INDUSTRIAL SUMMIT 2024

POWERING YOUR SUSTAINABLE INNOVATION

Wide Bandgap Technology And Innovative Package Solution For Industrial Application

Joe GUO

Agenda

1 WBG Materials Benefits

2 ST SiC Technology

3 SiC Package Roadmap

4 PowerGaN Technology

5 PowerGaN Package

6 Takeaway

7 Q&A

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WBG Material Benefits

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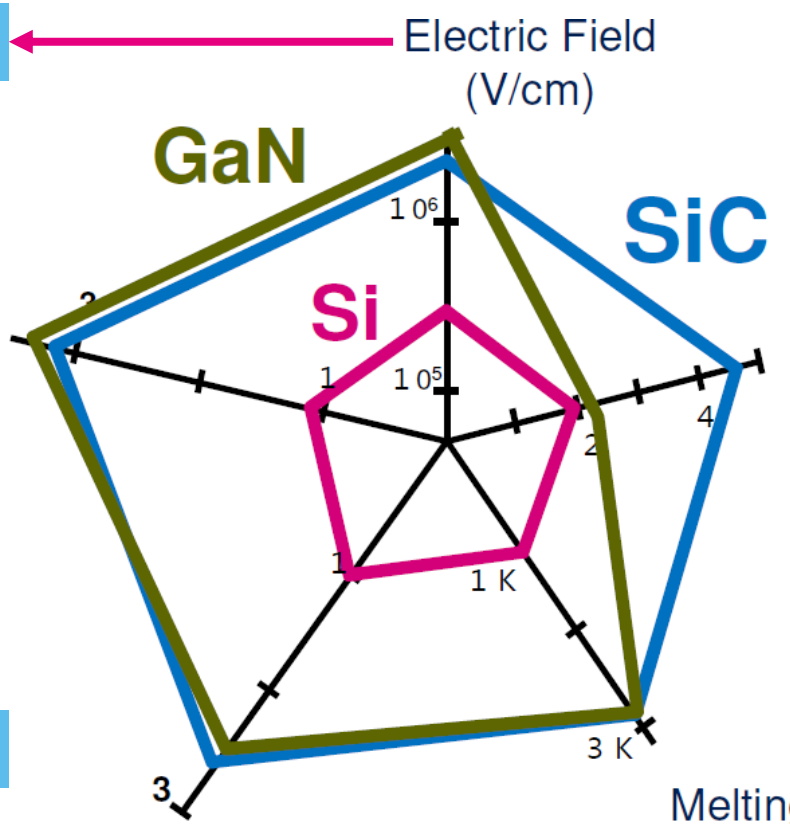
About Wide-Bandgap Materials

Lower ON-resistance & losses

Higher breakdown voltage

Higher switching frequency



Better thermal performance
Reduced cooling requirements

Higher junction temperature
Up to 200°C

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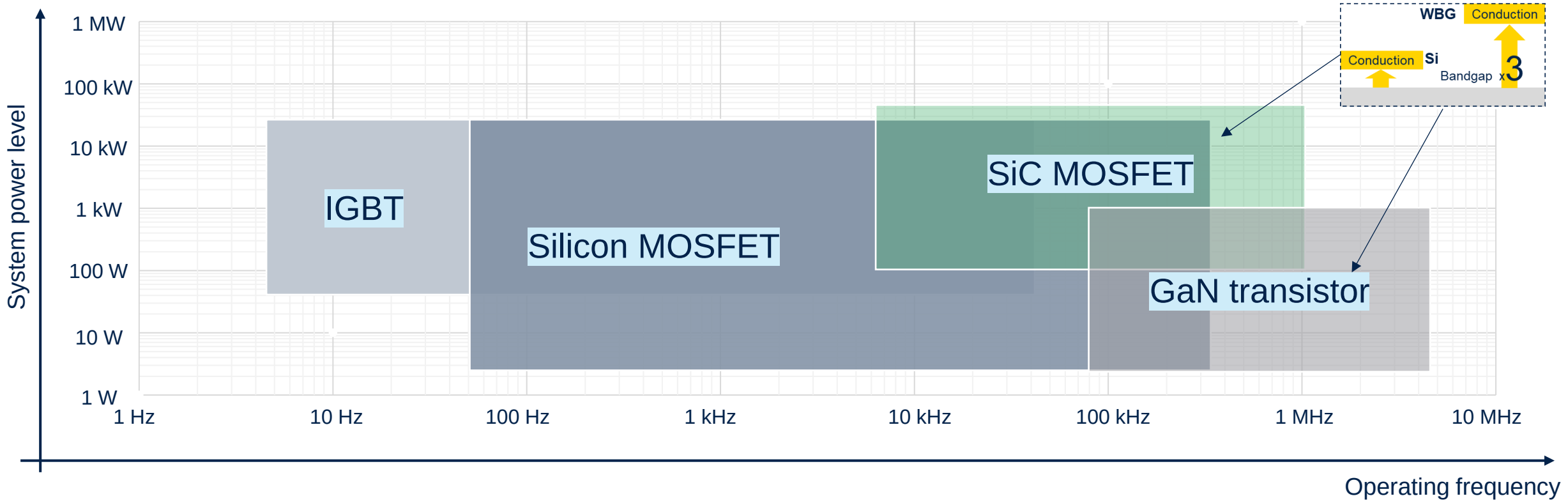
Silicon, SiC, And GaN Power Semiconductor Positioning

Higher power levels can be achieved with modules or paralleling



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ST SiC Technology

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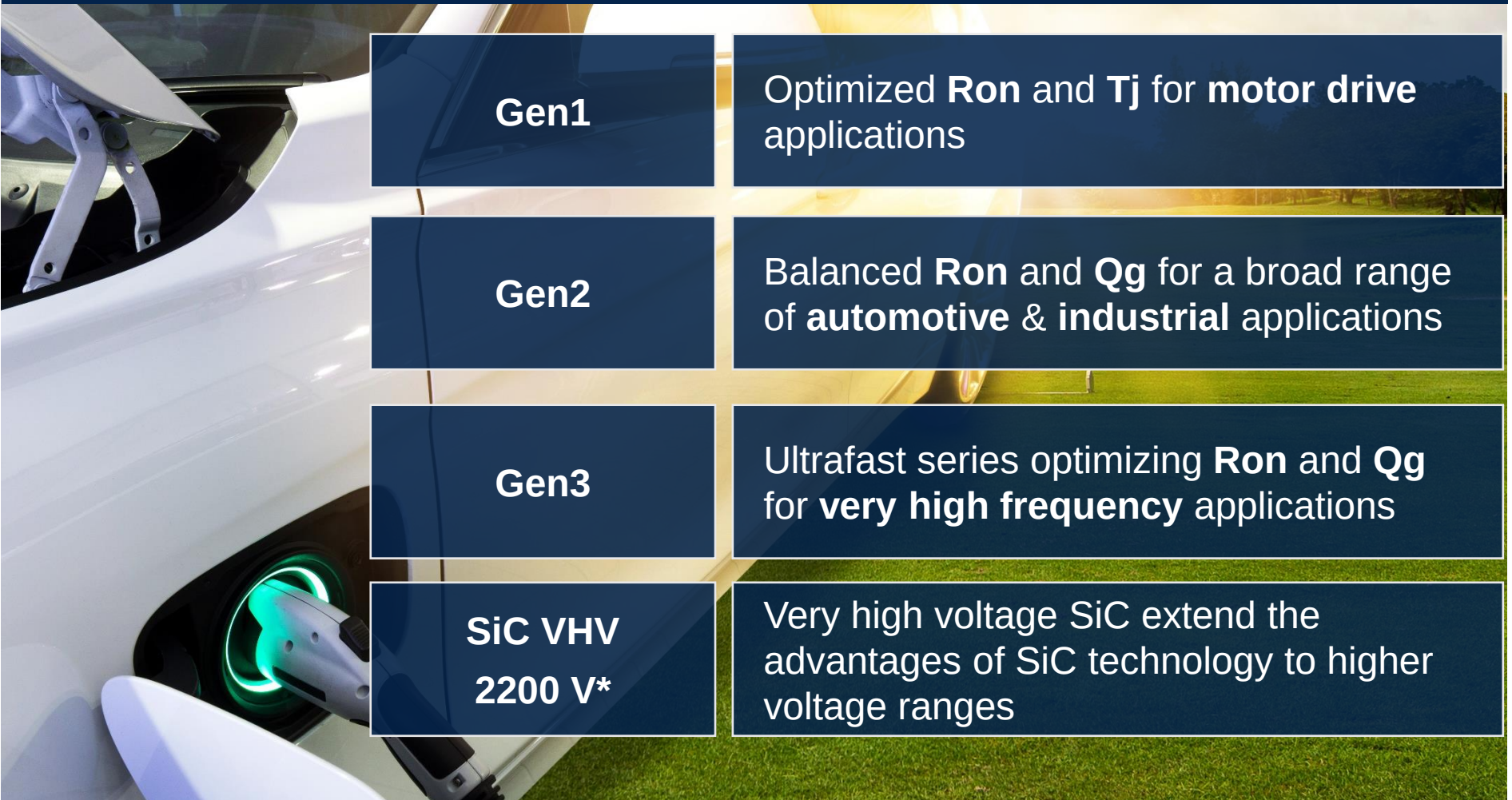
SiC MOSFET Range

