CoolSiC™ power MOSFETs – new additions to the portfolio

Fanny Björk, Laura Keuper, Andre Lenze, Karsten Schoo, **Peter Friedrichs**

Overview

Paper ID 1154

1 SiC & Infineon - Positioning

3 Current application targets and related portfolio

- Role of SiC diodes
- MOSFET portfolio expansion

3 Outlook

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SiC is a key topic for Infineon

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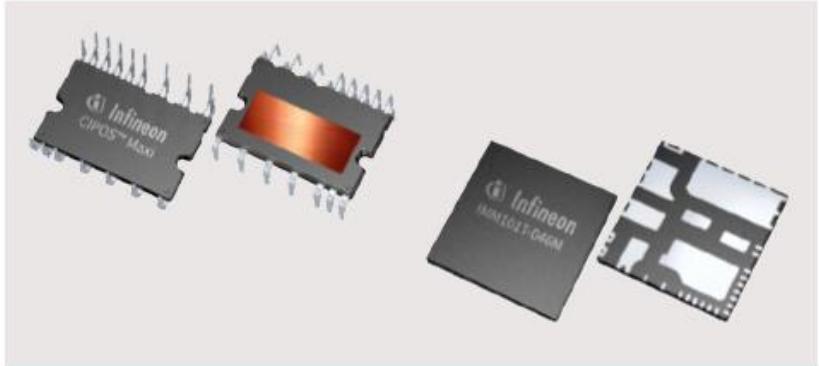
Core innovations by Infineon presented by CEO at IFX Day mid of 2018

Unique 300 mm thin wafer power semiconductor manufacturing

Compound semiconductors SiC and GaN

Digitalization of the power control loop



Functional integration in IGBT

Device opportunities for WBG power

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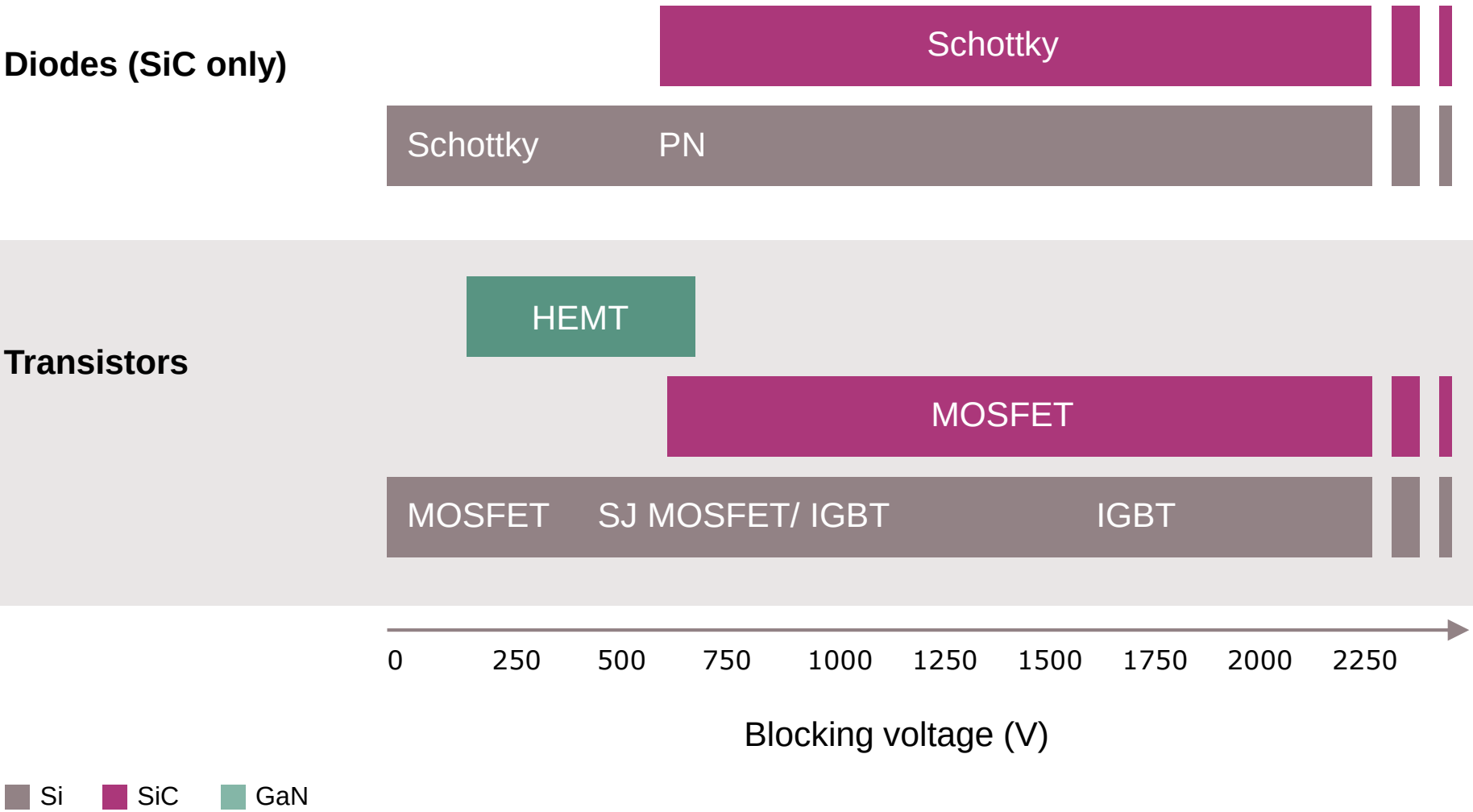

SiC and GaN enable higher efficiency through faster switching at lower losses than Si

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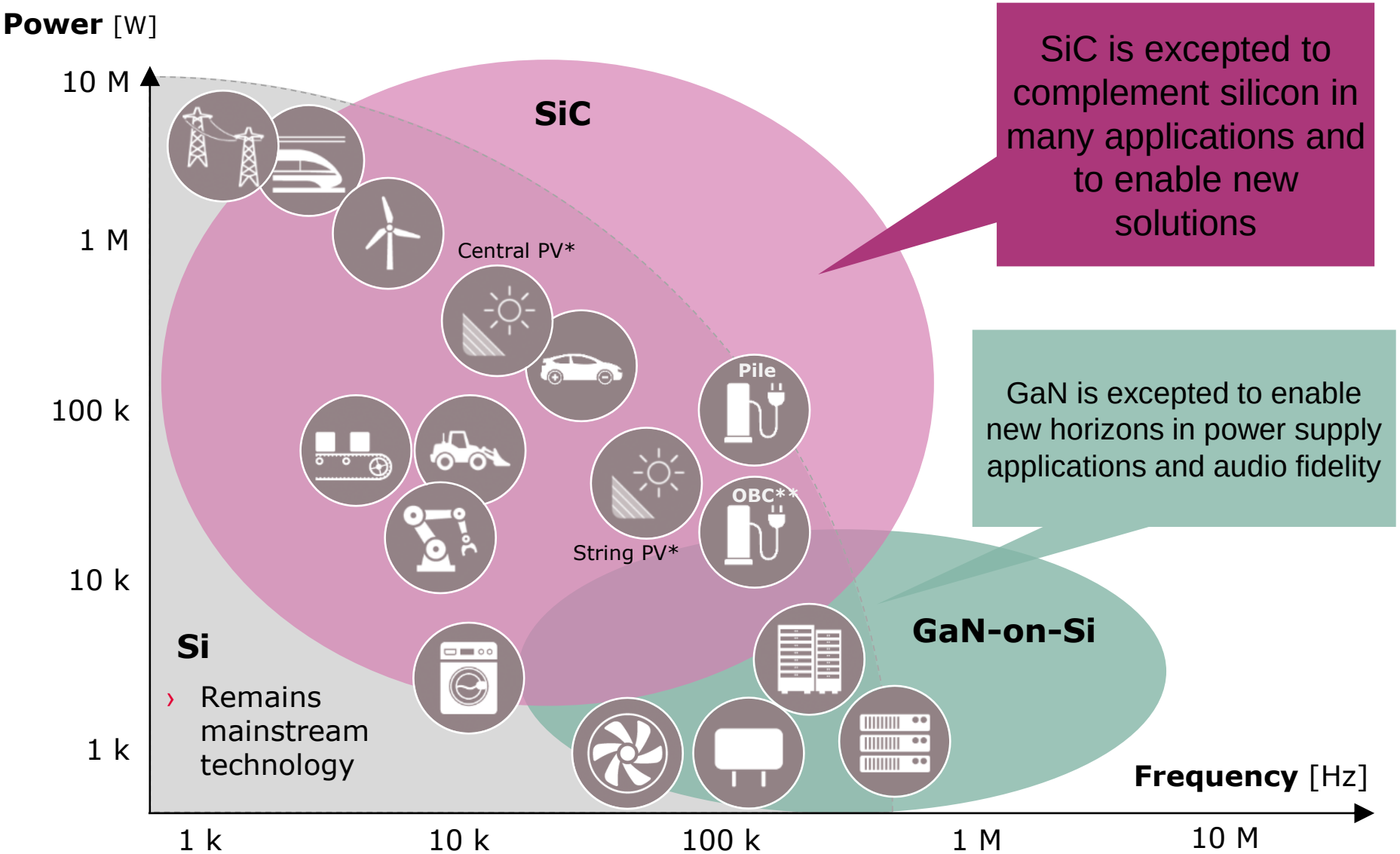

