGBT Best competitor



- Smooth switching waveforms
- Low dV/dt and dI/dt for reduced EMI

Infineon's High Speed 3 IGBT Portfolio
600V and 1200V Product Family

Continuous collector current at T_C=100° C		600V			1200V
		TO-263	TO-220	TO-247	TO-247
					
Single IGBT	15A				IGP15N120H3 ✓
	20A	IGB20N60H3*	IGP20N60H3 ✓		
	25A				IGP25N120H3 ✓
	30A	IGB30N60H3*	IGP30N60H3 ✓		
	40A			IGW40N60H3 ✓	IGP40N120H3 ✓
	50A			IGW50N60H3 ✓	
DuoPack™	15A				IKW15N120H3 ✓
	20A	IKB20N60H3*	IKP20N60H3*	IKW20N60H3 ✓	
	25A				IKW25N120H3 ✓
	30A	IKB30N60H3*	IKP20N60H3*	IKW30N60H3 ✓	
	40A			IKW40N60H3 ✓	IKW40N120H3 ✓
	50A			IKW50N60H3 ✓	
	75A			IKW75N60H3*	

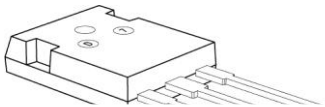
√ Devices are fully released! * Engineering samples October 2010

