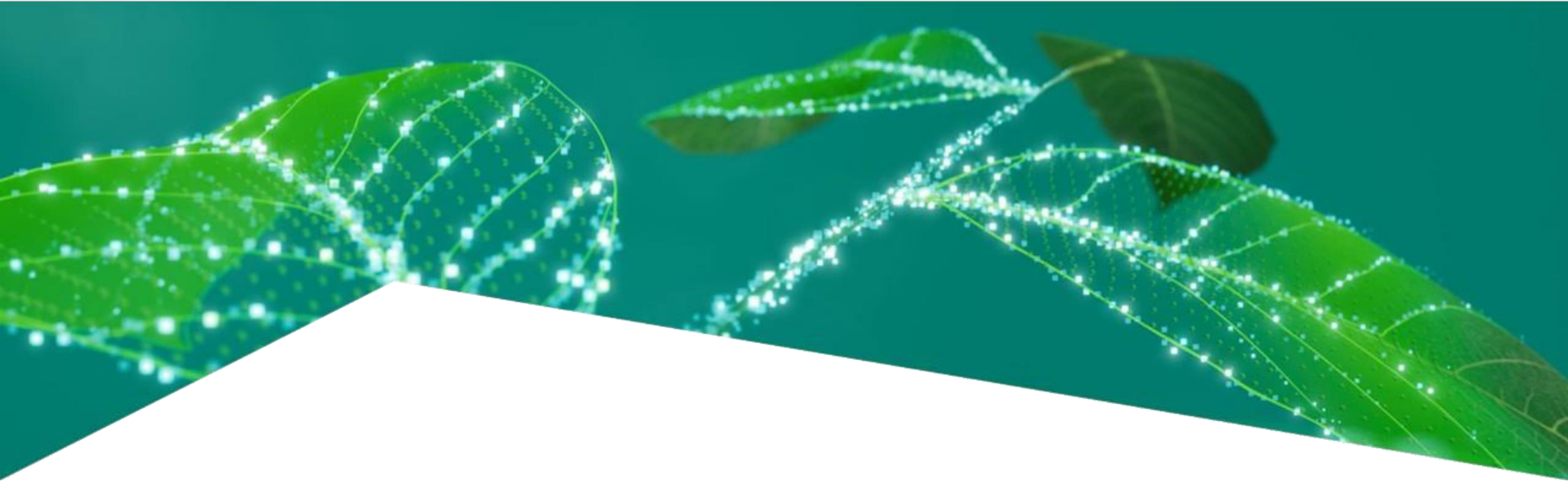
Pushing the SiC portfolio boudaries – 400V and 3.3kV SiC MOSFETs