SiC is excepted to complement silicon in many applications and to enable new solutions

GaN is excepted to enable new horizons in power supply applications and audio fidelity

* PV = photovoltaic inverter; ** OBC = onboard charger

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CoolSiC™ Schottky diode 650 V
G5 + G6 for a granular and complete portfolio

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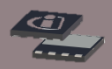
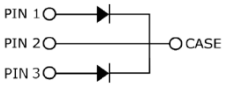
Ampere [A]	TO-220 R2L 	DDPAK 	TO-247 	D²PAK R2L 	ThinPAK 8x8 	TO-247 dual die 
2A	IDH02G65C5			IDK02G65C5	IDL02G65C5	
3A	IDH03G65C5			IDK03G65C5		
4A	IDH04G65C6	IDDD04G65C6		IDK04G65C5	IDL04G65C5	
5A	IDH05G65C5			IDK05G65C5		
6A	IDH06G65C6	IDDD06G65C6		IDK06G65C5	IDL06G65C5	
8A	IDH08G65C6	IDDD08G65C6		IDK08G65C5	IDL08G65C5	
9A	IDH09G65C5			IDK09G65C5		
10A	IDH10G65C6	IDDD10G65C6	IDW10G65C5	IDK10G65C5	IDL10G65C5	
12A	IDH12G65C6	IDDD12G65C6	IDW12G65C5	IDK12G65C5	IDL12G65C5	
16A	IDH16G65C6	IDDD16G65C6	IDW16G65C5			
20A	IDH20G65C6	IDDD20G65C6	IDW20G65C5			IDW20G65C5B*
24A						IDW24G65C5B*
30/32A			IDW30G65C5			IDW32G65C5B*
40A			IDW40G65C5			IDW40G65C5B*

*Common cathode



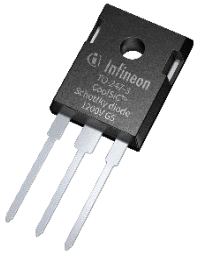
› G6 products › G5 products

G5 Diode technology also implemented in power modules

1200V CoolSiC™ Schottky Diode G5 Portfolio
Now in TO247-2pin package

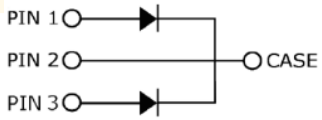
Paper ID 1154






New!

Continuous Forward Current, I_F	TO-252 (DPAK real 2-leg)	TO-220 (real 2-leg)	TO-247-3	TO-247-2
2A	IDM02G120C5	IDH02G120C5		
5A	IDM05G120C5	IDH05G120C5		Released!
8A	IDM08G120C5	IDH08G120C5		
10A	IDM10G120C5	IDH10G120C5	IDW10G120C5B	IDWD10G120C5
15-16A		IDH16G120C5	IDW15G120C5B	IDWD15G120C5
20A		IDH20G120C5	IDW20G120C5B	IDWD20G120C5
30A			IDW30G120C5B	IDWD30G120C5
40A			IDW40G120C5B	IDWD40G120C5



„B" in product name refers to common-cathode configuration:

G5 Diode technology also implemented in power modules

1200V CoolSiC™ G5 Schottky diode

Paper ID 1154

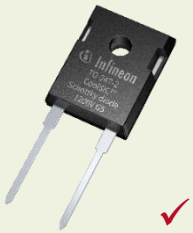
System improvements?

- Reach new efficiency targets
- Higher power density
- Upgrade designs towards higher output power

...while maintaining reliable system!

Easily enabled by SiC Schottky diodes

Benefit of TO247 2pin package



- ✓ Expanded creepage distance
- ✓ Suitable for high pollution environments
- ✓ Easy exchange of commonly used Si ultrafast diodes

Charging station: 1200V CoolSiC™ diode for high efficiency and high output power

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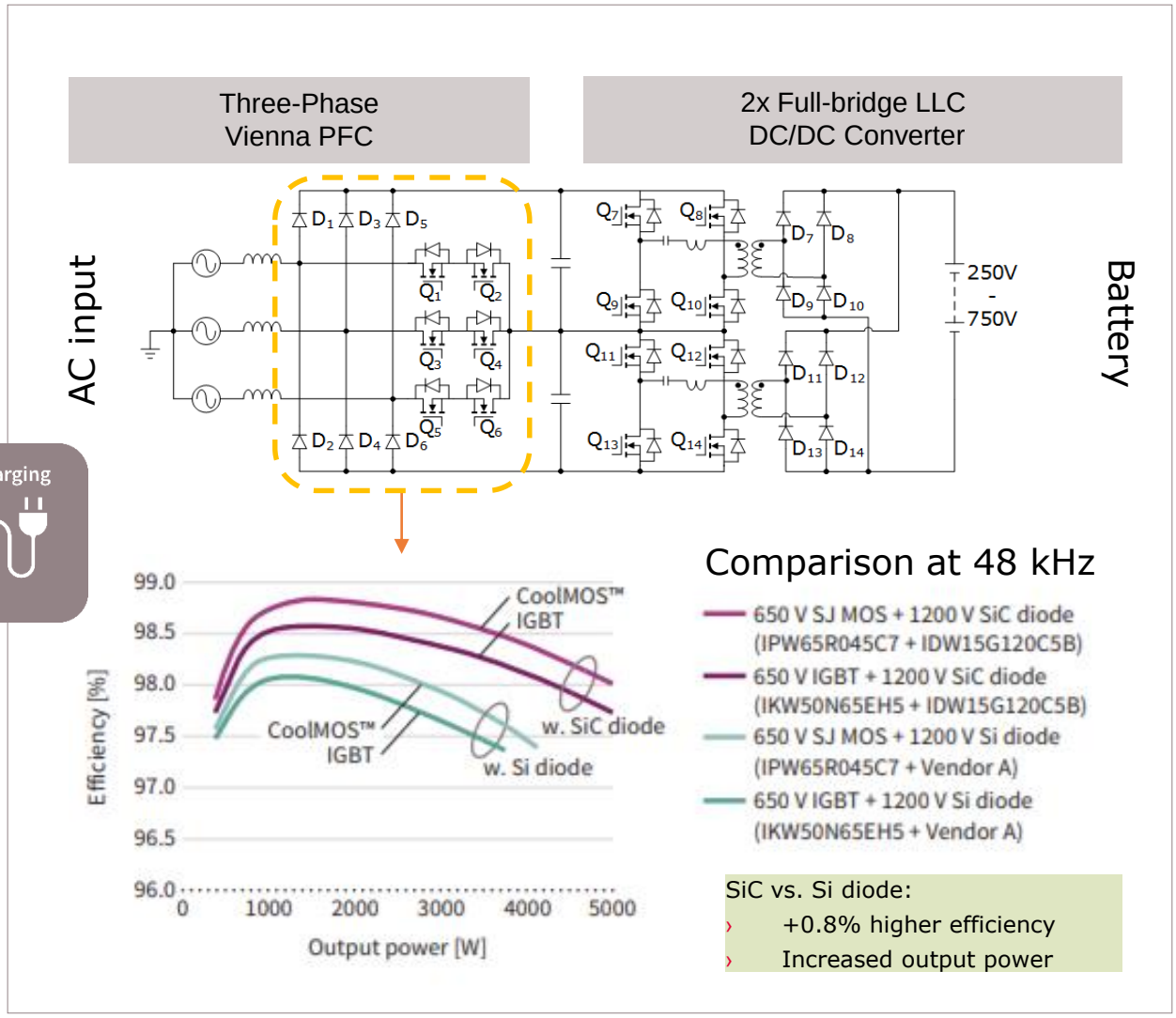


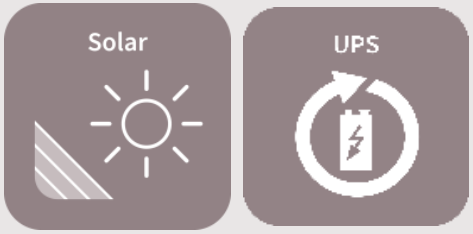
Easy Hybrid Modules with CoolSiC™ Schottky Diodes G5

Paper ID 1154

Key Features

- System efficiency improvement for reduced cooling requirements
- Enabling higher frequency to Increase Power density
- Reduction of IGBT turn-on loss
- Reduced EMI
- Switching loss independent from load current, switching speed and temperature