High voltage and fast switching for high density applications

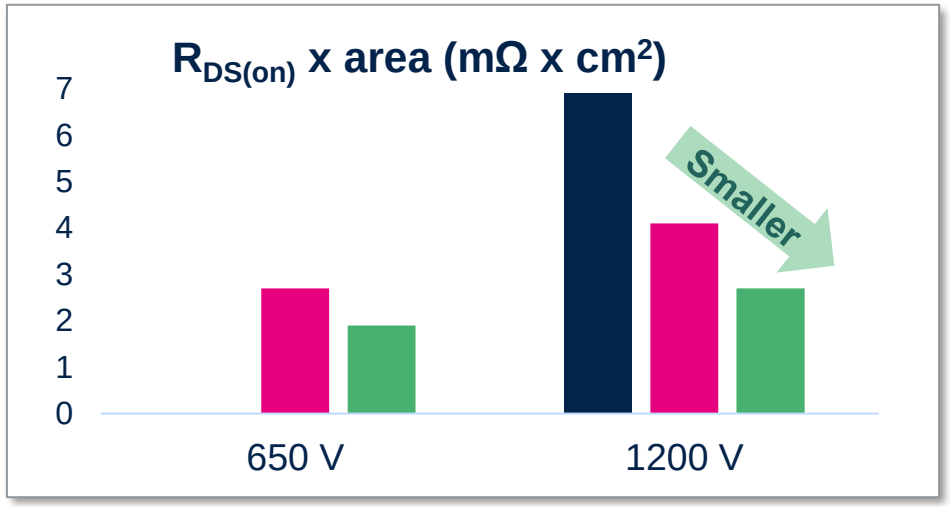


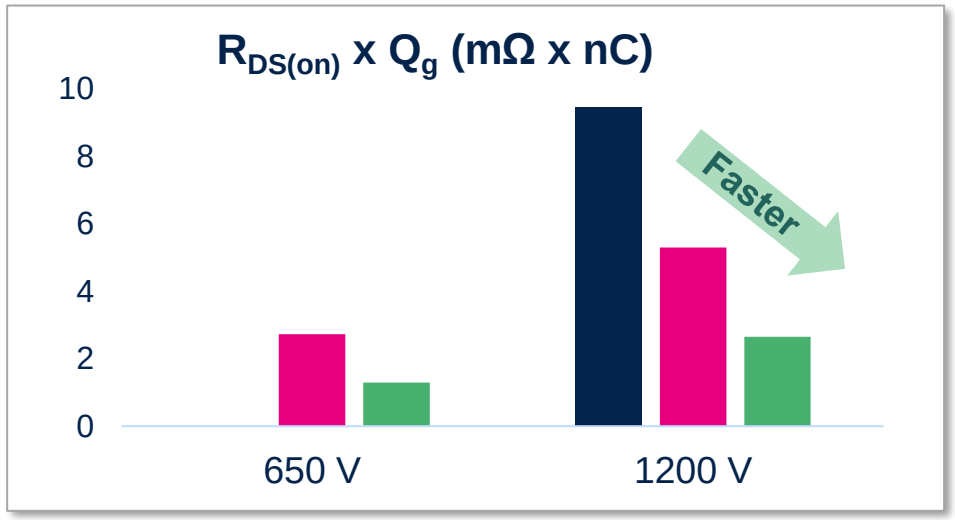
Gen1	Optimized **Ron** and **Tj** for **motor drive** applications	**1200–1700 V**
Gen2	Balanced **Ron** and **Qg** for a broad range of **automotive** & **industrial** applications	**650 V, 1200 V, 2200 V**
Gen3	Ultrafast series optimizing **Ron** and **Qg** for **very high frequency** applications	**650 V, 750 V, 900 V, 1200 V**
SiC VHV 2200 V*	Very high voltage SiC extend the advantages of SiC technology to higher voltage ranges	**2200 V**

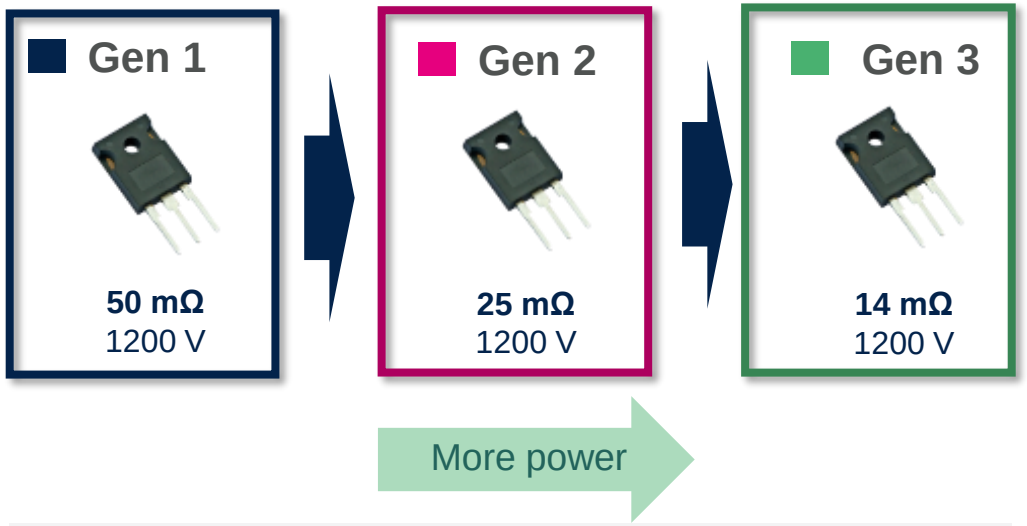
*** industrial grade**

SiC Diode Series Overview

SiC MOSFET Advances In Figures Of Merit







Improvement in MOSFET generations

- **Lower Ron x area** → lower Ron for a given chip size or smaller chip size for a given Ron, higher current capability, lower conduction losses → **higher power achievable in power module with the same form factor**
- **Lower Ron x Qg → lower switching losses, higher frequency (reduced board)**

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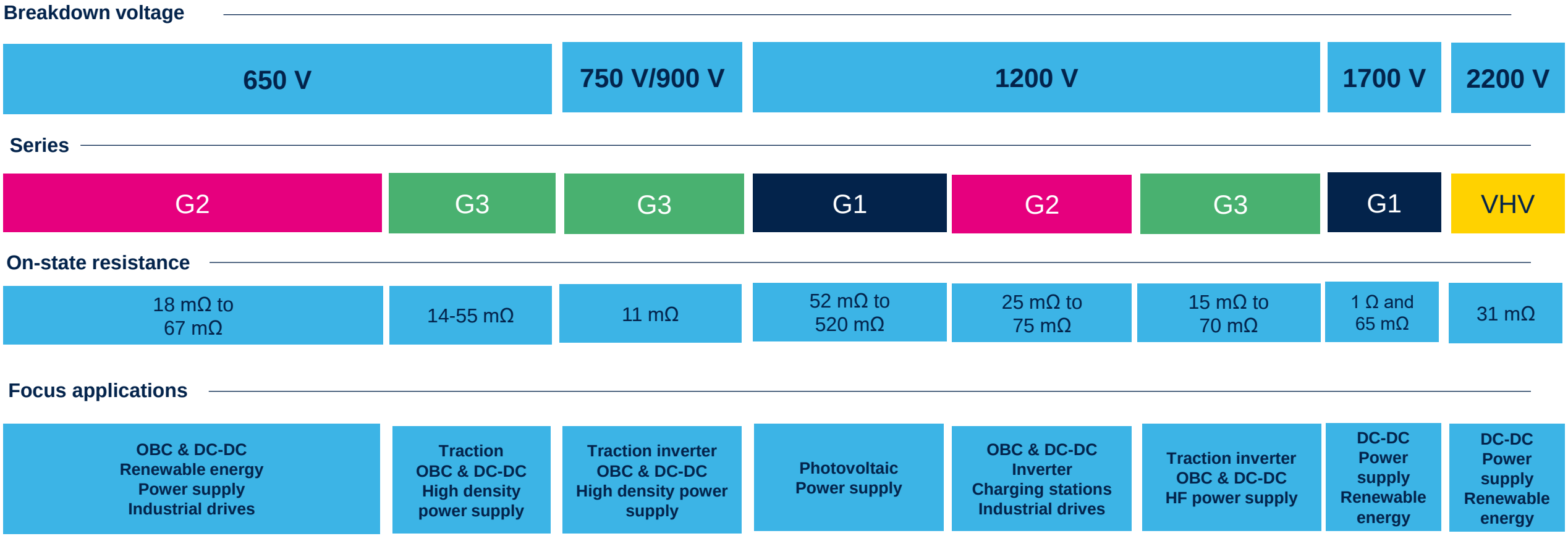
STPOWER SiC MOSFET Product Families And Applications