Dr. Peter Friedrichs, Fellow, Infineon Technologies

Bodo's Wide Bandgap Event 2024

Making WBG Designs Happen

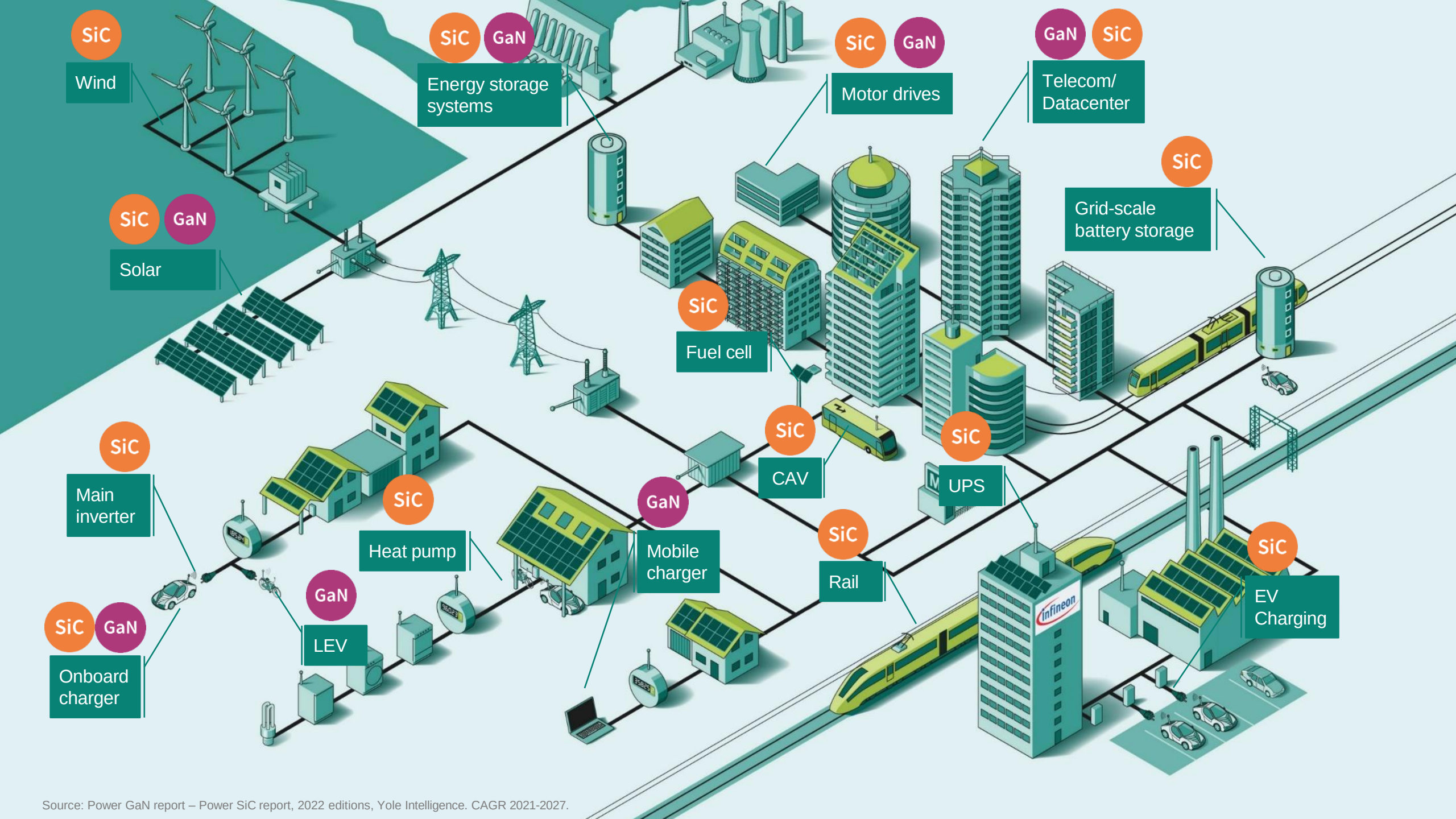
SiC



Pushing the SiC portfolio boundaries - 400V and 3.3kV SiC MOSFETs

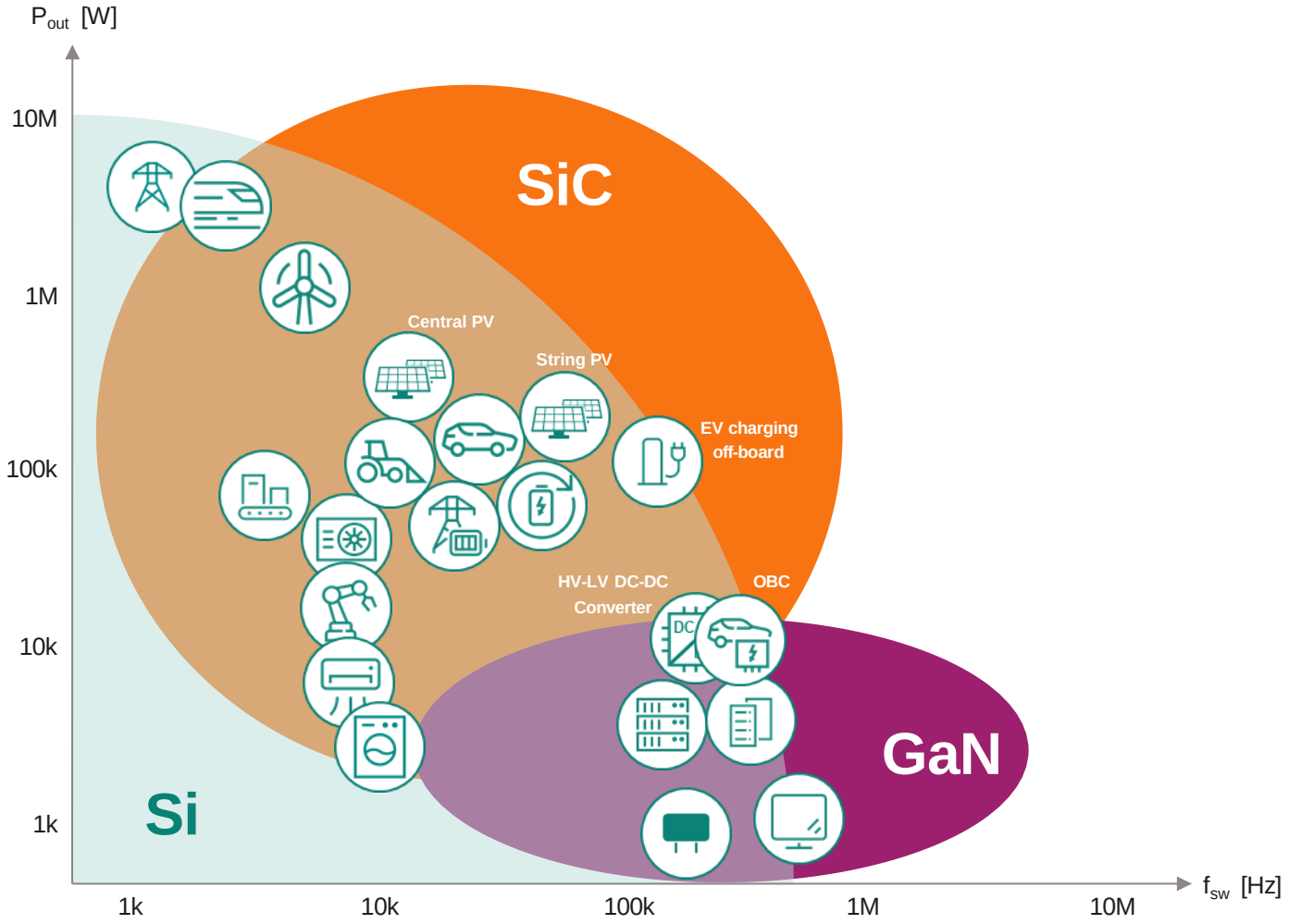
Dr. Peter Friedrichs, Fellow
Infineon Technologies AG

What drives the portfolio definition and how Infineon reacts



Source: Power GaN report – Power SiC report, 2022 editions, Yole Intelligence. CAGR 2021-2027.