Target Applications



Product	I_C	Voltage	Topology	Technology
FS3L40R07W2H5F_B11	40 A	650 V	3-level NPC1	TRENCHSTOP™ 5
FS3L50R07W2H3F_B11	50 A			Highspeed 3
DF80R07W1H5FP_B11	80 A		Booster	TRENCHSTOP™ 5
DF100R07W1H5FP_B53	100 A			
DF80R12W2H3F_B11	80 A	1200 V	Booster	Highspeed 3
DF160R12W1H3F_B11	160 A			
DF200R12W1H3F_B11	200 A			

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MOSFET portfolio expansion

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SiC MOSFET will adopted by various applications depending on the achievable cost performance level

Paper ID 1154

Application Driving forces

Reduction of system cost and size

Photovoltaics

Higher reach per charge and smaller systems

eMobility

Faster charging cycles

EV charging

Lower system cost and higher efficiency

Traction

Higher efficiency, reducing TCO

UPS/ SMPS[1]

System size and TCO reduction

Drives

Time

Note: 1) UPS = uninterrupted power supply; SMPS = Switched-mode power supply; TCO = total cost of ownership

System integration and energy savings will be a key lever for power electronics

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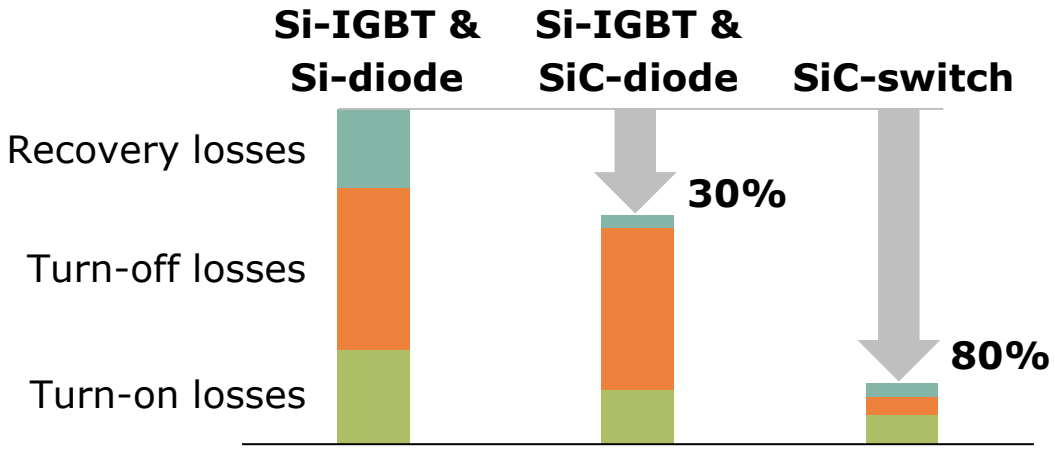
Cool SiC™

best in class switching frequency, conduction losses and radically improved efficiency



The broadest portfolio of CoolSiC™ MOSFET modules in Easy package on the market

Paper ID 1154

Key Features

- About 80% lower switching losses compared to Si
- Low conduction losses due to linear output characteristic
- Superior gate oxide reliability
- Intrinsic body diode with low reverse recovery charge
- Highest threshold voltage of V_{th} > 4 V

Target Applications

… and more

http://www.infineon.com/cms/en/product/promopages/coolsic-mosfet/

The broadest portfolio of CoolSiC™ MOSFET modules in Easy package in the market

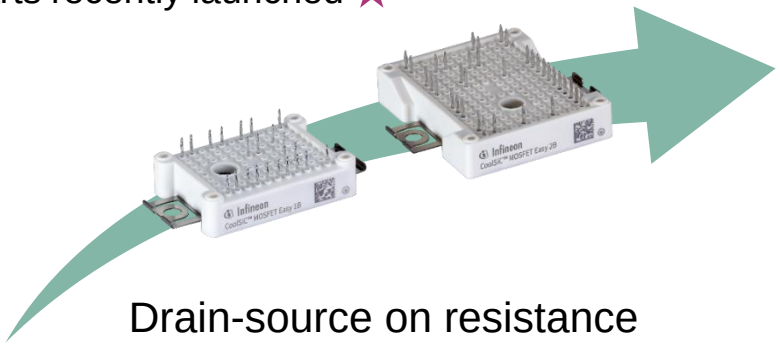
Paper ID 1154

Rdson	EasyDUAL™	Easy Booster	EasyPACK™	
[mOhm]	1200V Halfbridge	1200V Booster	1200V H-Bridge	1200V SixPACK
45	FF45MR12W1M1_B11 ★			FS45MR12W1M1_B11 ★
23	FF23MR12W1M1_B11	DF23MR12W1M1_B11	F4-23MR12W1M1_B11 ★	
11	FF11MR12W1M1_B11	DF11MR12W1M1_B11		
8	FF8MR12W2M1_B11 ★			
6	FF6MR12W2M1_B11 ★			

Rdson	EasyPACK™
[mOhm]	1200V 3-Level
15	F3L15MR12W2M1_B69 ★
11	F3L11MR12W2M1_B65 ★

Available

New parts recently launched ★



45mΩ Drain-source on resistance **6mΩ**

Sneak preview : 62mm module with CoolSiC™ MOSFET

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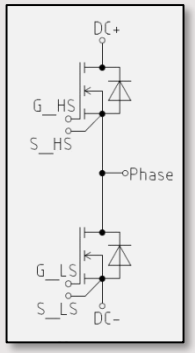
Experienced package with newest technology