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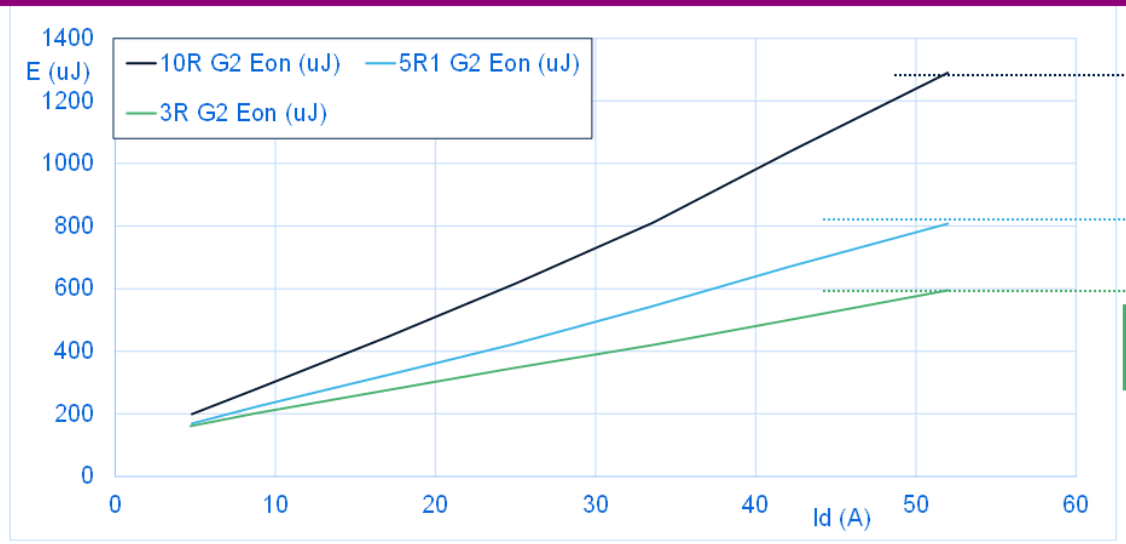
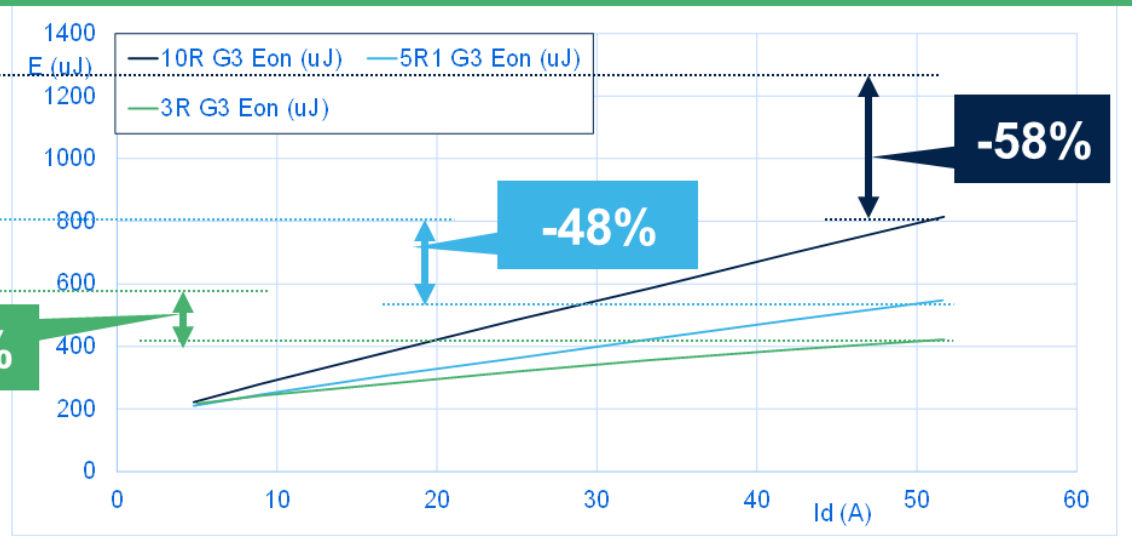
SiC MOSFET Switching
SiC Gen3 vs Gen2

SCTWA70N120G2V-4



SCT015W120G3-4AG



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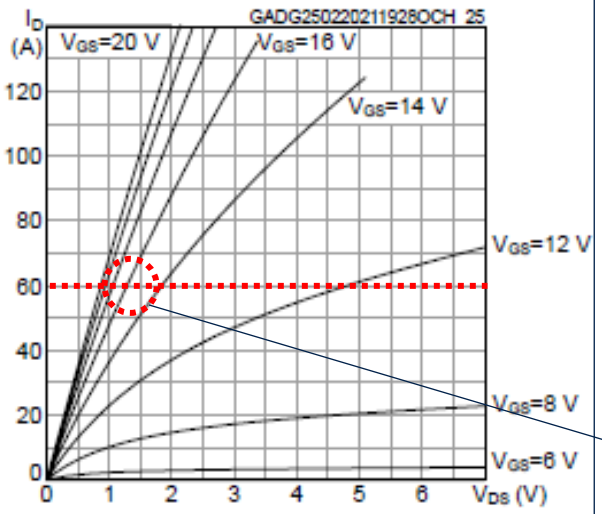
SiC Gen 3 MOSFETs Vgs Driving 18V For Best Ron But 15V Possible Too

Figure 3. Typical output characteristics (T_J = 25 °C)



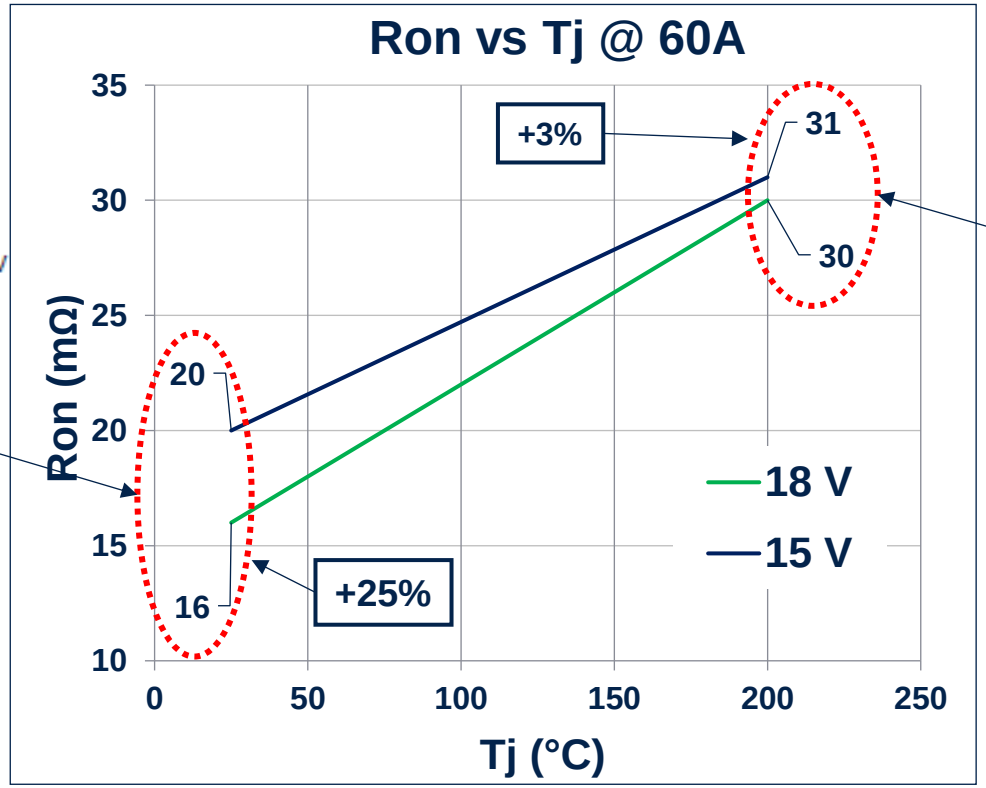


Figure 4. Typical output characteristics (T_J = 200 °C)

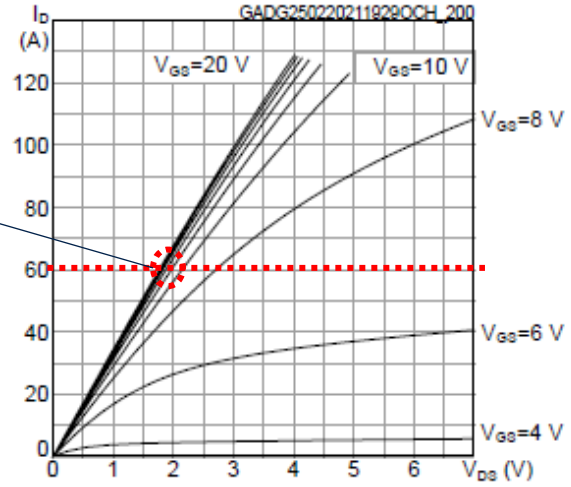
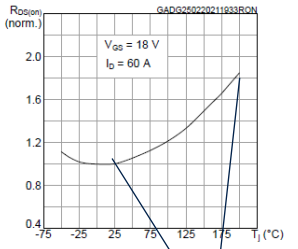