Which applications is relevant for which material?



Si

- Si today the mainstream technology
- Targeting 25 V - 6.5 kV

SiC

- SiC complements Si in many applications and enables new solutions
- Enables new levels of power density and performance
- Mainstream for many emerging applications
- Targeting 400 V - 3.3 kV

GaN

- Enables new horizons in efficiency and power density in wide range of applications
- Targeting 40 V - 850 V
- Medium power – superior switching performance results in higher efficiency and lower system cost

Mastering all three key materials power modern power conversion is key for a greener future

- Reliable multi sourcing of raw materials
- World-scale fabs

Controller | **Driver IC** | **Power switch** (Si/SiC/GaN)

Software + Algorithms

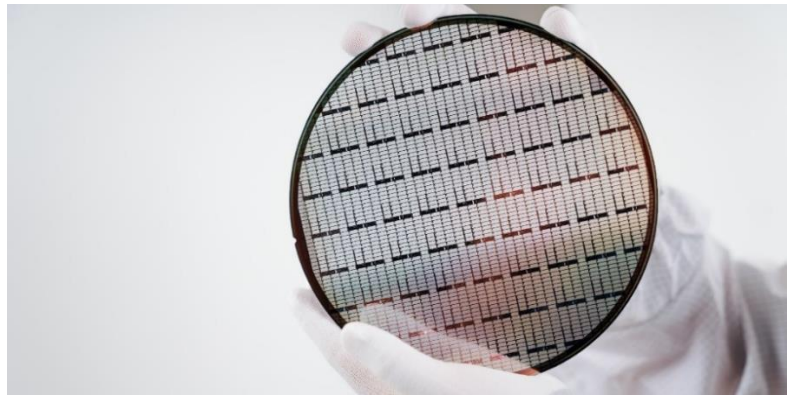
- Application understanding
- Packaging know-how and hybridization competence

Leadership in Power Systems across all materials and technologies

Silicon
Diode – MOSFET – IGBT – Driver – Controller

Silicon carbide
Diode – MOSFET

Gallium nitride
HEMT – Driver



Wide Band Gap based main inverter solutions enable wider range resp. 7..8% smaller battery – cost/performance defined by battery cost

Lowest System Cost		Battery Cost		
		[65€/kWh]	[85€/kWh]	[105€/kWh]
Battery Size	45 kWh	Si	Fusion	Fusion
	77 kWh	Fusion	Fusion	SiC
	97 kWh	Fusion	SiC	SiC

400 V BEV
175 kW 2WD

Specific insides into new SiC based products

CoolSiC™ MOSFETs entering a new era with G2

CoolSiC™ Generation 2

Improved chip performance and FOMs	5~20% lower power losses over typical load use cases
Improved .XT package interconnect	12% better thermal resistance, $R_{th,j-c}$
Best-in-class $R_{DS(on)}$ and the most granular portfolio in the market	Single digit with G2 compared to G1 6.7mΩ 650V and 7.7mΩ 1200V
Enlarged maximum gate-source voltage -10 V to +23 V	Serves all the SiC applications without any compromise in design flexibility
Overload operation up to Tvj = 200°C and avalanche robustness	Simplifies system design for over-current events, e.g. grid fluctuations (1200 V)
Robust **short-circuit** rating	2 µs guaranteed withstand time (1200V)
High reliability	Maintaining G1 proven level, very low DPM rates

Near-term roll-out of CoolSiC™ MOSFET G2 discretes industrial and automotive grade: 400 V, 650 V, 750 V and 1200 V

	CoolSiC™ G1	CoolSiC™ G2 released	CoolSiC™ G2 coming soon in 2024-2025
400 V		**TOLL** 5 products 11 mΩ - 45mΩ **D²PAK-7** 5 products 11 mΩ - 45 mΩ	
650 V / 750 V	**TO-247-3/4** 650 V/750 V 31 prod 16 mΩ - 140 mΩ TSC **QDPAK** 750 V 16 prod 8mΩ - 140 mΩ **D²PAK-7** 650 V/ 750 V 18 prod 9 mΩ - 260 mΩ **TOLL** 650 V 10 prod 22 mΩ - 260 mΩ	**D²PAK-7** 650 V 9 prod 7 mΩ - 60 mΩ **TO-247-3/4** 650 V 18 prod 7 mΩ - 60 mΩ TSC **TOLT** 650 V 5 prod 15/20/40/50/60mΩ **ThinTOLL 8x8** 650 V 4 prod 20mΩ - 60 mΩ	TSC **TOLT** 650V 3 prod 26/33/75mΩ **TOLL** 650V 9 prod 10 mΩ - 75 mΩ **ThinTOLL 8x8** 650V 3 prod 26/33/75mΩ TSC **QDPAK** 650V / 750V 4 / 13 prod 7-20mΩ/4-60 mΩ **D²PAK-7 TO-247-3/4** 650V/ 750V 75mΩ/ 7-60mΩ
1200 V	**TO-247-4** 27 products 7 mΩ - 350 mΩ **TO-247-3** 15 products 7 mΩ - 350 mΩ **D²PAK-7** 27 products 7 mΩ - 350 mΩ TSC **QDPAK** 7 products 20 mΩ - 160 mΩ	**D²PAK-7** 12 products 8 mΩ - 234 mΩ	**TO-247-4** 9 products 7 mΩ - 78 mΩ TSC **QDPAK Half-bridge** 4 products 12 mΩ - 53 mΩ TSC **QDPAK** 10 products 4 mΩ - 78 mΩ TSC **QDPAK Boost** 4 products 17 mΩ - 53 mΩ **TO-247-4 reflow** 6 products 5 mΩ - 26 mΩ

and more coming….