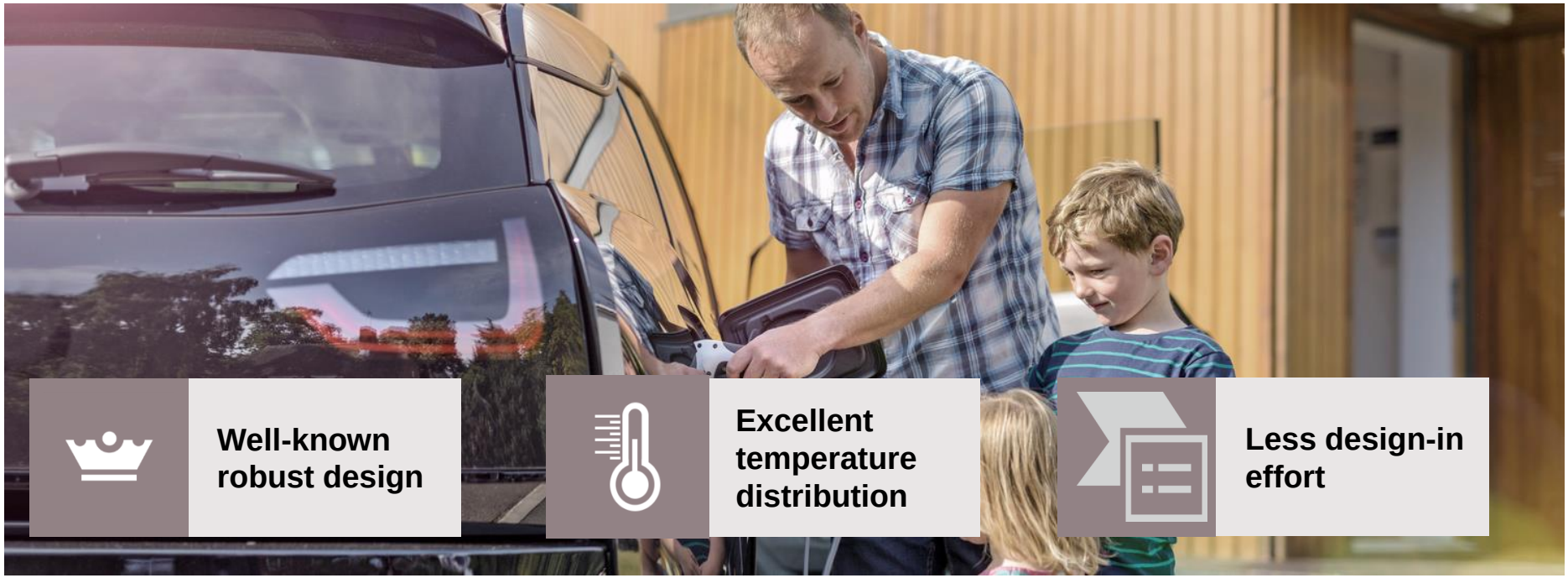


Upcoming module product

Half bridge 2-6mOhm

- FF4MR12KM1* New

*in development



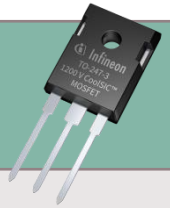
Well-known robust design

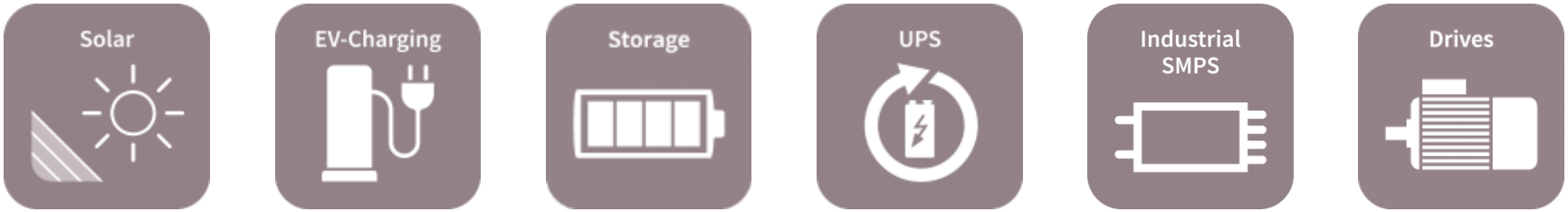
Excellent temperature distribution

Less design-in effort

1200V CoolSiC™ MOSFET:
Sneak Preview : roll-out in TO-247

Paper ID 1154

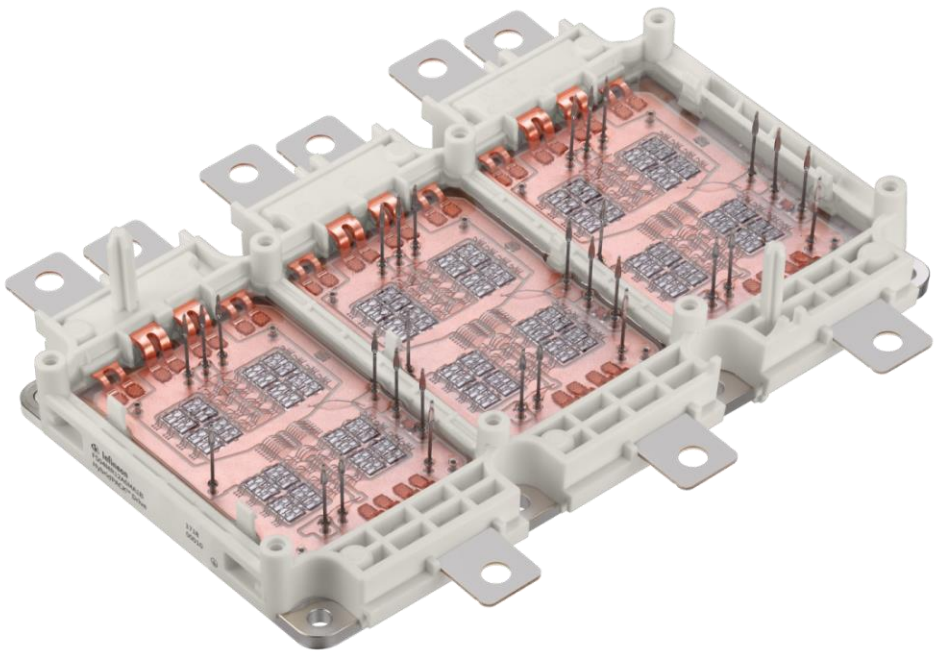
On-resistance, RDSon [mOhm]	TO247-3 	TO247-4 
45	Released	Released
60	Samples in Q2 2019	Samples in Q2 2019
90	Samples in Q2 2019	Samples in Q2 2019
140	Samples in Q2 2019	Samples in Q2 2019
220	Samples in Q4 2019	Samples in Q2 2019
350	Samples in Q4 2019	Samples in Q2 2019



Sneak Preview :
HybridPACK™ Drive for automotive drive train

Paper ID 1154

Infineon introduced SiC power module for automotive applications



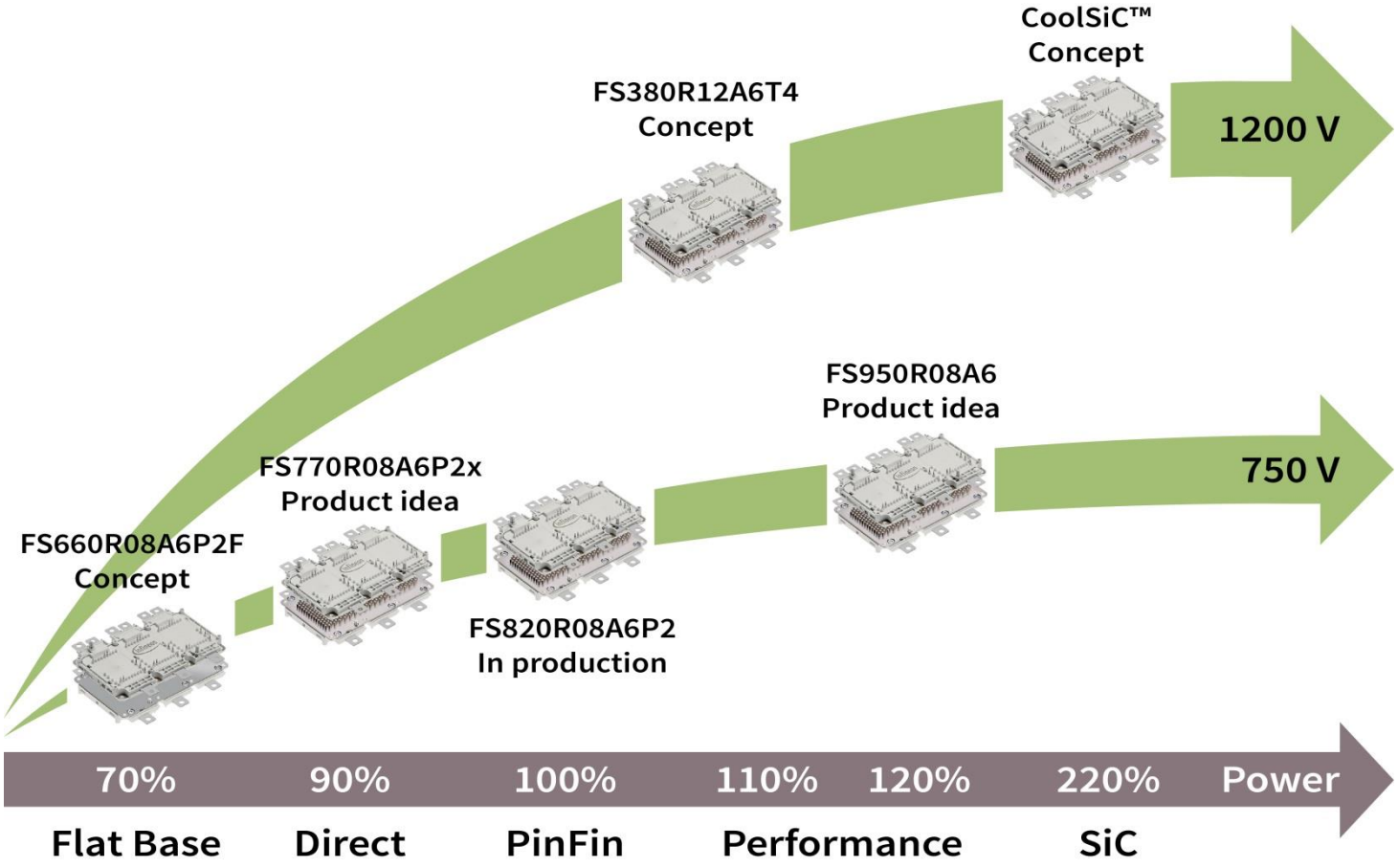
- 3-phase half-bridge module
- Power density doubled compared to IGBT
- HybridPACK™ Drive compatible
- Target applications:
  - Main inverter (300 kW)
  - high-voltage DC-DC converter

- More than 15 leading OEMs and tier-1s are evaluating Infineon's SiC-based HybridPACK™ Drive power module

HybridPACK™ Drive with SiC is part of a well adjusted portfolio enabling at customers variable designs