TrenchStop IGBT for PV inverter with low switching frequency,e.g. 50Hz

600V IGBT

TO-247

Continuous collector current at T_C=100°

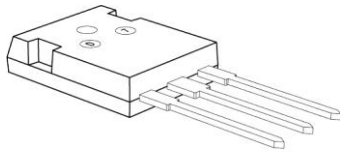


DuoPack™		
	20A	IKW20N60T
	30A	IKW30N60T
	50A	IKW50N60T
	75A	IKW75N60T

1200V IGBT

TO-247

Continuous collector current at T_C=100° C

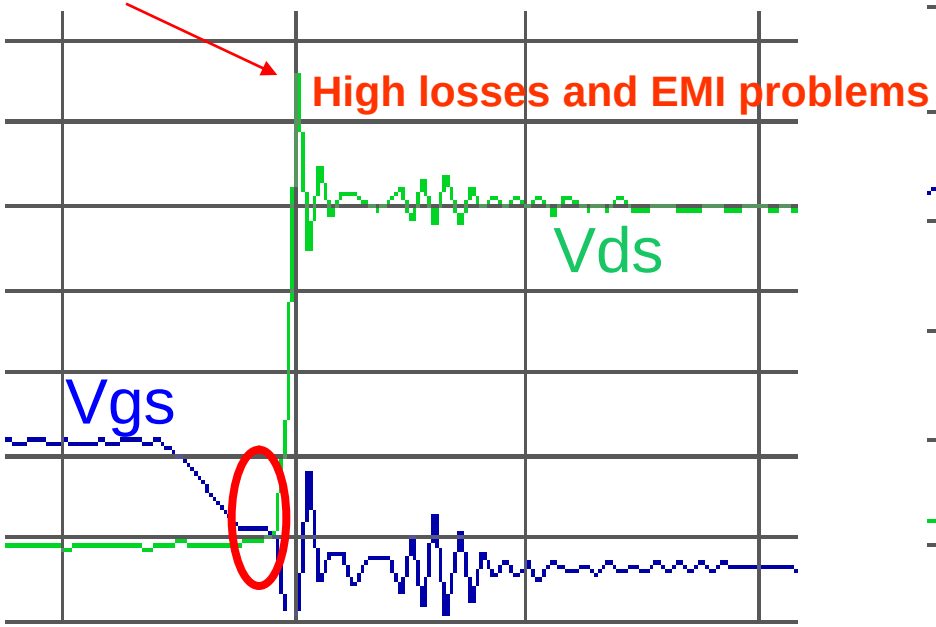


DuoPack™		
	15A	IKW15N120T2
	25A	IKW25N120T2
	40A	IKW40N120T2

SiC diode feature fast forward conduction

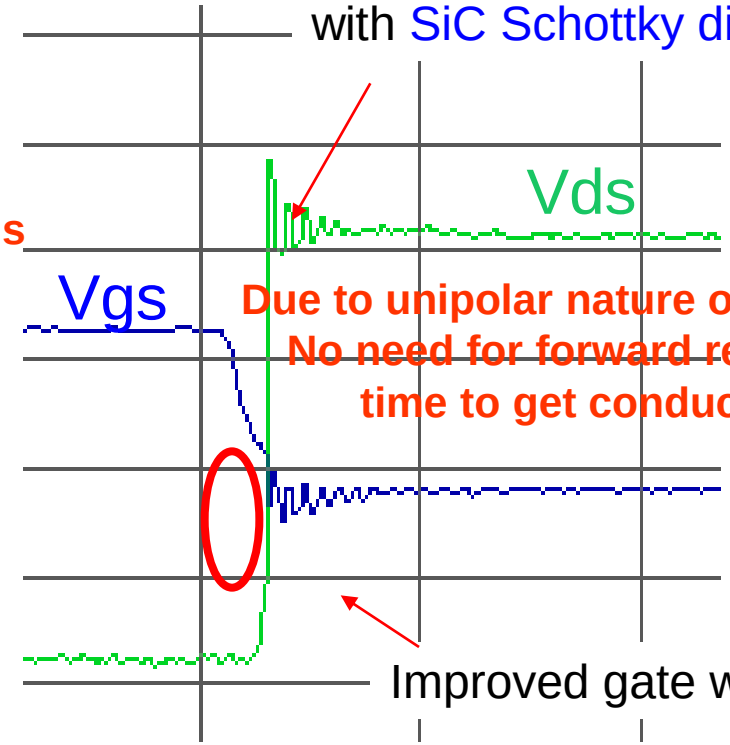
Reduce the Maximum V_{DS} Stress of Power MOSFET!

V_{DS} spike up to 600 V with extremely fast switching boost MOSFET and competitors tandem diode



Using competitor tandem diode

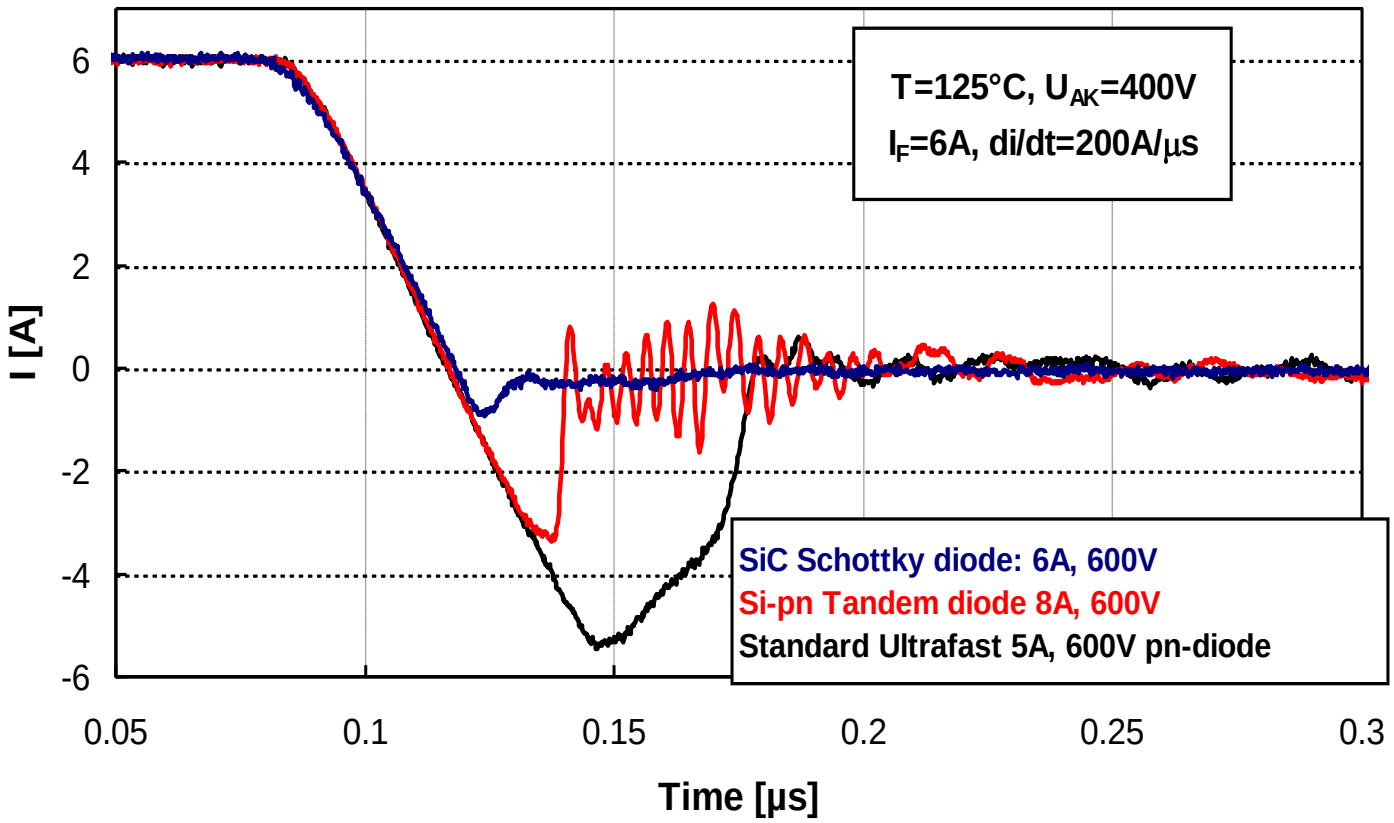
Very low Vds spike with SiC Schottky diode