Figure 11. Normalized on-resistance vs temperature



- **Gen3 Vgs driving**
  - Vgs recommended: 18 V
  - Driving @ 15 V, possible but with higher Rdson (about +25%)
  - Switching losses not significantly impacted (Rg fine tuning)
  - As a reference, see above example on a specific Gen 3 product (SCT130N120G3D8AG)

$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 60 A		16	22	mΩ
		V_{GS} = 15 V, I_D = 60 A		20		
		V_{GS} = 18 V, I_D = 60 A, T_J = 200 °C		30		

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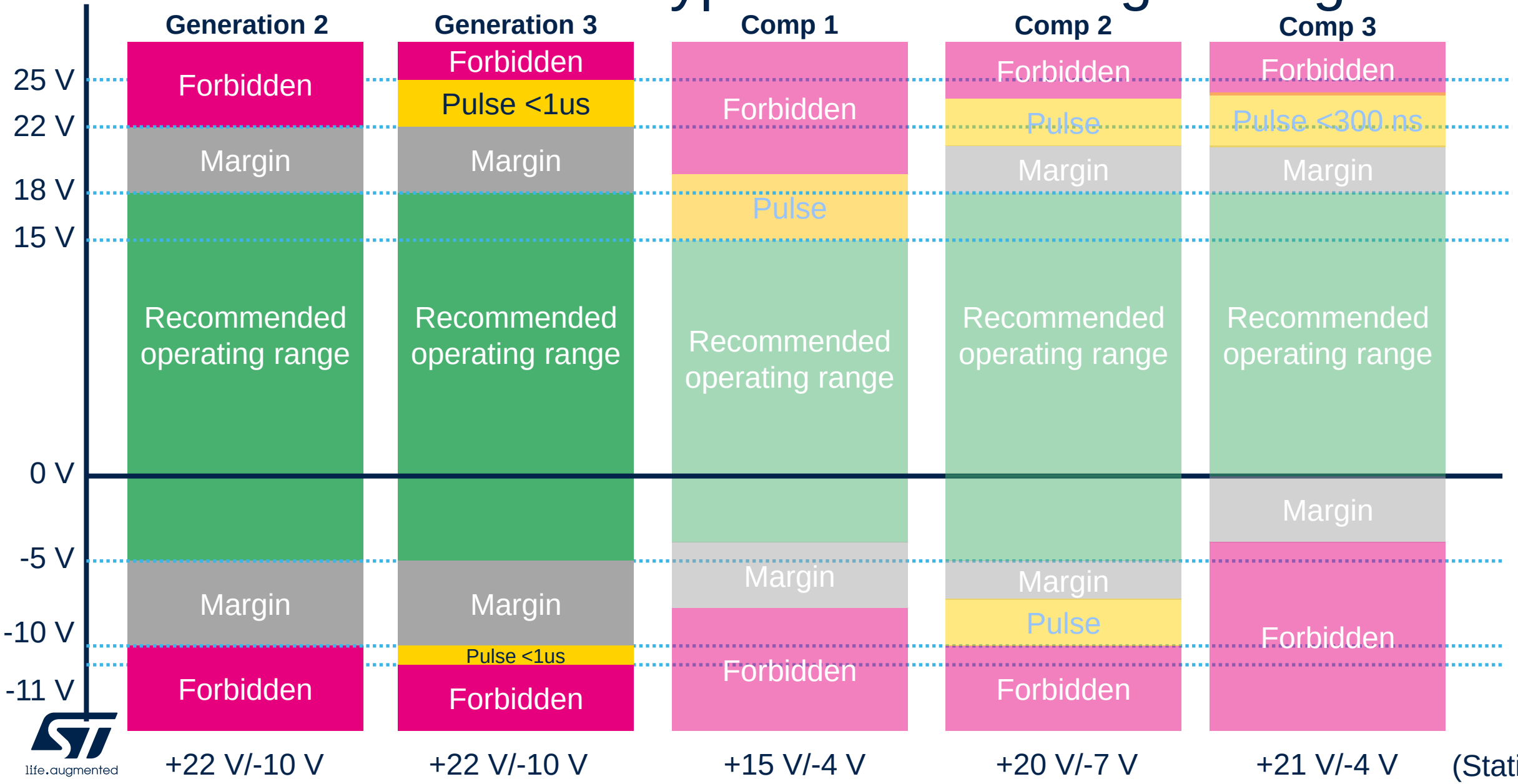
Typical Gate Voltage Range AMR



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SiC Package Roadmap

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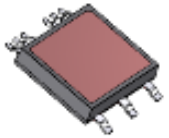
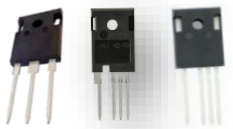
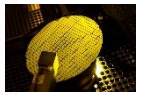
SiC MOSFET Package Technologies

PowerFLAT 8x8 STD & DSC	TO-LL	H2PAK-7L	HU3PAK	ACEPACK SMIT	HiP247 (3 ,4, long leads)	STPAK	Bare dice
							 
Surface mounting					**Through-hole**	**Special package solutions**	
Very thin (<1 mm) Well accepted in power conversion Dual side cooling option Leadless **Industrial domain**	**2.4 mm** (max) thickness Good Rthj-a performance Leadless **Industrial domain** **Kelvin source** for optimized driving Good thermal dissipation	**AG qualified at 175°C** Kelvin source for optimized driving High runner for automotive customers	**AG qualified at 175°C** **Top side cooling** Kelvin source for optimized driving Very good thermal dissipation	AG qualified at 175°C Isolated top side cooling Suitable for different configurations (HB, dual die, etc.) High power Modular approach	**AG qualified at 200°C** **Very common industry standard** Kelvin source option for optimized driving High creepage version (1700 V) in development	**Unique solution for traction inverter** **AG qualified at 200°C** **Very high thermal dissipation efficiency** Sense pin for optimized driving Multisintered package	**WLBI & KGD** **T&R or RWF options** **Compliant with the most stringent automotive quality requirements**

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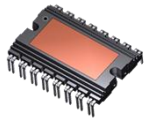
Power Modules For Industrial And Automotive

ACEPACK power module

Silicon MOSFET & IGBT, silicon carbide MOSFET

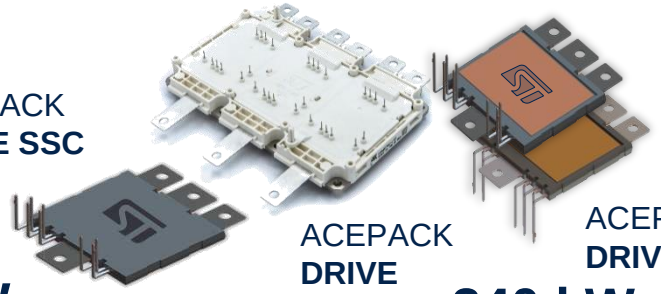


ACEPACK **DMT-32**

ACEPACK **SMIT**

ACEPACK **1 & 2**

ACEPACK **DRIVE SSC**



ACEPACK **DRIVE**

ACEPACK **DRIVE DSC**

5 kW — 10 kW — 30 kW — 150 kW — 340 kW →

Middle power applications

Solar Energy

Power Supply & UPS

HVAC

OBC

DC-DC converter

Charging Station

Motor Drives

Grid and Infrastructure

Wind and renewable energy

High power applications

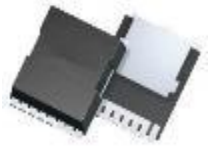
Traction inverter

Advanced Surface Mount Packages

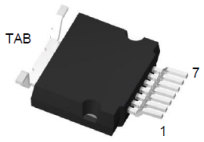
Advanced features:

Additional Kelvin source pin for driving optimization

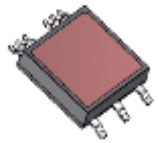
H²PAK-7I



TOLL



HU3PAK
Top side cooling SMD



ACEPACK
SMIT

SMD TSC (top-side-cooling)

Top-side-cooling for easier heat-sink connection

No thermal conduction trough PCB dramatically improves R_{TH}

HU3PAK

Kelvin source for improved switching performance

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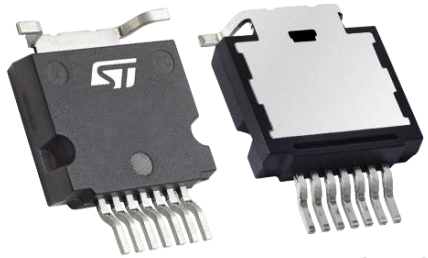
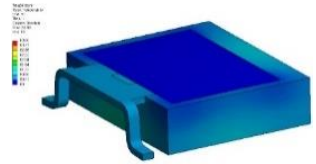
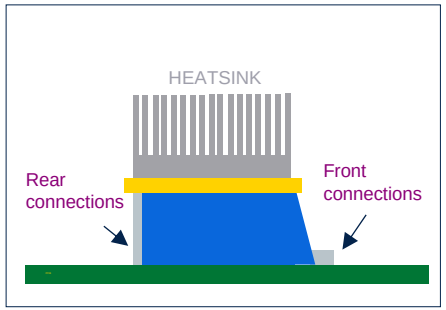
HU3PAK
Innovative Top-Side Cooling Solution