● Industrial ● Automotive

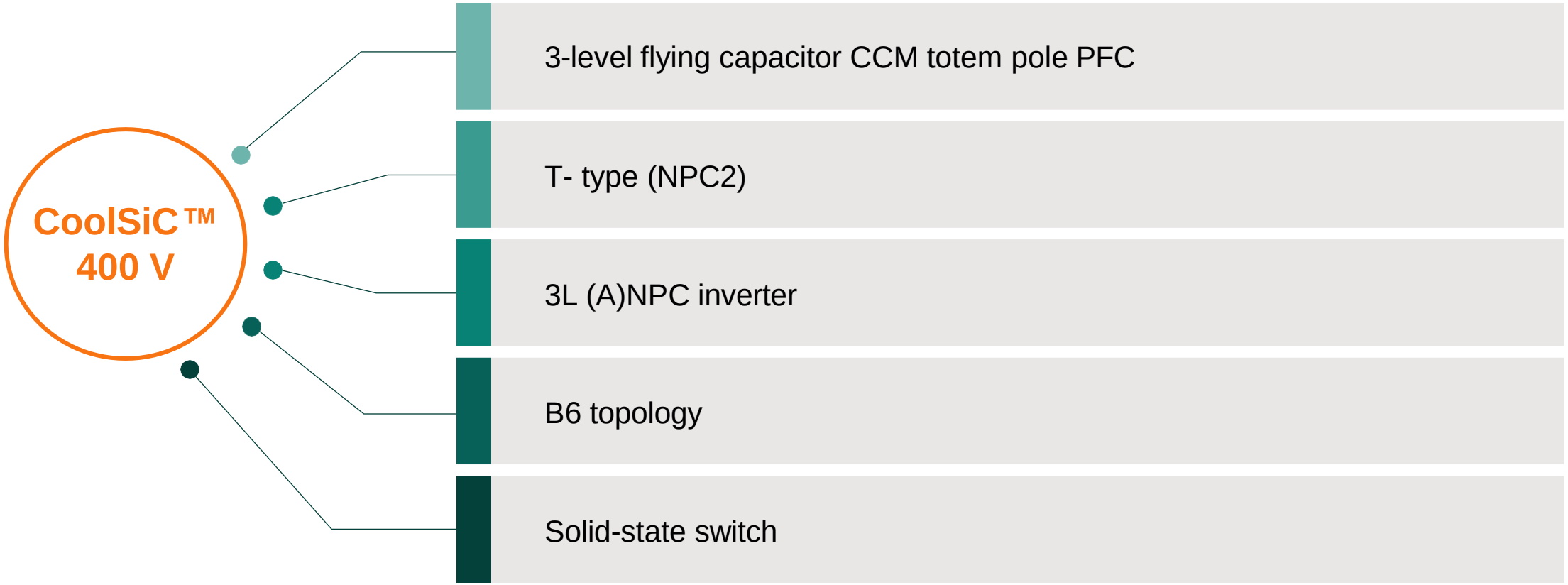
TSC = Top Side Cooling

Is SiC only good for very high voltages ? - CoolSiC ™ MOSFET 400 V
Based on the DC-link voltage, 400 V is a perfect fit

