



**INDUSTRIAL  
SUMMIT 2024**  
POWERING YOUR SUSTAINABLE INNOVATION



# Advanced Power Technology For High Efficiency And High- Density Power Conversion

Justin Tang

# Agenda

1 Power Discrete Product Portfolio

5 Diodes & Rectifiers








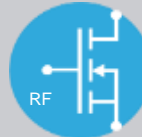
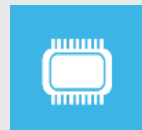
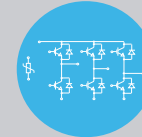




2 HV MOSFET & Package Innovation

6 Q&A

3 ST SiC MOSFET & Package Innovation

4 ST GaN Production

# Power Discrete Solution Technology Portfolio Overview

| High voltage power MOSFET  | Low voltage power MOSFET   | IGBT   | Power bipolar  | Hi-Rel & Space   | SCR   | Triac   |
|--|--|--|--|--|---|---|
|   |   |   |   |   |  |  |
| Planar and MDmesh*<br>250 V to 1700 V  | STripFET*<br>-100 V to 200 V   | IGBT<br>600/650 V, 1200 V  | Power bipolar<br>15 V to 1700 V  | Rad-hard bipolar and MOSFET<br>60 V, 200 V   | 400 V to 1200 V<br>0.25 A to 80 A<br>I <sub>GT</sub> 5 µA to 50 mA                  | 600 V to 1200 V<br>0.8 A to 40 A,<br>I <sub>GT</sub> 3 mA to 50 mA                  |
| Power RF   | Intelligent power module   | Power module   | Silicon carbide  | GaN FET  | Silicon carbide   | Diodes  |
|  |  |  |  |  |  |  |
| LDMOS, DMOS<br>28 V, 1000 V  | SLIMM*<br>500 V, 600 V   | ACEPACK*<br>650 V, 1200 V  | SiC MOSFET<br>650 V, 1200 V  | GaN-on-Si<br>100 V, 650 V<br>(In development)  | SiC DIODE<br>650 V, 1200 V  | Schottky<br>15 V to 200 V<br>FERD<br>45 V to 100 V<br>Ultrafast<br>200 V to 1200 V  |

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# HV MOSFET & Advanced Packaging



# High voltage MOSFET series superjunction MDmesh\* and STMESH trench

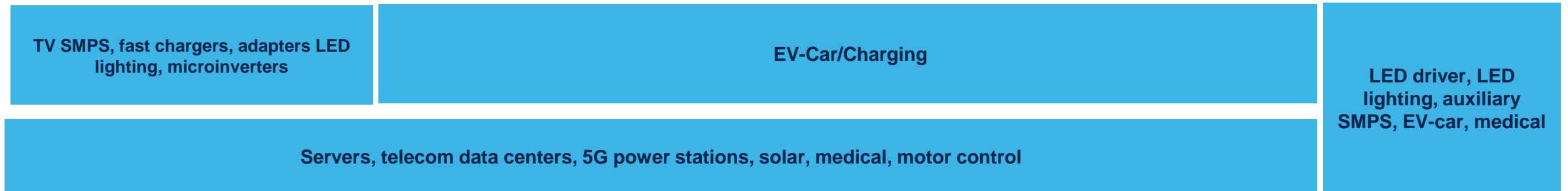
## MDmesh series



## Focus topology



## Focus applications





# High-voltage silicon MOSFETs

**MDmesh: the most complete product portfolio for industrial & multisegment systems**

**M2/DM2**

Balanced cost & performance for a broad range of power applications

400 V, 500 V,  
600 V, 650 V

**M6/DM6**

Superjunction technology for high efficiency in resonant converters and soft-switching applications