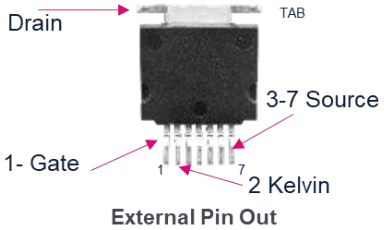


Top view (heatsink side)

High temperature capability **Tj (max)= 175° C**	**Improved thermal performances** Avoiding thermal conduction through PCB Optimizing heatsink form factor and efficiency
Improved thermal dissipation **Top side cooling**	**Higher efficiency enabler** A better Tj management permits to rise up system efficiency
Kelvin source pin **SMD package**	**Enables higher efficiency** **Enables more compact systems**
Higher creepage distance	**Electric arc prevention** Better isolation to pass safety regulations
Adopting a planar and simple heatsink	**BOM cost reduction** Using a simple FR-4 PCB instead of an expensive IMS one







External Pin Out

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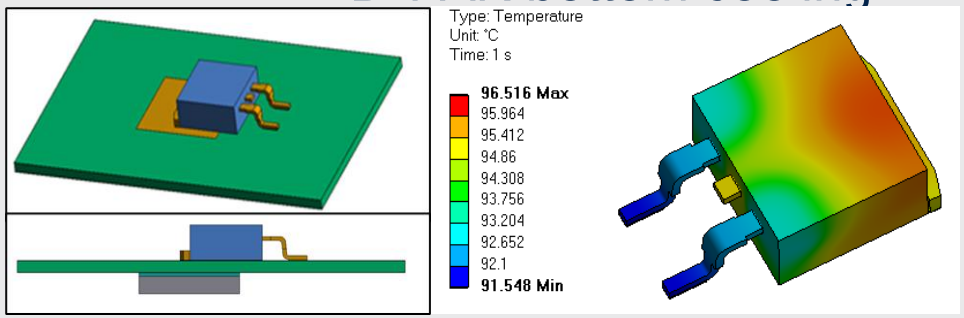
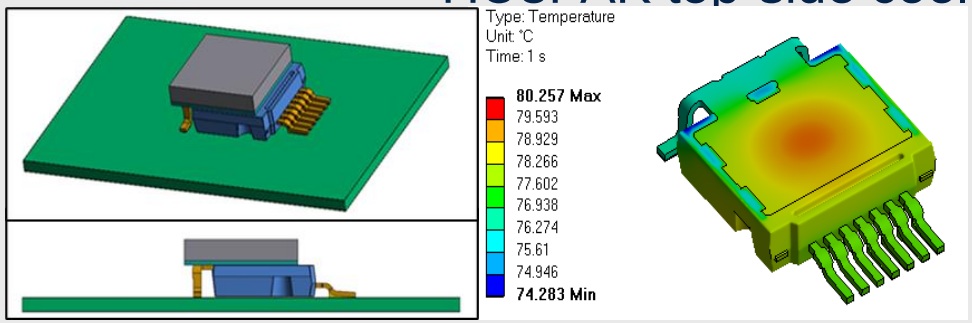
HU3PAK
Outperforming Alternative To D2PAK / H2PAK-7

Thermal map @ full load

D²PAK bottom cooling



HU3PAK top-side cooling

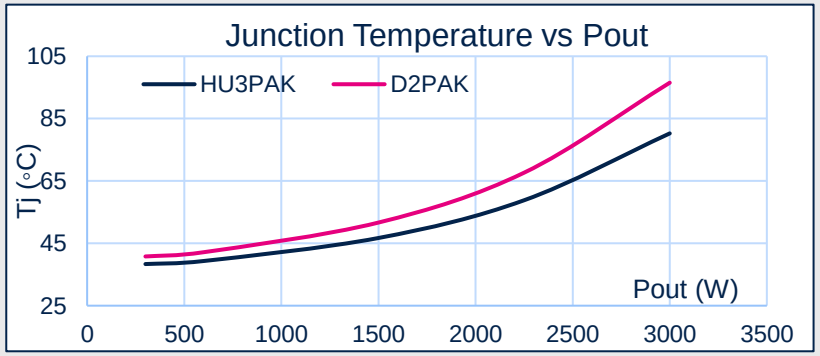


Same heatsink positioned on
- D²PAK bottom side of the PCB trough thermal vias
- HU3PAK directly on the top exposed copper frame

	HU3PAK	D²PAK	
$R_{th(J-H)}$(K/W)	8.91	10.47	-15%
$R_{package}$(mΩ)	80	80	//

Losses in 3 kW FB LLC

	D²PAK	HU3PAK	
P_{die} (W)	0.578	0.568	@ Pout 300 W
T_j(°C)	40.7	38.4	- 2.3°C
P_{die} (W)	5.908	5.275	@ Pout 3 kW
T_j(°C)	96.52	80.26	-16.26°C



Top-side cooling solution improves heat dissipation capability keeping the same heat sink and PCB, allowing lower T_j.

Cooler devices work with lower RDS(on), lowering the conduction losses

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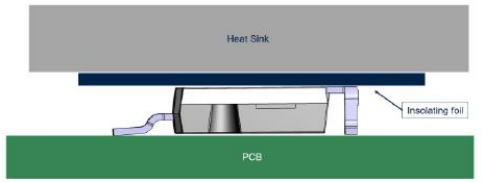
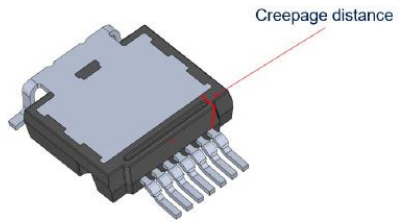
HU3PAK
Mounting Instructions & Thermal Management

Title	Type	Icon
TN1378: HU3PAK package mounting and thermal behavior	Technical Note	PDF

Figure 17. **Creepage distance in HU3PAK on uncemented insulating foil**

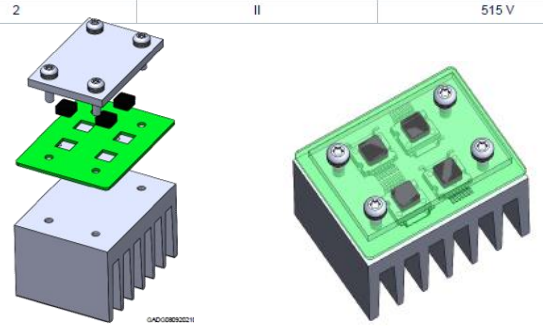




Depending on the pollution degree and the material group of the resin, the maximum rms voltage that can be withstand by the package is defined in the table below:

Table 4. **Maximum rms voltage capability with a creepage distance of 3.7 mm**

Pollution degree	Material group	Max rms voltage
1	I and II	1070 V
2	II	515 V



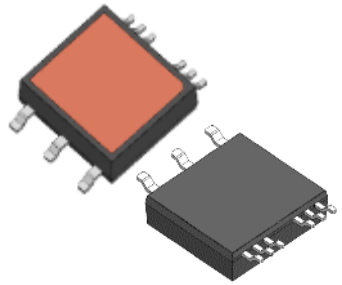
Example of heat sink assembly with counter plate

Why ACEPACK SMIT?

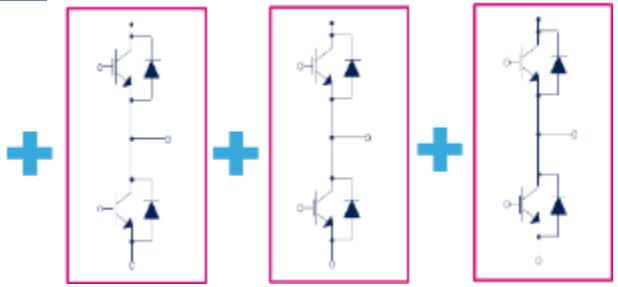
AQG 324 qualified

Features & benefits

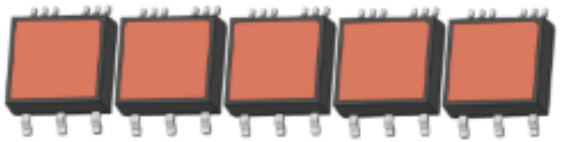
- Insulation voltage: 4 kV_{rms} - UL 1557 certification
- SMD assembly
- Dice chips on direct bonded copper (DBC) substrate
- Reduced parasitic inductance and capacitance
- Suitable for several switch technologies
- Package molding compound group I with CTI > 600: 1000 Vrms in pollution degree 2



- Several configurations available and low stray inductance
- High reliability and robustness, miniaturized power side board occupation
- Compact design and cost-effective system approach
- Very high power density
- Ideal to realize a complete system