Paper ID 1154

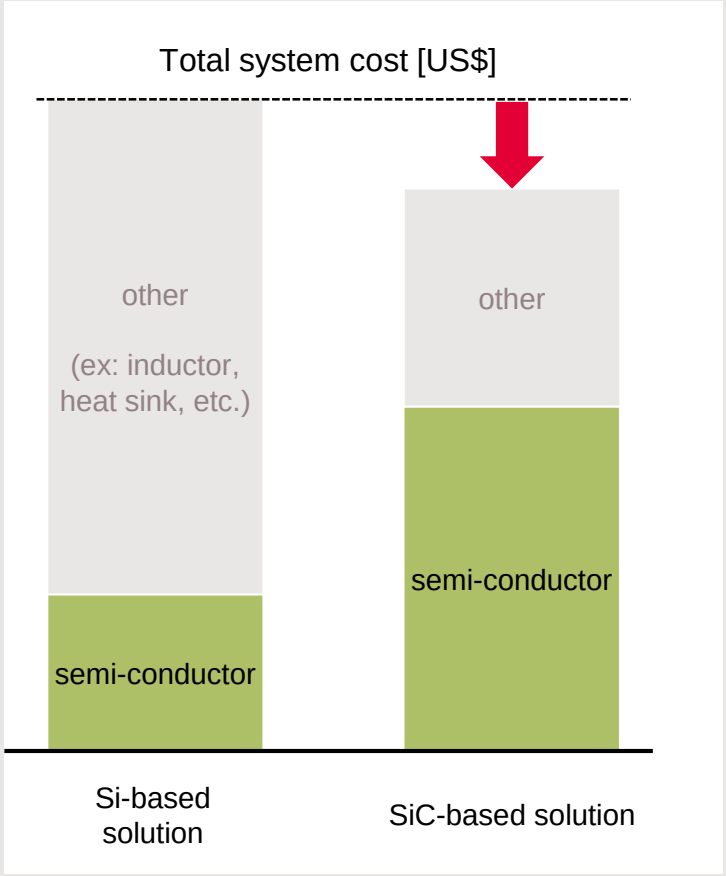
- Performance tuning by
  - Chipset (technology and voltage rating)
  - Cooling concept



The backbone of SiC MOSFET production today - opportunities for solar conversion systems

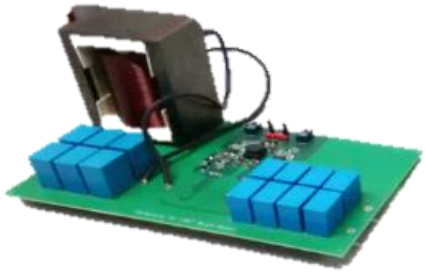
Paper ID 1154

15-20% lower bill of material for inverter manufacturer



- Simpler topologies with less control effort
- Higher switching frequency with smaller transformers
- Same power in smaller box size results in a significant system cost reduction

Si IGBT reference



SiC MOSFET demonstrator

Customer value proposition for PV string Inverters: Power density increase by 2,5

Paper ID 1154

Development of Kaco String Inverters

Year 2008, 100 kW, 1129 kg, 2,12m Height
Si

Year 2011, 50 kW, 151 kg 1,36 m Height
Si

Year 2016, **50 kW**, 70 kg, 0,76 m Height
Si

Year 2018, 125 kW, 77 kg, 0,72 m Height
SiC

Value Proposition

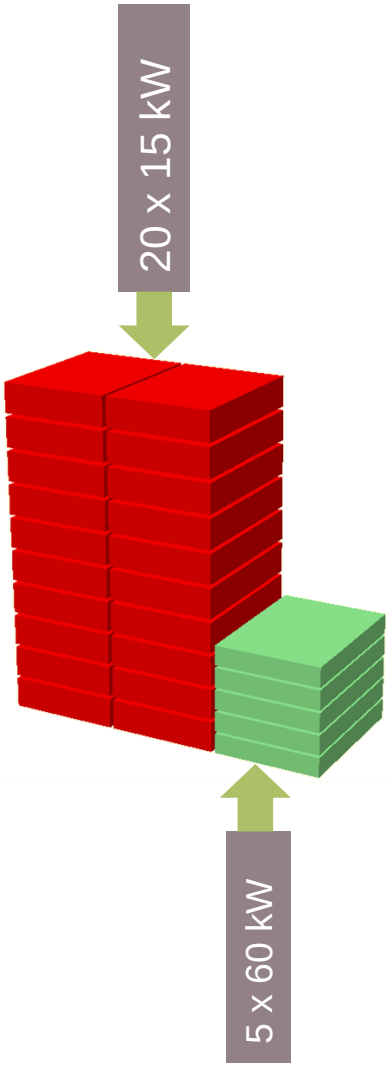
- Power density increase by factor 2,5 (50kW → 125kW)
- Reduction of number of switches (5-level to 3-level) leads to reduced risk of field failures
- SiC provides less reduction in efficiency at high operating temperatures → better efficiency (99,1% vs 98,9%)

Source:
https://www.pv-magazine.de/2018/11/14/pv-magazine-top-innovation-kacos-neuer-siliziumkarbid-wechselrichter/

EV charging will benefit from SiC based components regarding system simplification

Paper ID 1154

- Today 15 kW-units using discrete components are state of the art, currently upgraded to 20…30 kW 19" x 3 HU x 800 mm, forced air cooling
- New infrastructure is targeting DC-chargers exceeding 300 kW leading to two changes:
  - Liquid cooling is used in these designs
  - Power per subunit is growing to 60…75 kW in even smaller spaces
- Coming now are units exceeding 60 kW 19" x 2 HU x 800 mm, liquid cooling ➔ possible with SiC only



EV charging will benefit from SiC based components regarding system simplification

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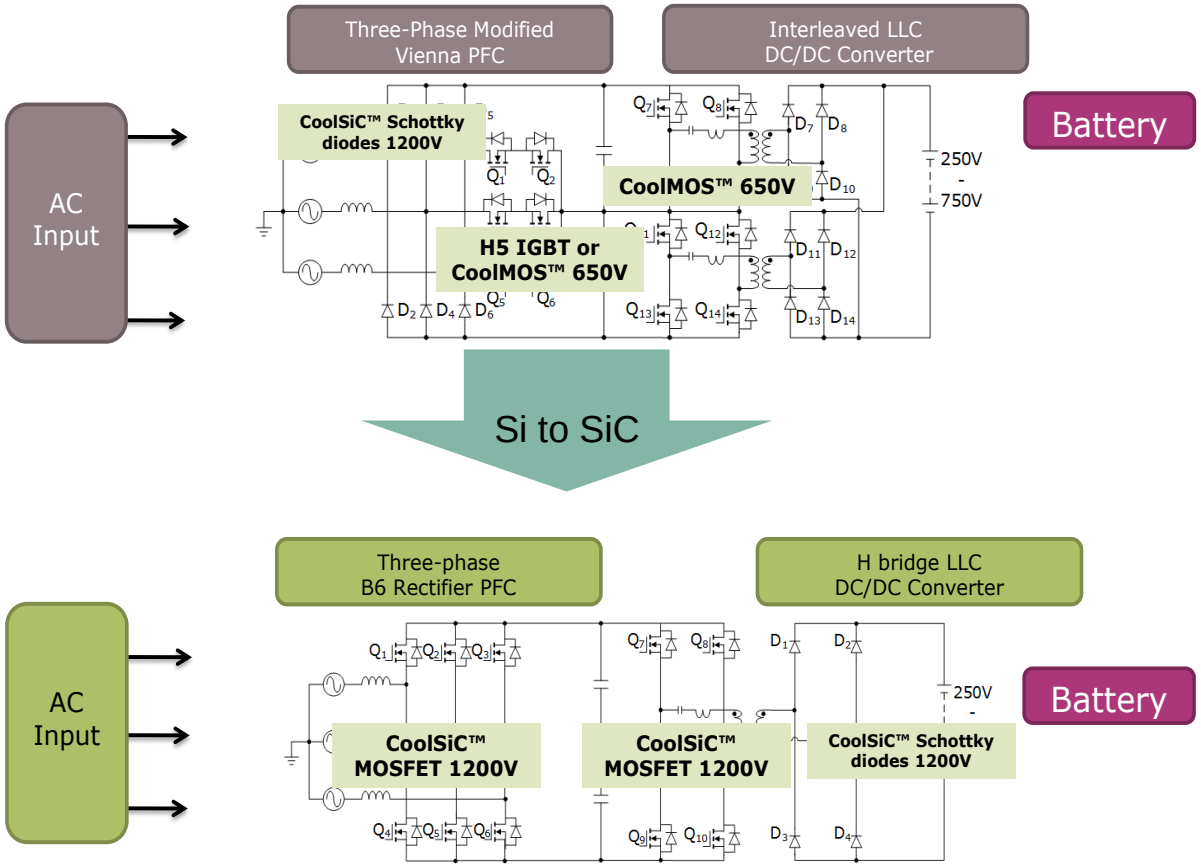
Off-board EV charger:
CoolSiC™ MOSFET simplifies the system



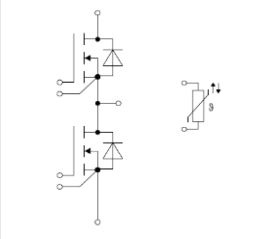
1200V CoolSiC™ MOSFET in Easy 2B package: excellent value proposition for online UPS systems

Paper ID 1154

New!