600 V, 650 V

**M5**

Outstanding  $R_{DS(on)}$  in high-power PFC and compact solutions

550 V, 650 V

**M9/DM9**

Enables higher power density and efficiency

250 V, 600 V, 650 V

**K5/DK5**

First superjunction technology > 1000 V for very high voltage applications

800 V, 900 V, 950 V,  
1050 V, 1200 V,  
1500 V, 1700 V

**K6**

Industry's lowest  $R_{DS(on)}$  in the very high voltage market. Suitable for very high voltage range

800 V, 950 V, 1050 V,  
1200 V, 1500 V,  
1700 V

Latest lines



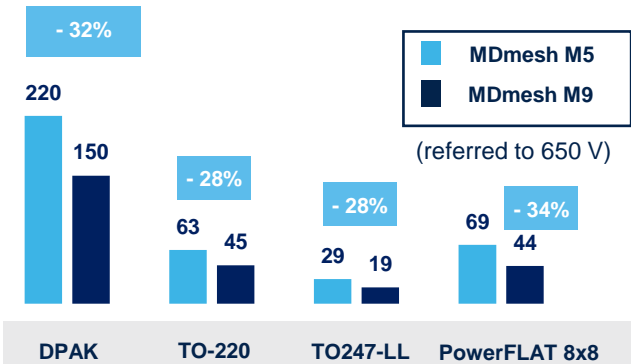
# MDmesh M9/DM9 series

250, 600, and 650 V MDmesh M9/DM9 superjunction MOSFETs for highest application efficiency

Impressive ultralow FoM ( $R_{DS(on)} \times Q_g$ ) enables increased power levels and higher power density for more compact solutions

**Improvement** hard and soft switching and higher system ruggedness with fast embedded diode

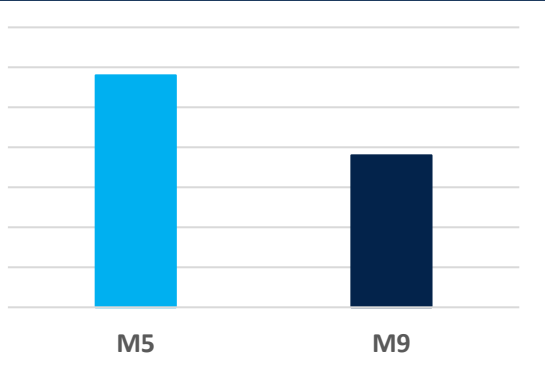
Telecom data centers  
Solar and energy storage systems





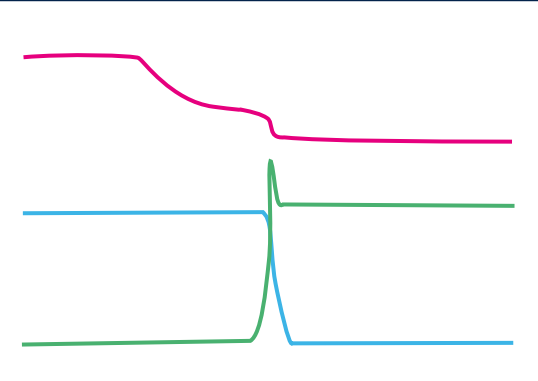
# 250, 600, 650 V MDmesh M9/DM9 series features

## Outstanding $R_{DS(on)}$ \* area



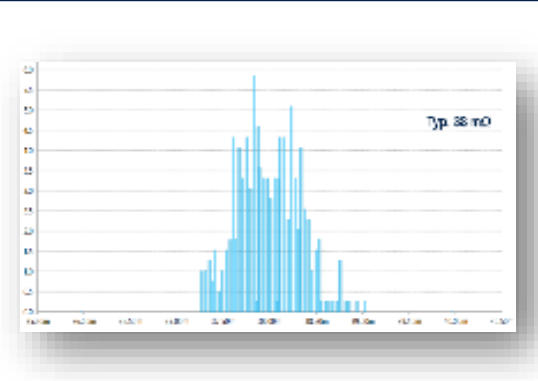
- Very low  $R_{DS(on)}$  per area
- Suitable for Hard switching topologies
- Best choice for resonant high power density systems