High level of modularity



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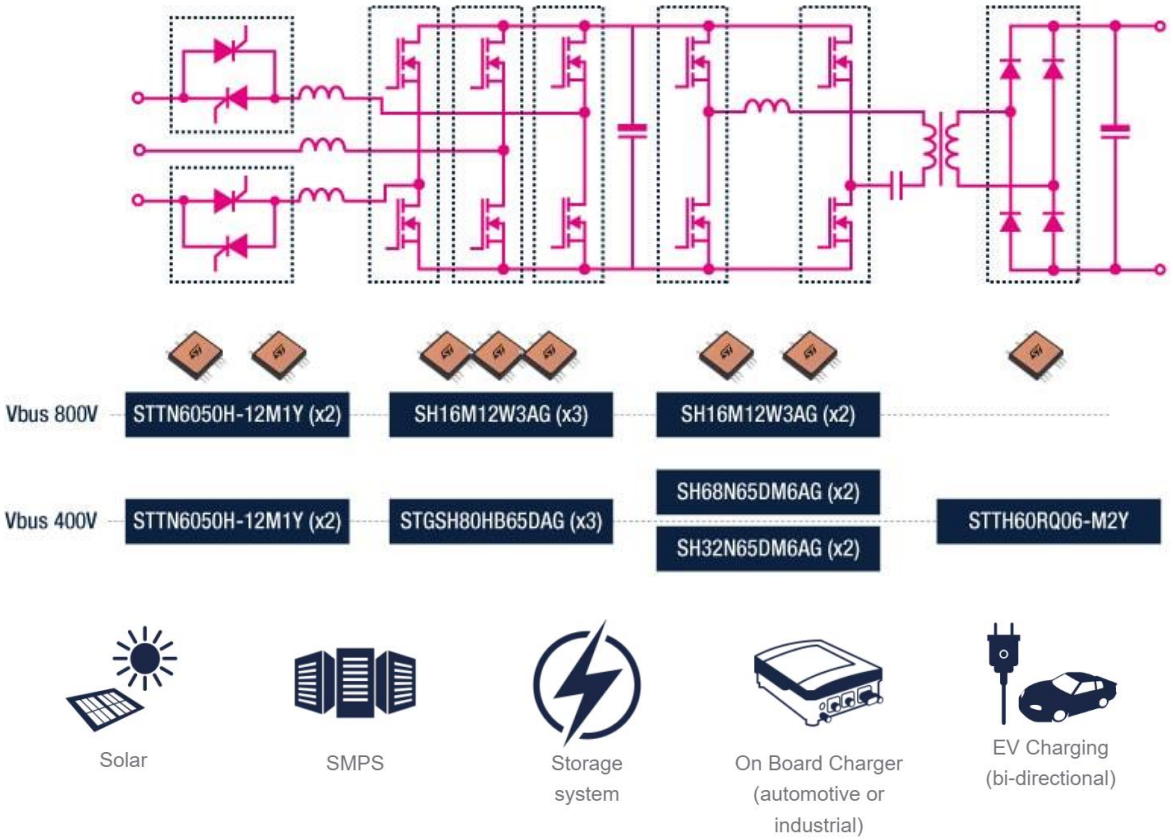
ACEPACK SMIT
Surface Mounted Isolated Top-Side Cooled Package

Typical application diagram for an on-board charger (OBC)



- ACEPACK SMIT devices are AQG-324-qualified
- Tailored for AC/DC and DC-DC converters like OBC, DC wallbox and motor control like servo drives
- The ACEPACK SMIT allows high modular flexibility by enabling many topology options like totem pole, B6, 3-Level T-Type
- It is available with multiple ST power technologies including SiC, SJ fast body diode MOSFETs, IGBTs, thyristors, and diodes

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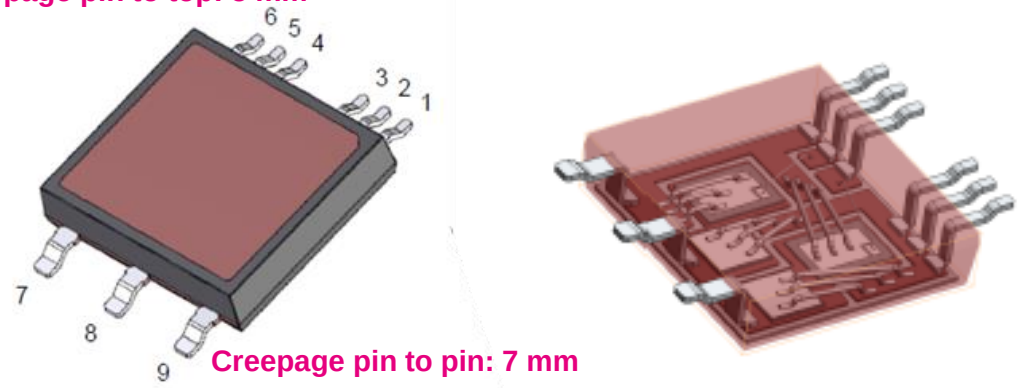
ACEPACK SMIT Characteristics

A module that looks like a discrete



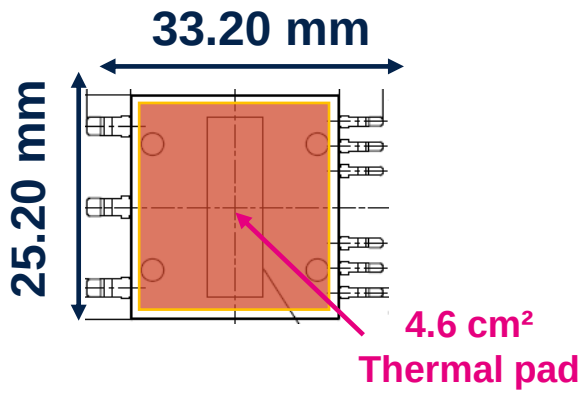
- Is molded
- Has a leadframe
- Is an SMD
- Is available in T&R*

- Contains a DBC**
- Has integrated dice forming simple topologies
- Has an isolated thermal pad

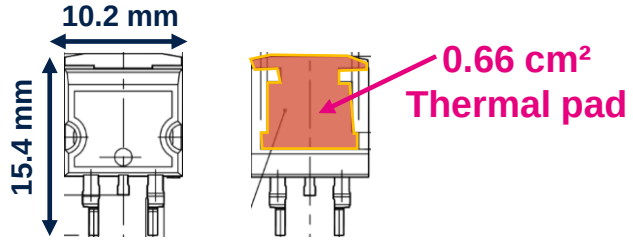
* Tape and reel

** Direct bonded copper

Dimensions



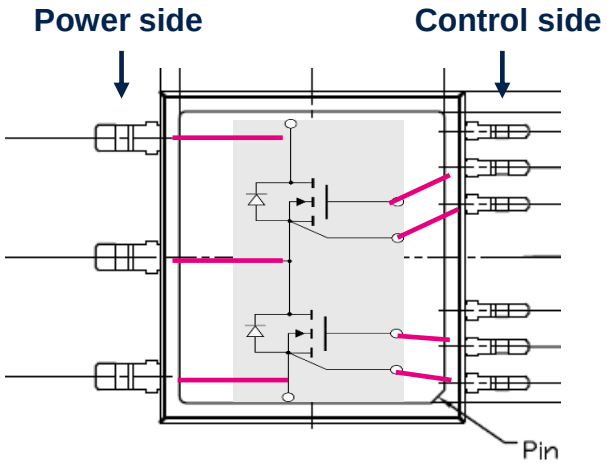
For comparison: D2PAK



~5x smaller

~7x smaller

Pinout



- This assembly is merely illustrative. Pin connections in real products may differ
- In rectifiers, the control pins might also be used for power

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ST PowerGaN Technology

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Main Application Trends For PowerGaN

Smart Mobility

Electrification at the center of the mobility revolution

- Traction inverters
- DC-DC converters
- On-board chargers
- Wireless chargers

Power & Energy

Maximizing efficiency & consolidating renewable energy generation

- SMPS and LED lighting
- 5G & datacenter power supplies
- Solar and energy storage
- Charging stations
- Motor control and appliances