Using SiC Schottky diode

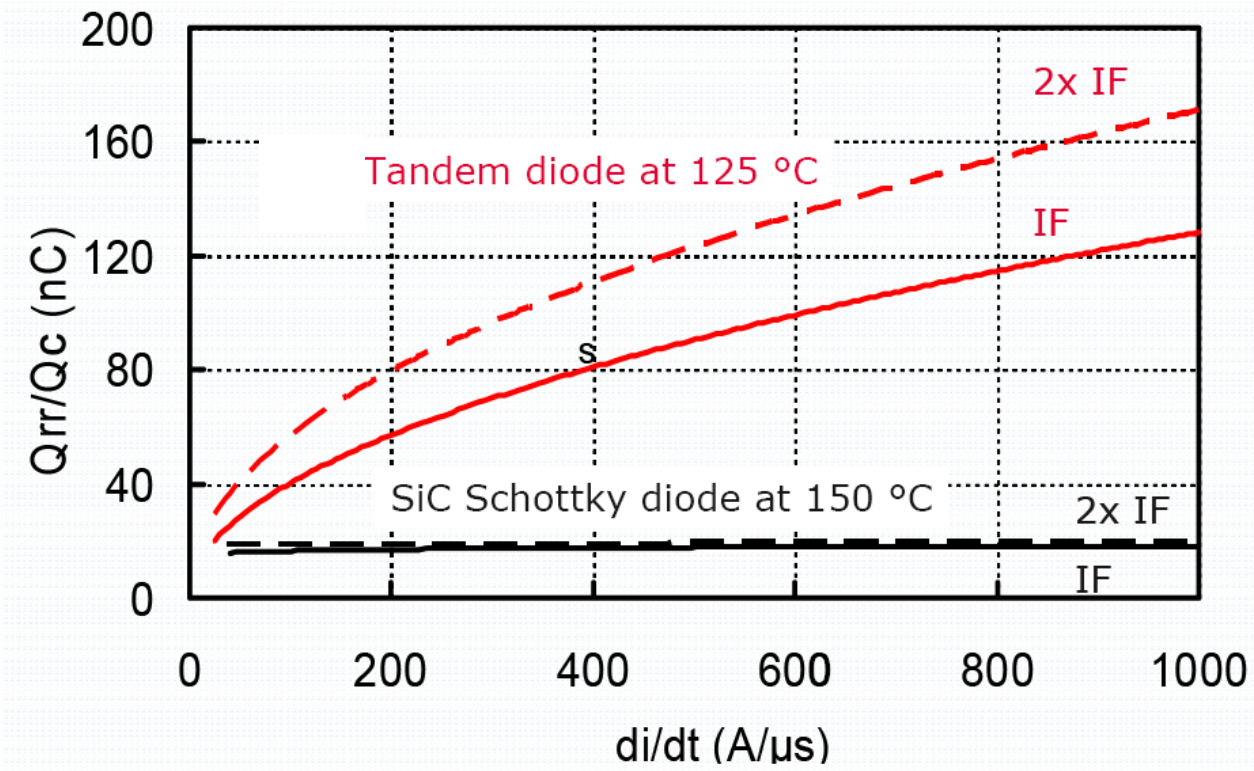
- Replacement of diode allows spike **reduction of more than 100 V**
- Full switching speed range of boost MOSFET useable for highest efficiency

Zero reverse recovery charge only with unipolar devices… SiC Schottky diode



Not possible with Si technology at 600 V rating…
…therefore *SiC Schottky diode* concept required!