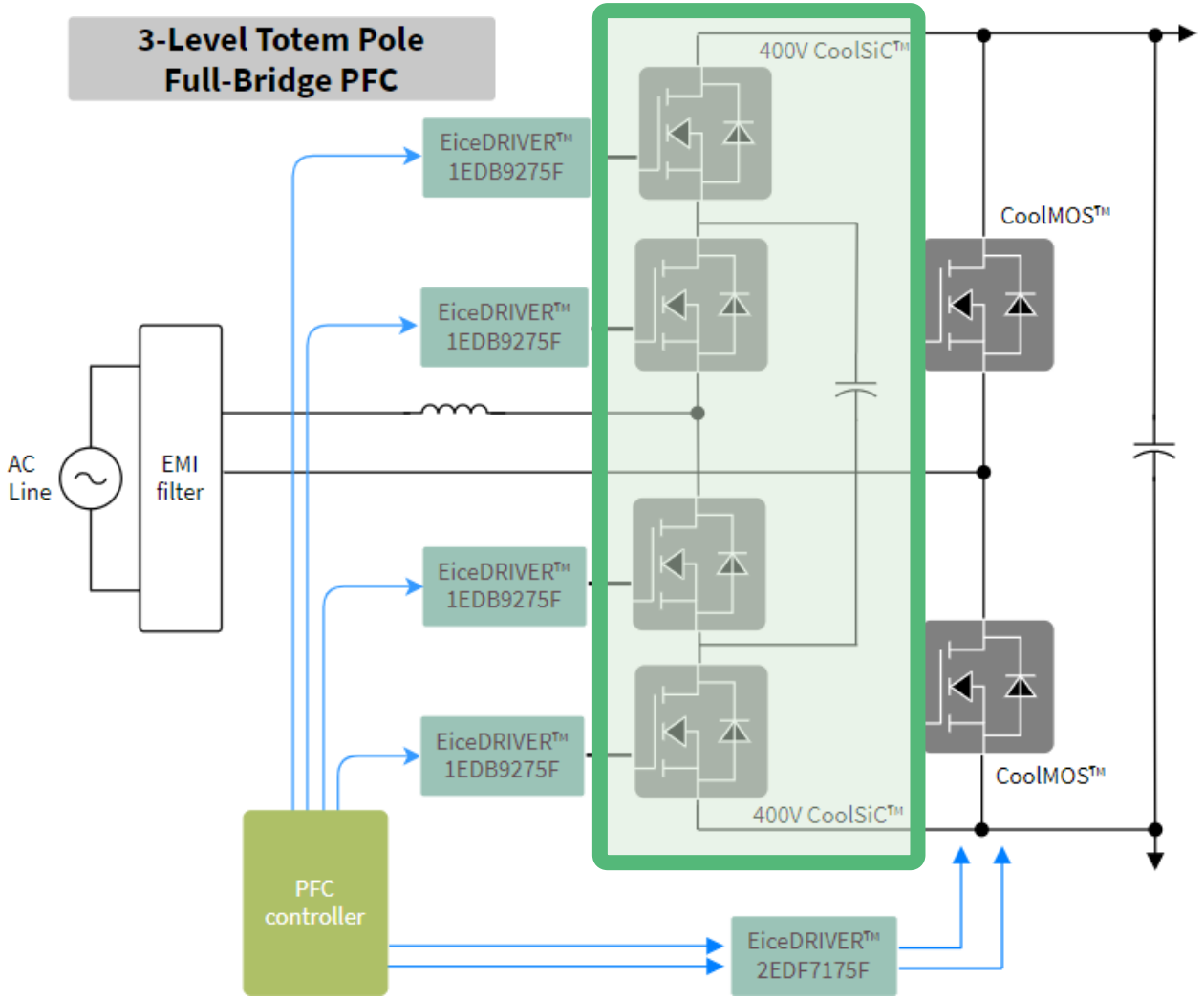
Topology \ V_{BUS}	≤ 130 VAC RMS $300V_{DC}$ [1]	≤ 277 VAC RMS $400V_{DC}$ [1]	347 VAC RMS [2] $560V_{DC}$
2-level	400 V	650 V	750 V
3-level	200 V	400 V	400 V
Application			
Battery operated			
AC line voltage			

[1] PFC or battery regulated
[2] Generation 2 AI Server PSU

SiC MOSFET 400 V
Target topologies



CoolSiC™ MOSFET 400 V G2
3-level flying capacitor CCM totem pole PFC for AI server PSU



Suitable for:

PFC design with higher power density (greater than 100 W/in³) and >99.4% efficiency

Benefits:

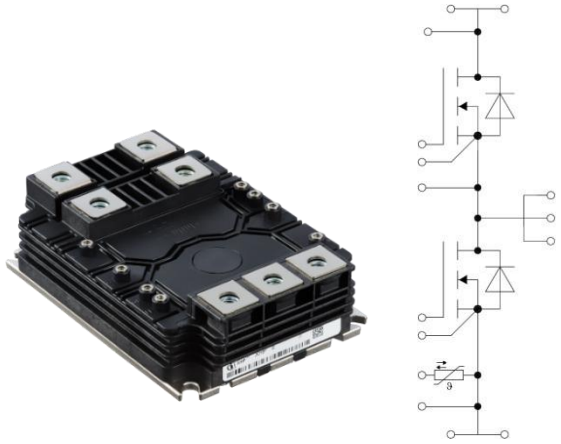
- Highest efficiency
- Highest power density
- Reduced EMI

Applications:

Server | Telecom | Energy storage | Solar

XHP™ 2 CoolSiC™ MOSFET 3.3 kV with .XT: Product Introduction

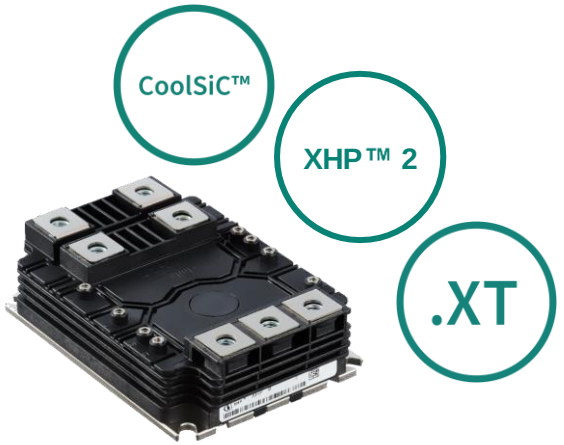
Products



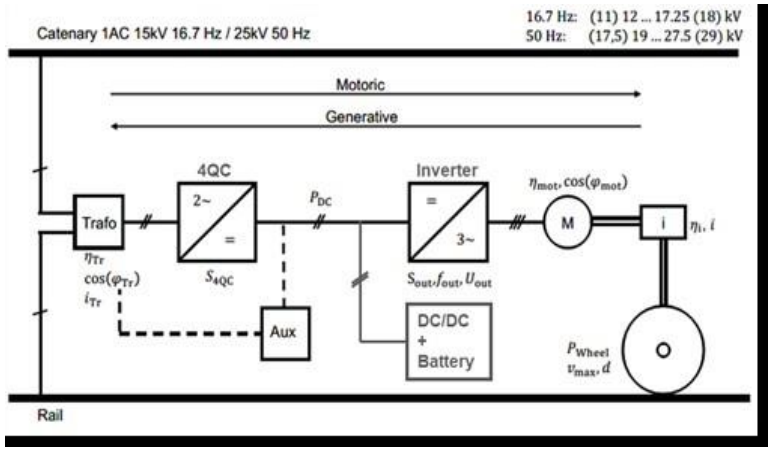
- **FF2000UXTR33T2M1**
  - R_{DSon} (25°C) = 2.0 mΩ
  - **I_{Dnom} = 1000 A**
- **FF2600UXTR33T2M1**
  - R_{DSon} (25°C) = 2.6 mΩ
  - I_{Dnom} = 750 A