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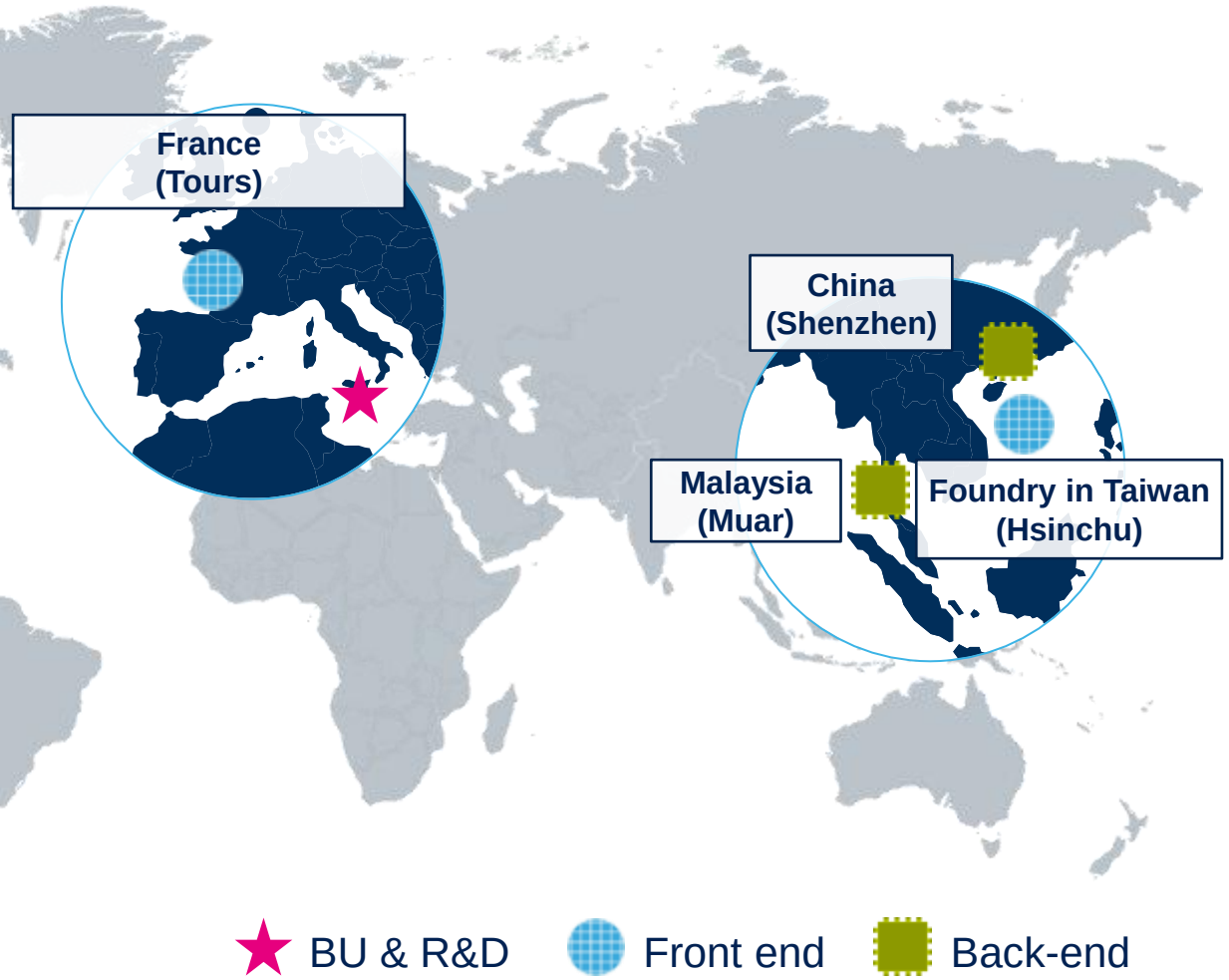
ST GaN Technology And Manufacturing

Partnership with leading GaN foundry	650 V products qualified and released
Developing own IPs and front end processes	Proprietary 650 and 100 V power GaN technologies: own epitaxy and FE processes and IPs
Dedicated 8-inch PowerGaN fab in Europe (France)	• Vertical integrated epitaxy and FE line • Volume production ramp up in 2025 • 2nd source to foundry, enabling cost competitiveness
Very high volume and low-cost assembly in Malaysia	• In-house panel-based PQFN manufacturing • PowerFLAT and LFPAK @OSAT • Volume production ramp up in 2024



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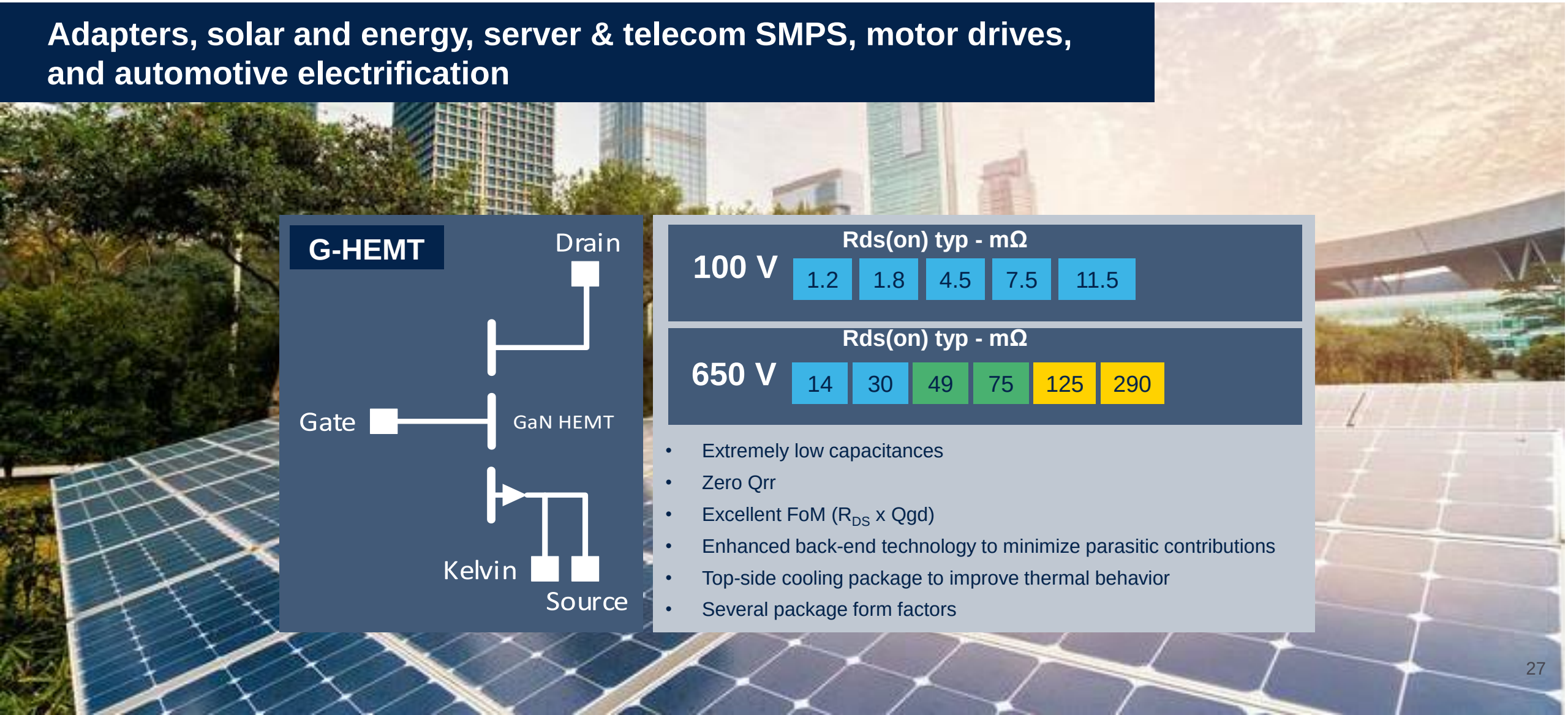
PowerGaN Range For Various Applications

Adapters, solar and energy, server & telecom SMPS, motor drives, and automotive electrification



G-HEMT

	Rds(on) typ - mΩ					
100 V	1.2	1.8	4.5	7.5	11.5	
	Rds(on) typ - mΩ					
650 V	14	30	49	75	125	290

- Extremely low capacitances
- Zero Qrr
- Excellent FoM (R_{DS} x Qgd)
- Enhanced back-end technology to minimize parasitic contributions
- Top-side cooling package to improve thermal behavior
- Several package form factors

PowerGaN Package

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Packages For PowerGaN

PowerFLAT 5x6 HV

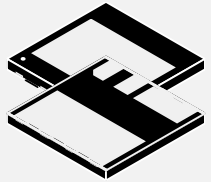
Qualified

- In-house manufacturing
- Established package solution
- Flexible solution
- Multiple sources

Gaming & adapters

LED lighting

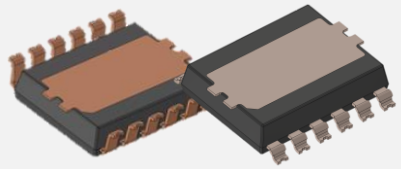
PowerFLAT 8x8 BSC/DSC



- Exposed metal on top side and bottom side
- Low package profile
- Cu clip technology
- Low operating temperature
- Creepage >3.5 mm
- 8 x 8 mm
- Kelvin source for optimized driving

Server and telecom power

LFPAK 12x12 TSC/BSC



- Exposed metal on top side or bottom side
- Low profile
- Cu clip technology
- Lower operating temperature
- Creepage >3.5 mm
- Top-side or bottom-side cooling
- 12 x 12 mm
- Kelvin source for optimized driving

OBC & DC-DC converters, solar energy, and server SMPS

New package

- Manufactured in-house
- Exposed metal on top side and bottom side
- Low package profile
- Low operating temperature
- Flexible form factor
- Optimized for low voltage