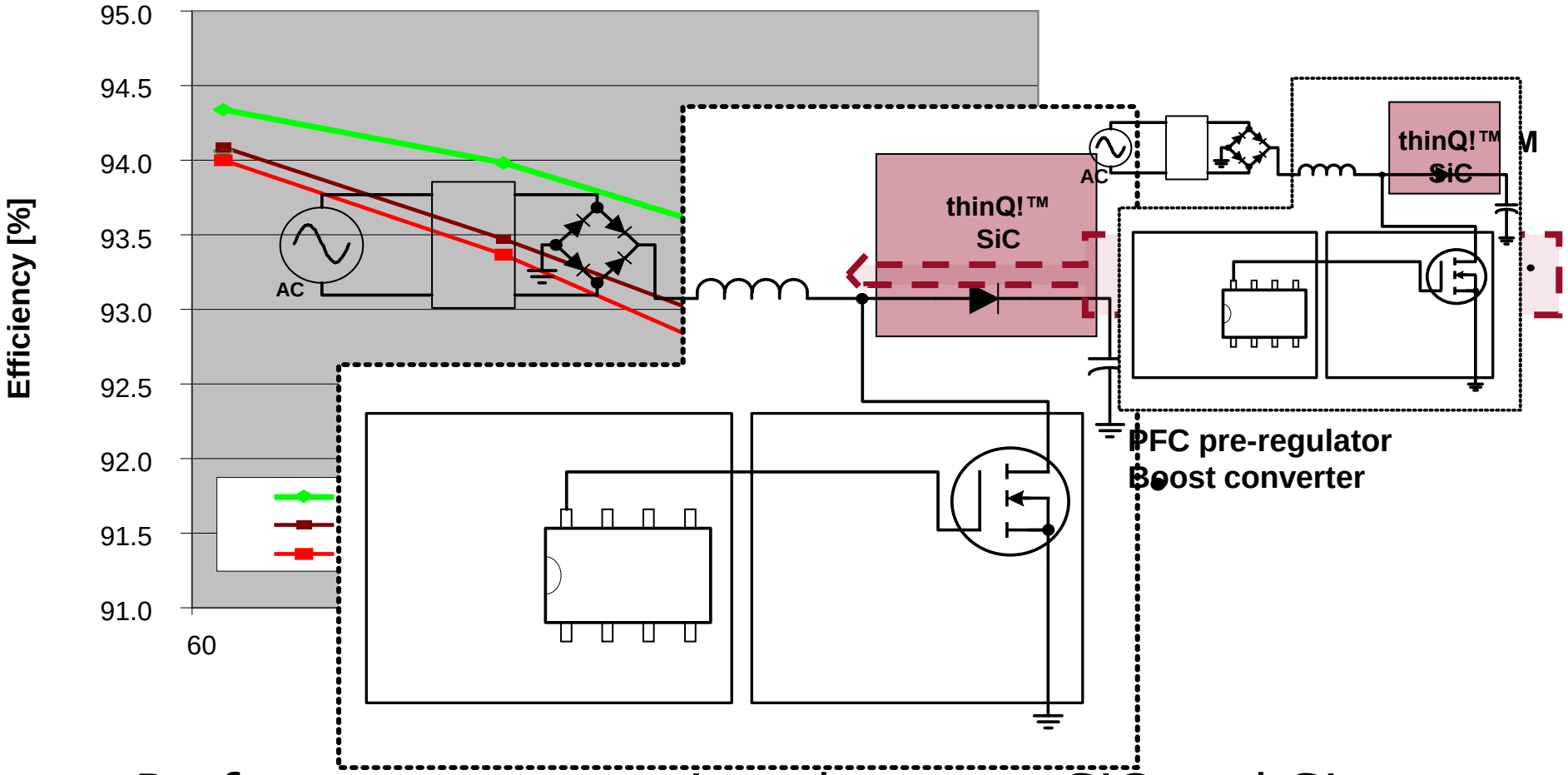
Switching loss of SiC keep constant vs Io,Rg and Tc



Advantages of your design - > switching loss does not change with

1) Load condition
2) Switching speed of MOSFET
3) Temperature.