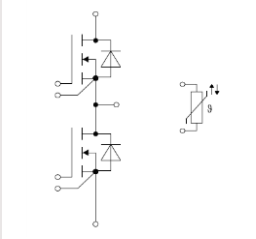
- **Using CoolSiC™ MOSFETs in a high power UPS can save ~€40,000 over 5 years operating in electricity costs (see calculation).**
- In addition: heatsinks and filters can be reduced, making size, floor footprint and enclosure smaller.
- Easy 2B CoolSiC™ MOSFET modules can be paralleled to achieve a high current SiC MOSFET solution with very low inductance!

Halfbridge 6mΩ Easy 2B



FF6MR12W2M1_B11

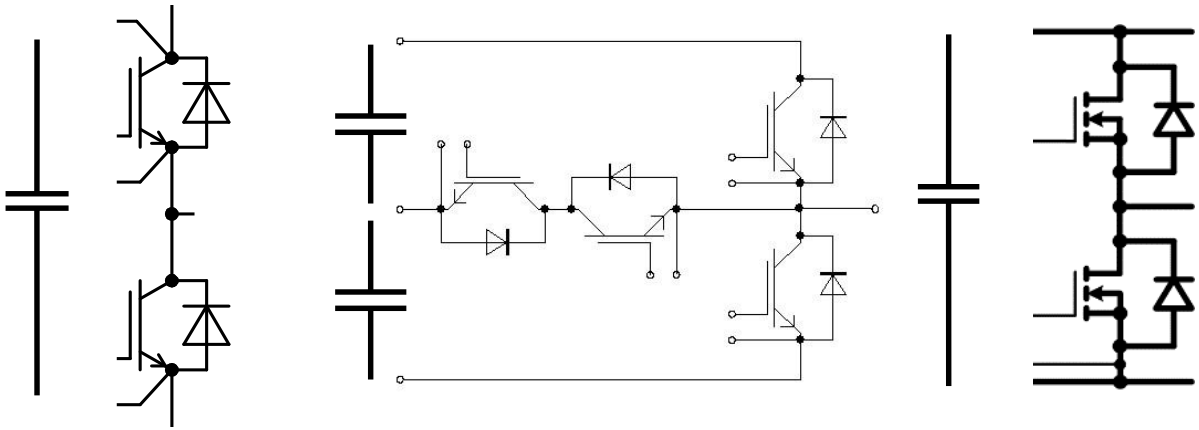
Halfbridge 8mΩ Easy 2B



FF8MR12W2M1_B11

High Power UPS Topologies

Paper ID 1154



Si 2-Level	Si 3-Level NPCT	SiC 2-Level
10 Years ago	5 Years ago	In 2019
3.2% losses* at 6kHz	2.9% losses* at 8kHz	1.7% losses* at 32kHz

*% Losses of Power Semi Devices at 300kW and 400Vac

Calculating the energy losses for a 1MW UPS operating at 50% load for 5 years

Paper ID 1154

500kWhrs x 24 hours x 365 days x 5 years =
22 million kWhrs processed power through UPS

- **Si 2-Level at 3.2% loss** = 700,000 kWhrs x 1.2 factor* = 840,000 kWhrs
  - In EU at €.10 per kWhr = **€84,000**

- **Si 3-Level at 2.9% loss** = 640,000 kWhrs x 1.2 factor* = 760,000 kWhrs
  - In EU at €.10 per kWhr = **€76,000**

- **SiC 2-Level at 1.7% loss** = 374,000 kWhrs x 1.2 factor* = 450,000 kWhrs
  - In EU at €.10 per kWhr = **€45,000**

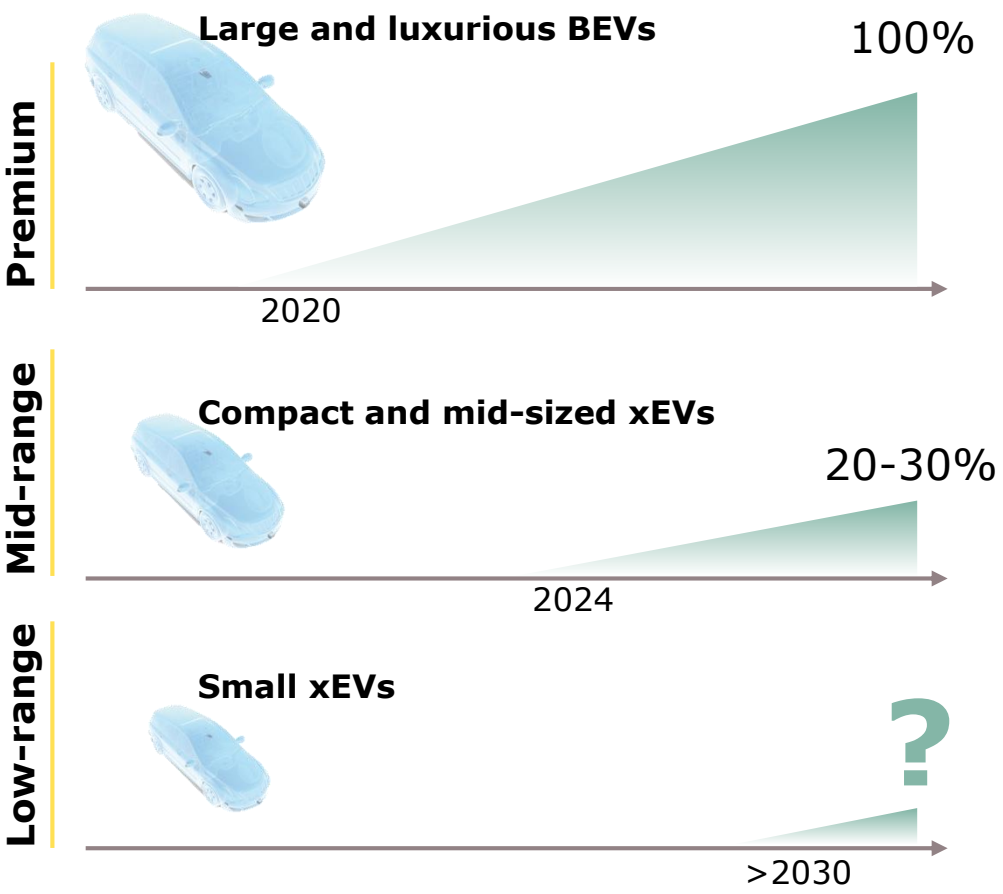
+SiC

*1.2 factor reflects the energy used for air conditioning to extract heat from a building with UPS installed

Main inverter applications will account for ~80% of the overall automotive SiC market

Paper ID 1154

Main Inverter SiC Penetration



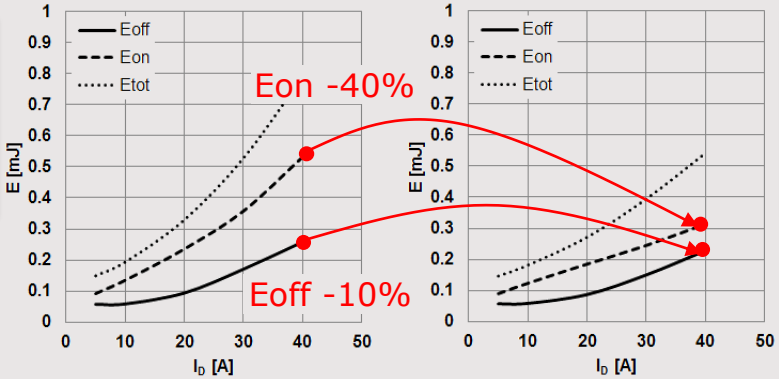
- As costs improve, advantages such as performance increase, range extension, and faster charging cycles will be fully adopted for premium cars
- The advantages of a SiC based main inverter are utilized on a use case base: e.g. form factor benefits for PHEV
- Si will be still more cost competitive for a long time and it is unlikely that low-range cars will be able to unfold the true potential of SiC