Key components

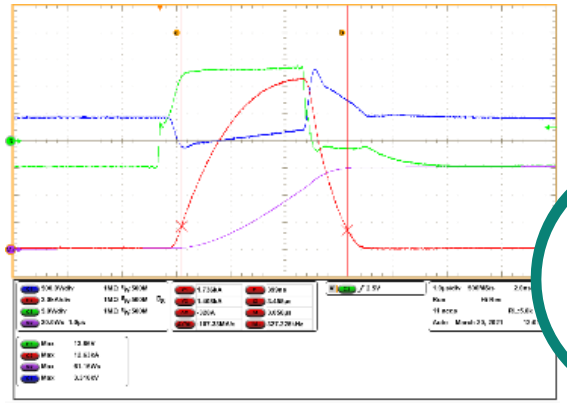
- 3.3 kV CoolSiC™ MOSFET with integrated body diode
- XHP™ 2 housing
- .XT interconnection technology



Lead application



3.3kV XHP™ 2 CoolSiC™ MOSFET with .XT - a new differentiating product bei Infineon



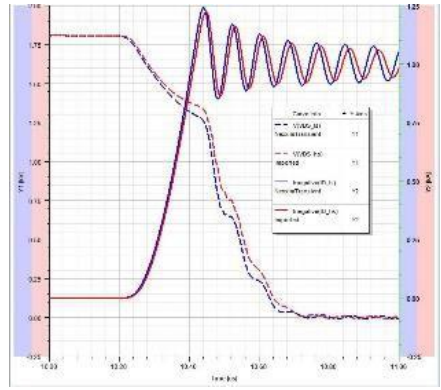
High surge current

3 µs SC robust

High cycling capabili-ties

PC and TC – new benchmark for SiC high power modules

Best utilization of SiC chips and increased I_{RMS}



Fast switching speed

dv/dt ~ 20kV/µs

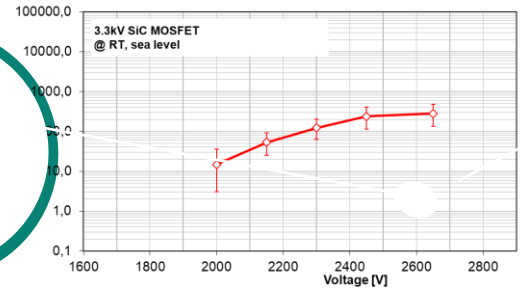
Symmetrical Design

$R_{DS(on)}$ < 2mΩ @ 25°C

Low $R_{DS(on)}$

In Top 3 for German Innovation Award this year

CR FIT < 100



XHP™ 2 CoolSiC™ MOSFET 3.3 kV with .XT: Key Features translate to System Benefits

Key Feature		
Compact size	**Low losses**	**High Fsw or More Current**
↓	↓	↓
System Benefit		
smaller / lighter converters ~10-25% volume reduction	**reduced cooling need, audible noise reduction (no fans)**	**smaller/lighter magnetic components**
 Si-based converter SiC-based converter	Passive motion cooling instead of forced air cooling No fan noise Simplified maintenance	**audible noise reduction (quiet motor)**
		or
		more power/less paralleling

XHP™ 2 CoolSiC™ MOSFET .XT in a Munich tram: Field test demonstrates ~10% energy savings on system level

CoolSiC™ MOSFET XHP™ 2 | **Field test in a tram** | **Energy savings**

Assumptions: 60.000 km per tram, 5 kWh/km; 3.75 MWh annually for average household

XHP™ 2 CoolSiC™ MOSFET .XT enables **~10% energy savings**, which amounts to **~ 30 MWh per year per tram**. This is an equivalent of the yearly energy consumption of 8 average households!

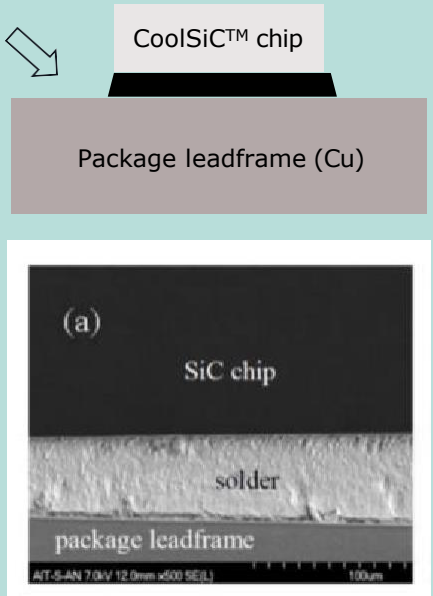
https://www.infineon.com/cms/en/about-infineon/press/press-releases/2022/INFIPC202202-049.html