SiC and Energy Efficiency Improvement



Performance comparison between SiC and Si on system level

Example: PFC stage, full load, low line

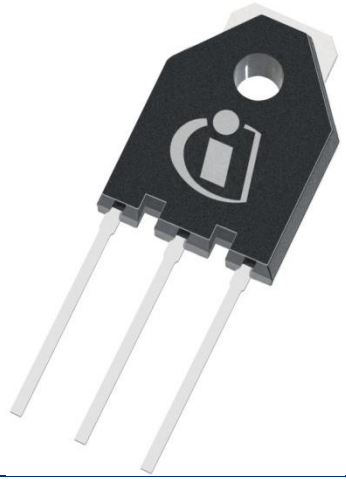
Infineon SiC diode package

TO220 real 2pin

- average creepage distance 3.63mm

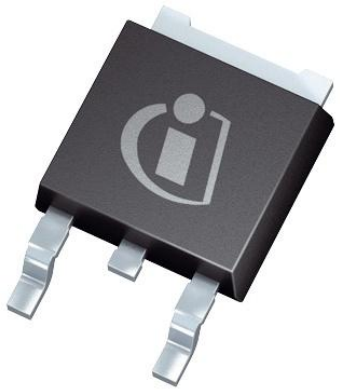
TO247HC

- package pin dimensions compatible to TO3P TO247
- high creepage / air distance of 6.35 / 3.6mm at pins

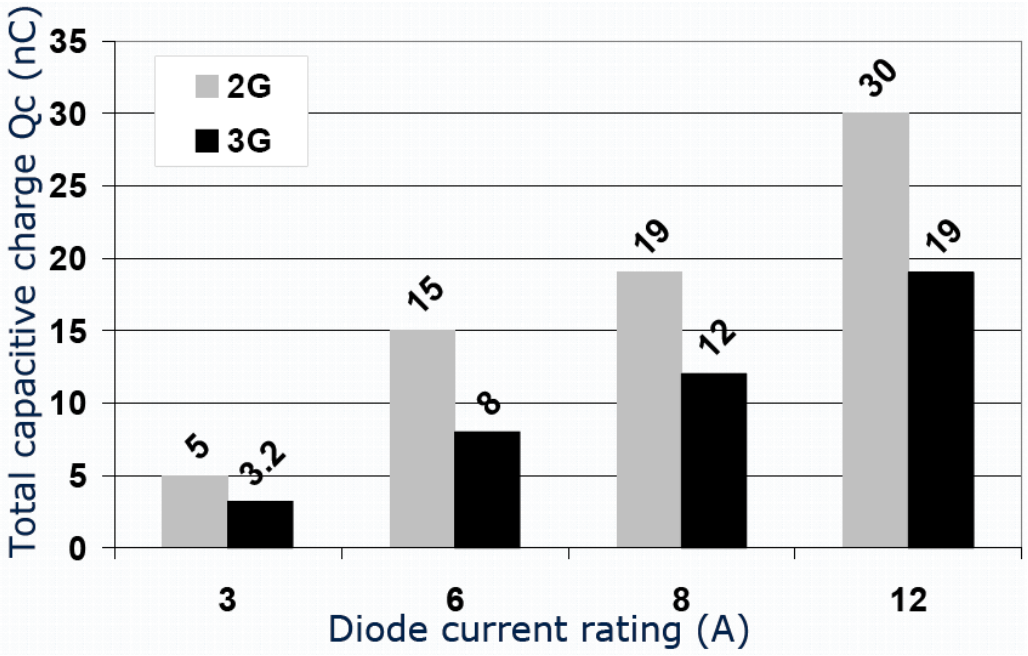


DPAK(TO252)