The right package is key for full utilization of SiC benefits

Paper ID 1154

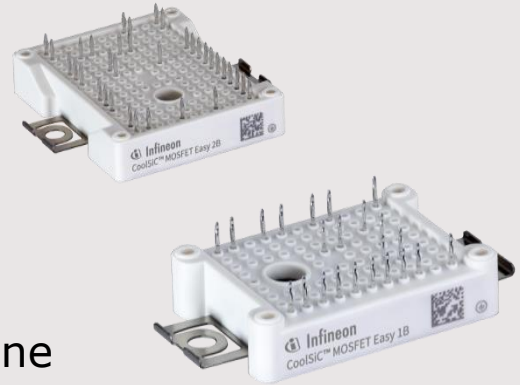
TO-247 with 4 pins

- Drastically reduced switching losses due to additional source connection



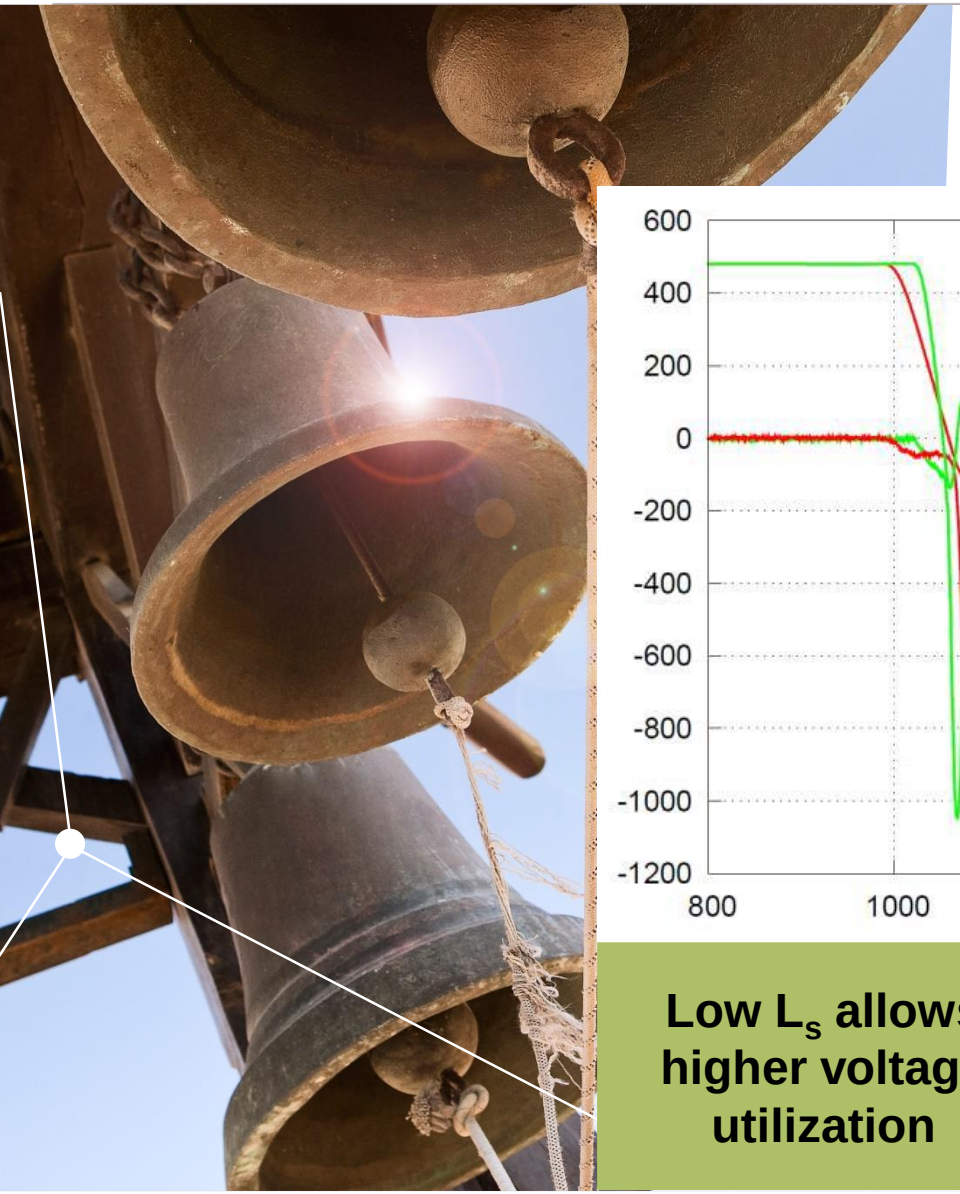
Our modules

- Low stray inductances
- Optimized paralleling
- Easy PCB routing
- Highly symmetric strip line

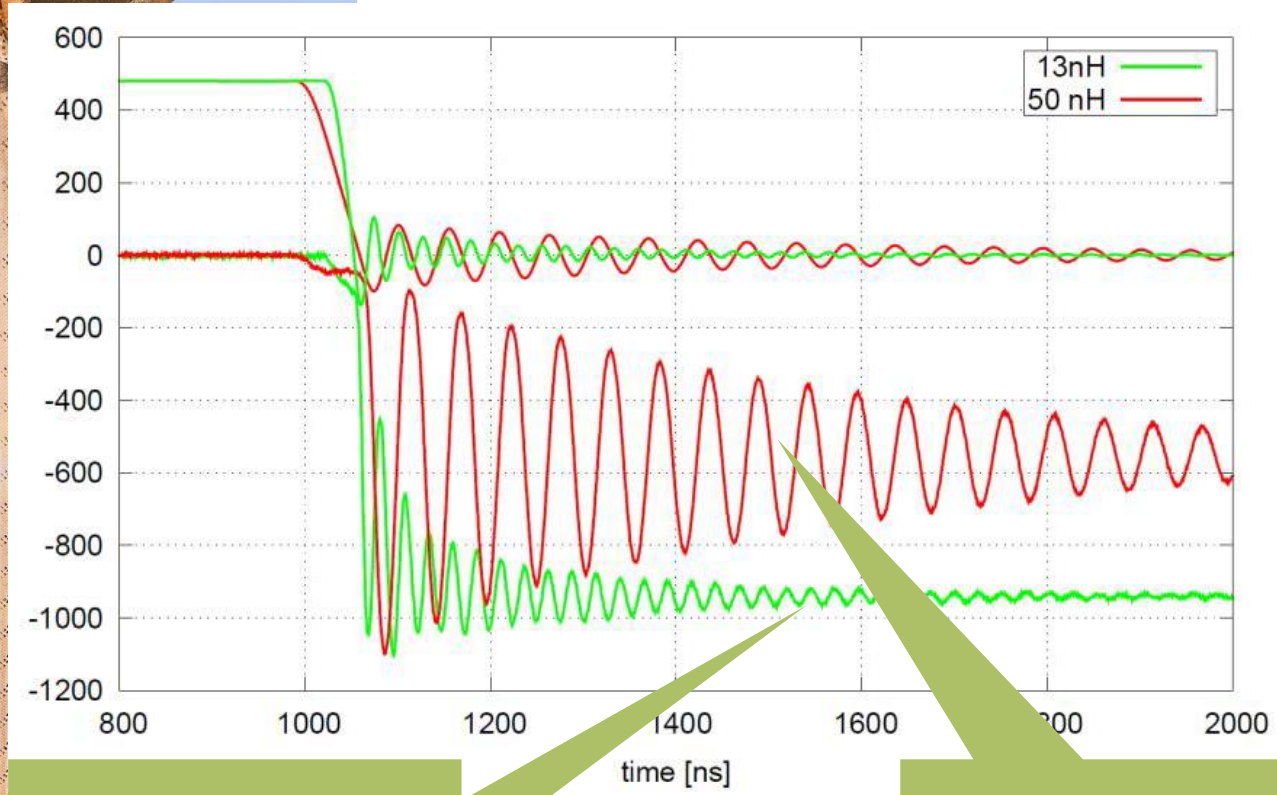


Why low inductance?

Paper ID 1154



Ringing between stray inductance and capacitance.



Low L_s allows higher voltage utilization

Low L_s reduces EMI trouble

Infineon SiC MOSFET Driver

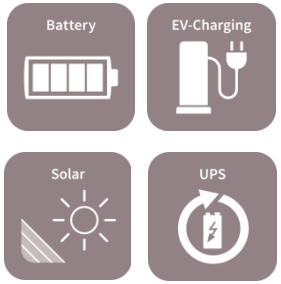
Paper ID 1154

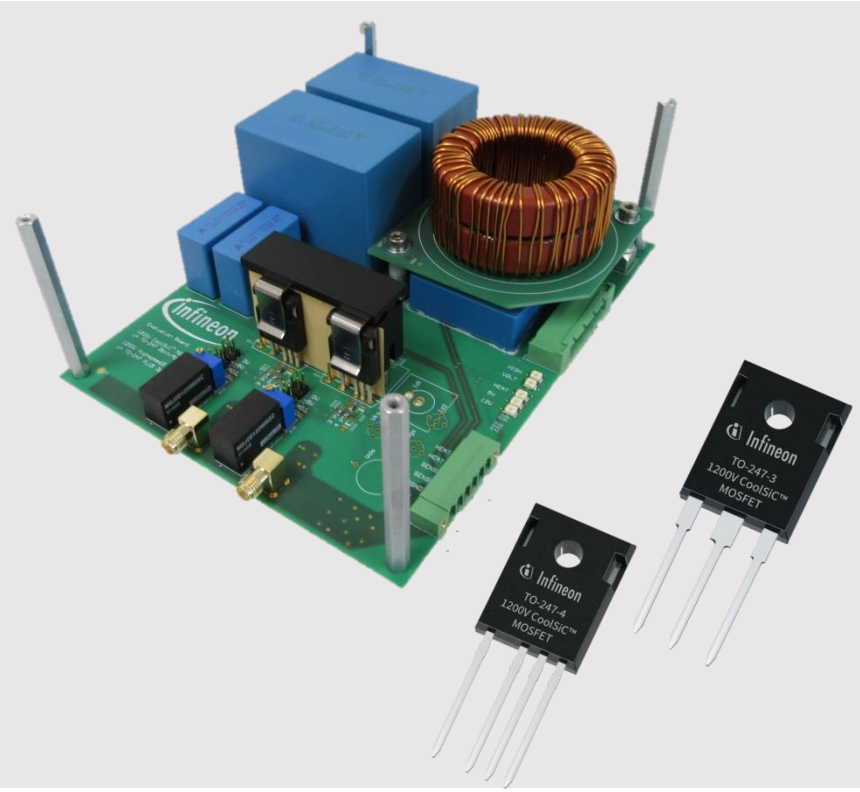
- SiC MOSFETs are fast switching AND high voltage devices, which common mode transient (CMT) can reach 50 V/ns or above
- Higher switching speed requires higher gate drive current strength as well as well-matched delays and accurate timing and tight tolerances
- SiC MOSFETs may need a negative gate voltage or a Miller clamp
- SiC MOSFETs may need fast short circuit protection as its short circuit capability is less than traditional IGBT
- To fully utilize the low Ron capability of SiC MOSFET, higher gate drive voltage is also required