Importance of dedicated package solutions to bring SiC performance into real systems

Package innovation - Significant improvement of thermal capabilities by .XT interconnection for discrete housings

Standard interconnection

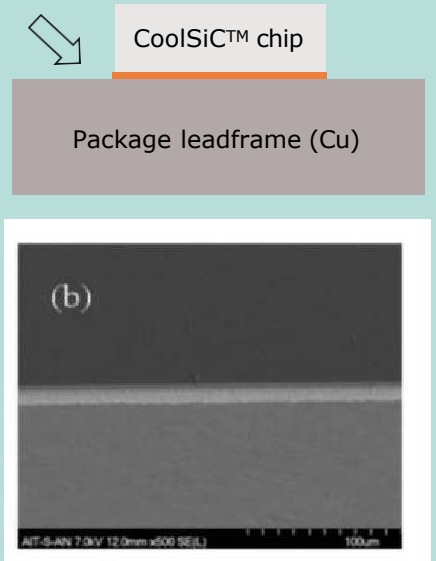
Standard soldering
with J-alloy



Standard soldering

.XT interconnection

Diffusion soldering



Elimination of solder joint through diffusion soldering

.XT technology benefits

Higher thermal conductivity

- Reduction of junction-to-case thermal resistance ($R_{thj\text{-}case}$)
- Reduction of junction-to-case thermal impedance ($Z_{thj\text{-}case}$)

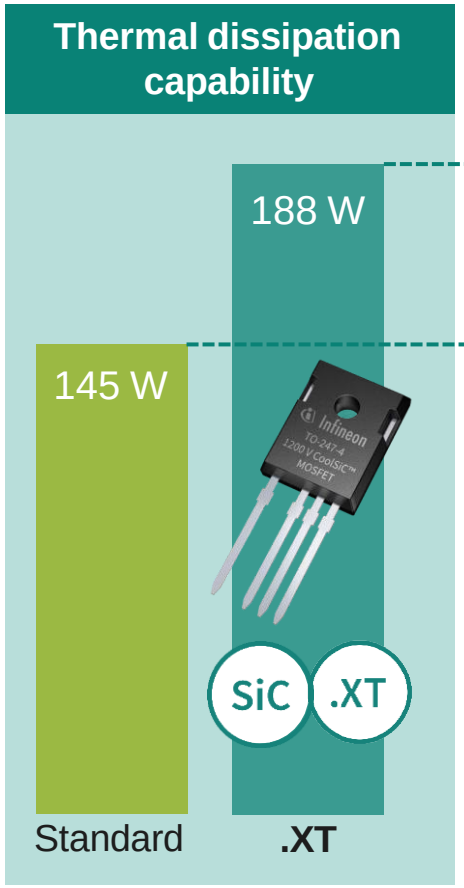
Better assembly control

- Prevents die tilt and solder bleed-out

Better performance under thermo-mechanical stress

- Increases active and passive thermal cycling capacity due lower operating temperature

The latest award-winning .XT interconnection technology enhances optimization potential even further for SiC-based designs



Conditions:

- T_{case} = 100°C;
- CoolSiC™ MOSFET: 20 mOhm, IMZA120R020M1H

Up to **30% higher** thermal dissipation capability with **.XT interconnection**

Examples of application optimizations

Increase output current up to 15%

Extra power in given system size

OR

Increase f_{SW}

Reduce the passives

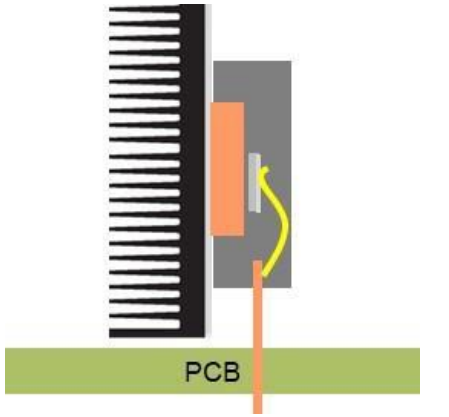
OR

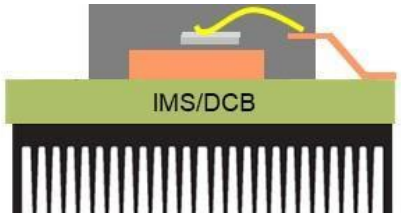
Up to 15K lower junction temperature

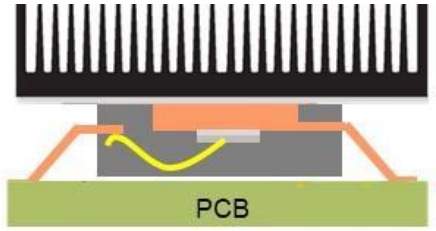
Increase lifetime expectancy

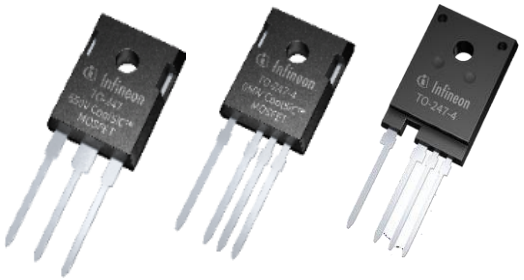
Note: This technology is “Winner 2022 Der Deutsche Innovationspreis”