- SMD
- Best for high power density,compact design

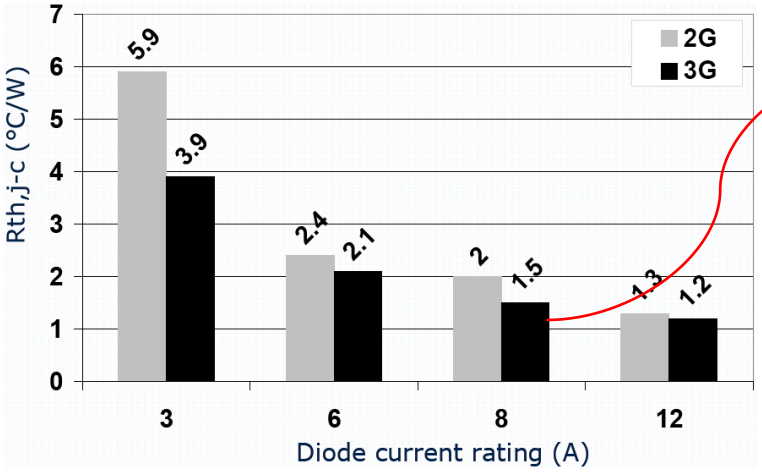


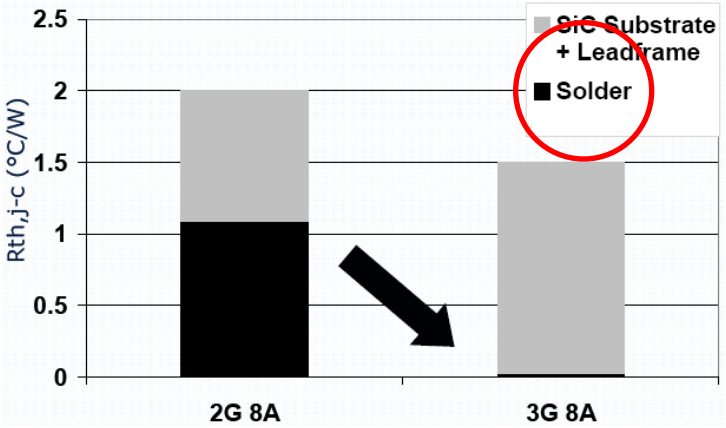
Improved switching loss
Reduction of device capacitances



- 3G SiC offers ever lowest Qc(Qrr) per given current rating in the market
- Enable higher switching frequency
- Enable smaller form-factor design
- Attain higher efficiency at light load

Improved thermal performance
Reduction of thermal resistance junction to case

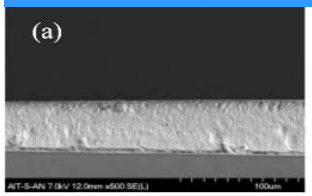


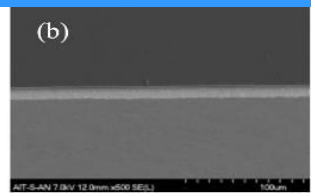


8A SiC diode

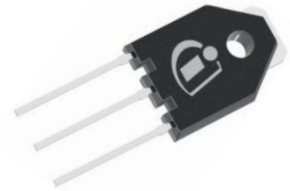
- Thin soldering technique reduces dramatically solder contribution to RthJC
- Thermal margin (Tcase) in your design may be improved.

New die attachment method
Diffusion soldering technology





SiC Diode for solar inverter

Package	Voltage	P/N	I_F	Q_C
DPAK(TO-252) 	600V	IDD03SG60C	3.0 A	3.2 nC
		IDD04SG60C	4.0 A	4.5 nC
		IDD05SG60C	5.0 A	6.0 nC
		IDD06SG60C	6.0 A	8.0 nC
		IDD08SG60C	8.0 A	12.0 nC
		IDD09SG60C	9.0 A	15.0 nC
		IDD10SG60C	10.0 A	16.0 nC
		IDD12SG60C	12.0 A	19.0 nC
TO-220 real 2pin 	600V	IDH03SG60C	3.0 A	3.2 nC
		IDH04SG60C	4.0 A	4.5 nC
		IDH05SG60C	5.0 A	6.0 nC
		IDH06SG60C	6.0 A	8.0 nC
		IDH08SG60C	8.0 A	12.0 nC
		IDH09SG60C	9.0 A	15.0 nC
		IDH10SG60C	10.0 A	16.0 nC
		IDH12SG60C	12.0 A	19.0 nC
	1200V	IDH02SG120	2.0A	7.2 nC
		IDH05S120	5.0 A	18.0 nC
		IDH08S120	7.5 A	27.0 nC
		IDH10S120	10.0 A	36.0 nC
		IDH15S120	15.0 A	54.0 nC
TO247HC 	1200V	IDY10S120	10 A	36 nC
		IDY15S120	15A	54 nC

Content

- Solar inverter overview and market outlook
- Topologies and power components
- Infineon best-in-class power discretes for solar inverter
- Summary

Summary

- Microinverter, String and multi string inverters use specific, often customer IP protected topologies
- OptiMOS, CoolMOS, IGBT and SiC Schottky barrier diodes will boost system efficiency and provide more flexibility to designer. Infineon can serve all applications.
  - CoolMOS (500V~900V)
    - www.infineon.com/CoolMOS
  - OptiMOS (25V~250V)
    - www.infineon.com/OptiMOS
  - IGBT
    - www.infineon.com/IGBT
  - SiC diode (600V/1200V)
    - www.infineon.com/SiC

ENERGY EFFICIENCY
COMMUNICATIONS
SECURITY

Innovative semiconductor solutions for energy efficiency, communications and security.