Evaluation Boards
1200V CoolSiC™ MOSFET

Paper ID 1154

- Complete set-up for evaluation of CoolSiC™ MOSFET **switching behavior**
- Configurable for **continuous operation** as a buck or boost converter
- Includes recommended EICEDRIVER™ IC 1EDI Compact
- Test of devices in **TO-247 3pin/4pin** and **Easy1B Halfbridge**





Overview

1 SiC & Infineon - Positioning

3 Current application targets and related portfolio

Role of SiC diodes

MOSFET portfolio expansion

3 Outlook

Summary Key features CoolSiC™ MOSFET

Paper ID 1154

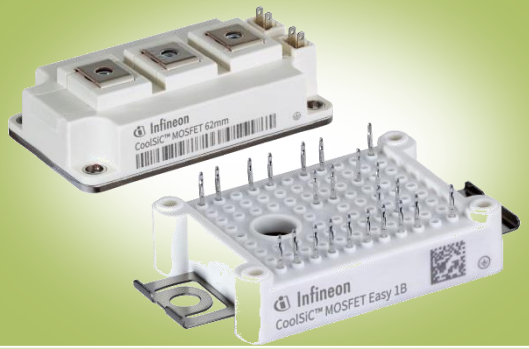
SiC MOSFETs vs Si IGBT

- Low Qg & device capacitances
- Temperature- independent switching losses
- Intrinsic diode with low reverse recovery charge
- Knee voltage-free on-state

Features

CoolSiC™ MOSFET vs Competition

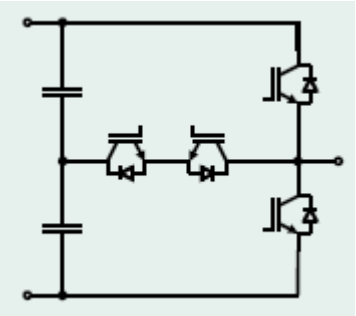
- Superior gate oxide reliability
- Threshold voltage, V_{th} > 4 V
- Short-circuit robustness, 2 µs
- IGBT-compatible gate driving, +15 V for turn-on
- Body diode use enabled w/o restrictions
- Safe turn off with 0V in booster



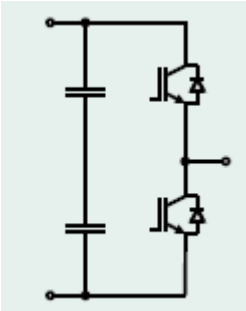
WBG‘s fast switching capability must be handled well, plug and play usually doesn´t work

Paper ID 1154

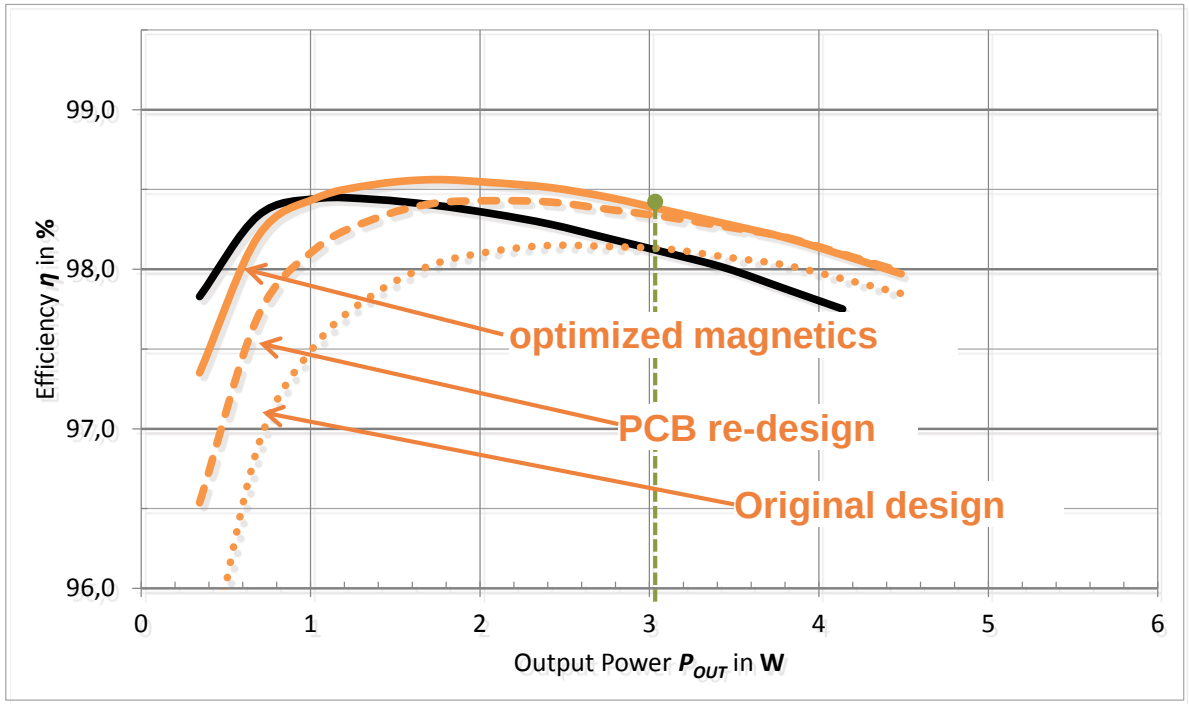
3L IGBT @24kHz
State of the art solution



Si to SiC



2L SiC @48kHz



Source: Sobe et al. PCIM 2017, “ Experimental study of Si- and SiC-based Voltage Source Inverters “

Key ingredients for a successful roll out of WBG in mainstream applications

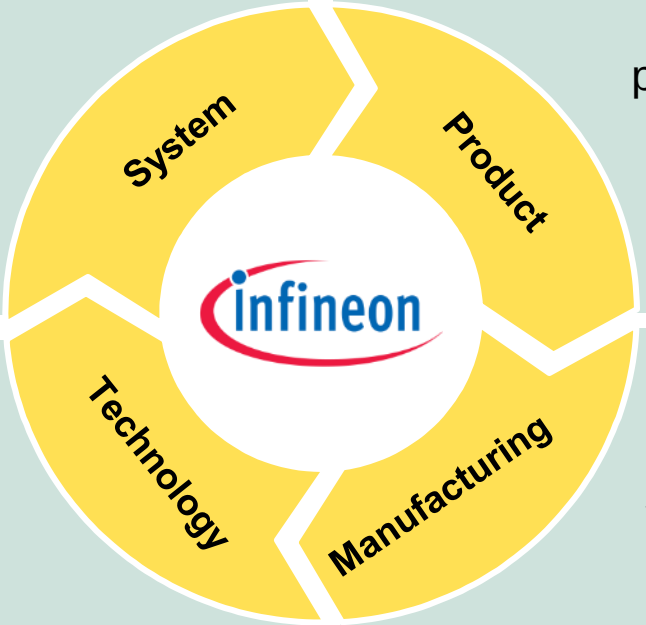
Paper ID 1154

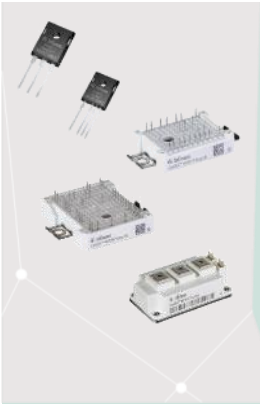
Extensive system expertise

Extensive application system under-standing and global support

Application-dedicated products

Most comprehensive power portfolio in the market ensures always best-fit





Innovative technology and expertise in all leading power materials (Si, SiC, GaN)

Unique power technology portfolio

Extreme high volume flexibility and reliability proven by multi million track record

Benchmark in manufacturing

Part of your life. Part of tomorrow.