OBC & DC-DC converters, server and telecom power

LFPAK 12x12
TSC And BSC Options For G-HEMT

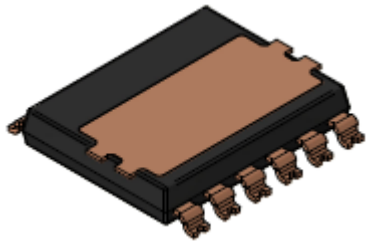
LFPAK 12x12 -

Key features

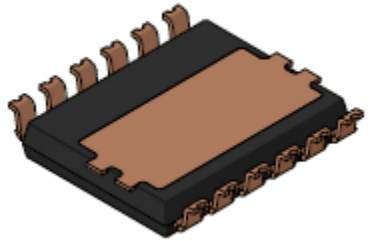
- **Cu CLIP technology**
  - Much lower stray inductance than industry standard packages for lower switching losses and EMI
- **Thermal performances**
  - $Rth_{j\text{-}c\ top}$ max = 0.263 [°C/W]
  - $Rth_{j\text{-}c\ top}$ typ = 0.163 [°C/W]
- **Robustness**
  - Supplying high-volume, high-quality Cu CLIP products to the automotive industry for many years
  - Gull wing leads for high BLR
  - Fully compatible with SMD soldering and AOI
  - 3.5 mm creepage for high voltage rating
- **Qualification plan**
  - AEC-Q101
  - MSL 1
  - Halogen free

LFPAK 12x12

Top side cooling



Bottom side cooling



Key benefits

- **Enhanced thermal performances**
  - Much lower operating temperature
  - Higher reliability compared to wire bonding technology
  - Higher current capability
  - Higher power density
  - Low package profile (2 mm typ)

Applications

- **Automotive EV**
  - OBC, DC-DC, traction inverter
- **Industrial**
  - Solar PV inverter
  - Telecom and server power supply
  - Industrial vehicle charging
  - Battery storage
  - UPS inverters

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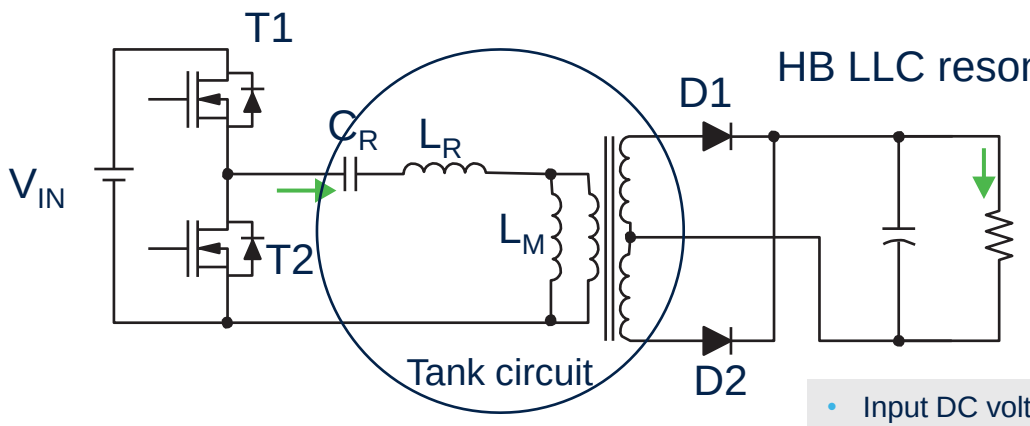
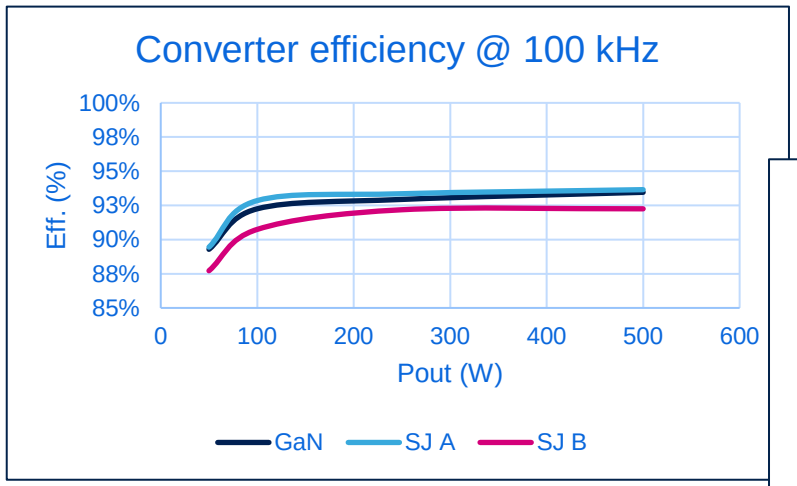
SGT120R65AL vs Superjunction MOSFET

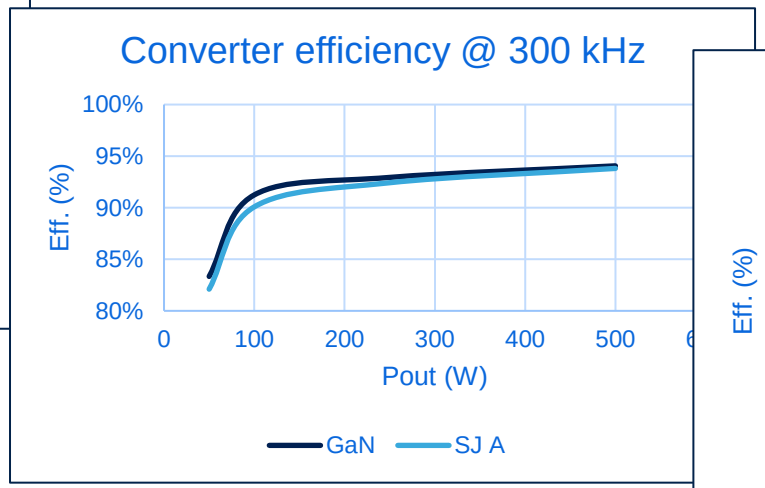
Device	BV_{DSS} @ 1 mA [V]	V_{GSth} @ 250 µA [V]	$R_{DS(on)}$ @ 5A [mΩ]	Chip size Normalized %
GaN	750	1.8	75	22.9
SJ A	645	4.38	114	90.5
SJ B	635	4.18	112	100

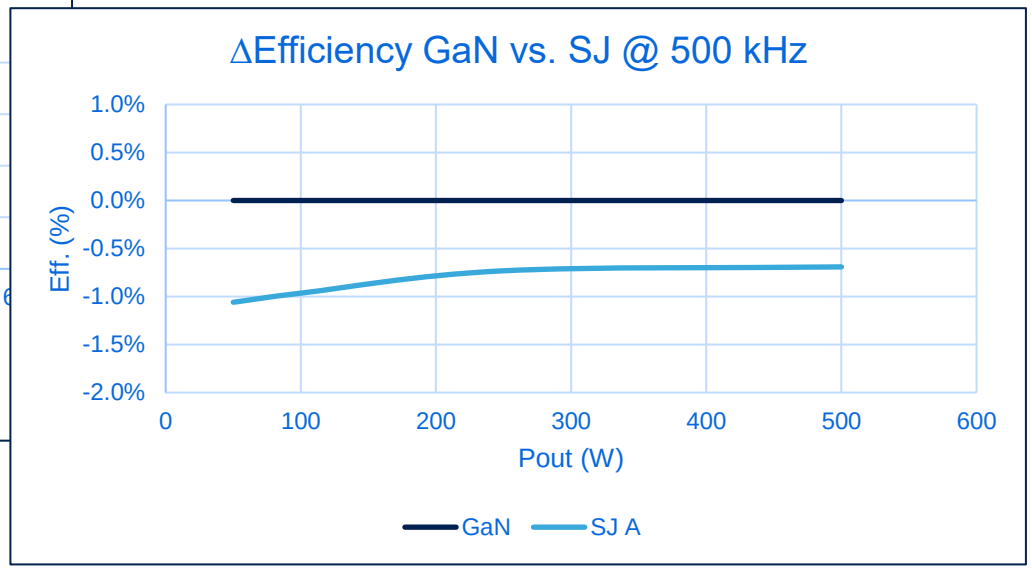
SJ A die area ~ 4 x GaN die area



- Input DC voltage: 380 to 420 V
- Output voltage: 48 V dc
- Max output power: 0.5 kW







Takeaways

ST is leader in the SiC MOSFET industry through dedicated lines, and the ramp up of SiC technology is exceeding than market expectations

ST WBG technology innovation plus the complete industrialization of new power packages leads to a strong product range for many power systems.

ST can offer a broad product range: discrete, bare dice, modules, and investing continuously to expand capacity.

ST can leverage on a dedicated team of experts in new WBG materials and power solutions to replicate a new success story on GaN as already done with SiC

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Industrial Summit
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ST Power & SPIN
microsite (CN Only)

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Our technology starts with You

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