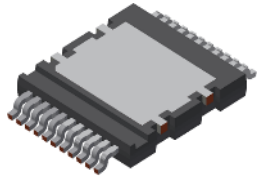
Package evolution which enables high volume assembly and PCB design improvement at expensive assembly location











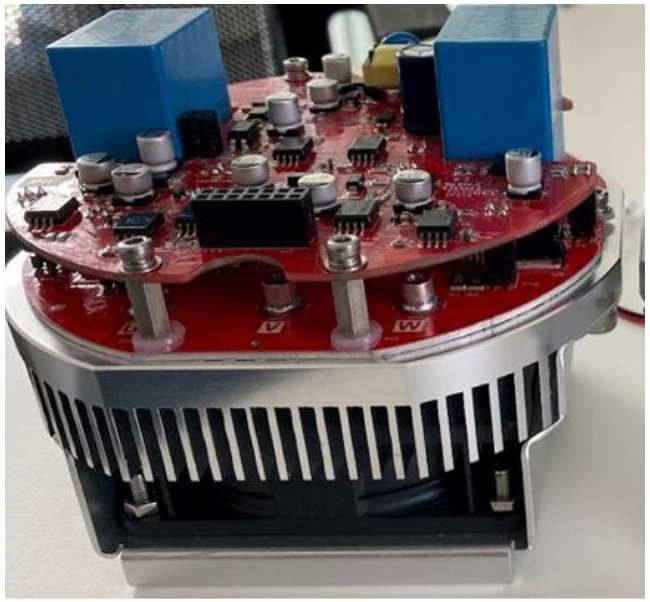
THD – Through Hole Device	SMD Bottom-side cooling	SMD top-side cooling
– Robust thermal performance	– Medium thermal performance	– **Optimal** thermal performance
– Manual handling	– Fully automatic handling	– **Fully automatic** handling
– Low pin count, improved with 4-pin variant	– High pin count	– **High** pin count

Significant production cost reduction with simplified design
1.2 kV SiC servo motor drive demonstrator

Standard cooling assembly

Stack: FR4 + IMS + 

- IMS board used for power components
- FR4 PCB used for IC/driver/magnetics components



Top-side cooling assembly

Stack: FR4 + 

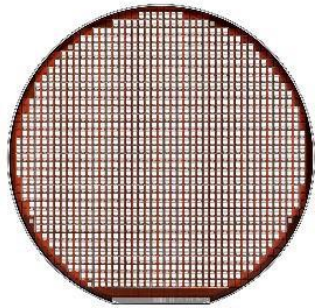
IMS board eliminated

- Single FR4 PCB used on both sides for **all** power components
- Reduced stray inductance

- 65% Rth

Joining Technology: CoolSiC™ MOSFET & .XT are the perfect match

Technology

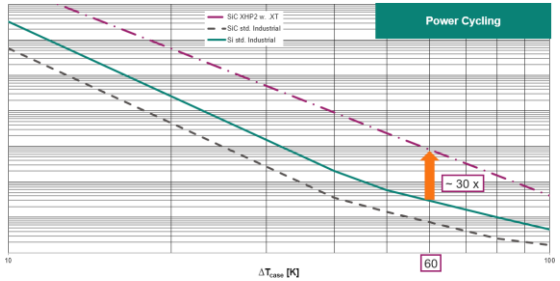


- SiC chips are significantly smaller than IGBTs
- Heat dissipation over a smaller area

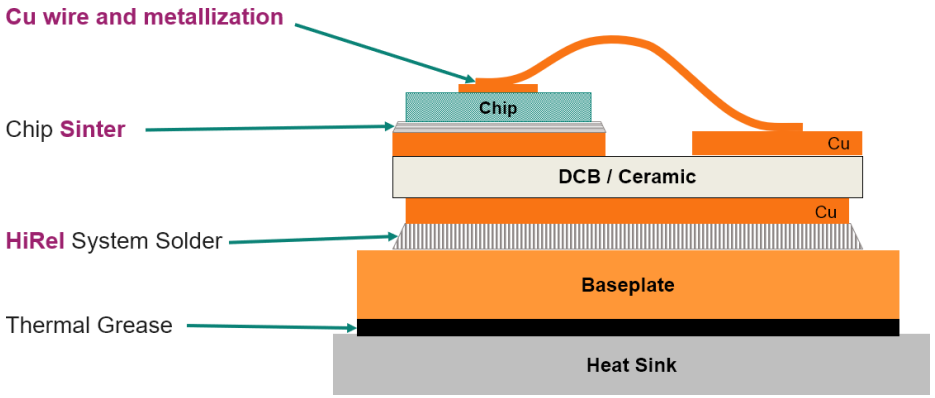
Requirements

- Full exploitability of the SiC devices is expected to design optimum inverters

Renewables | Electrolysis | Energy storage | Traction



.XT for SiC



Lowest switching losses with highest cycling capabilities are the perfect match for high power applications

Thank you for your attention

In Germany this work of Infineon was funded in the frame of the
Important Project of Common European Interest on
Microelectronics and Communication Technologies (IPCEI ME/CT)

Supported by:

Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

Sponsored by
Bavarian Ministry of Economic Affairs,
Regional Development and Energy

**Co-funded by
Ministry of Economic Affairs, Industry,
Climate Action and Energy of the
State of North Rhine-Westphalia.**

**Funded by
the European Union**
NextGenerationEU

Find more information on

www.infineon.com/coolsic-g2