## Power losses



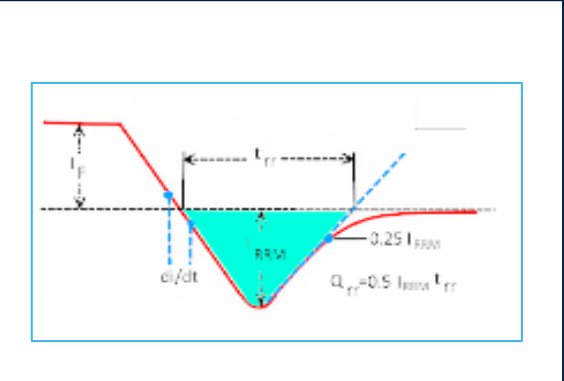
- Reducing switching energy losses
- Reducing switching time
- Increasing switching frequency

## Process



- Reduced  $V_{TH}$  spread < 1 V
- Reduced  $I_{GSS}$  leakage
- Higher  $V_{GS}$  AMR ( $\pm 30$  V)

## Robustness

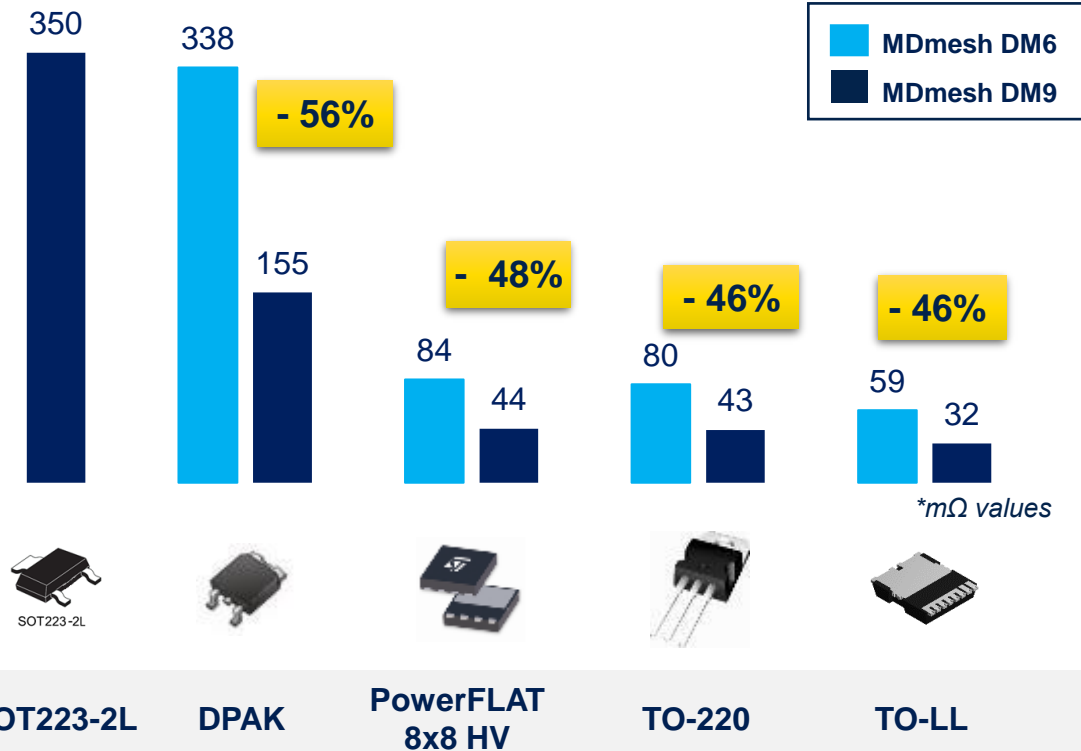


- Static  $dv/dt$  up to 120 V/ns
- $dv/dt$  ruggedness up to 50 V/ns (M9)
- $dv/dt$  ruggedness up to 120 V (DM9)
- $di/dt$  ruggedness up to 1300 A/ $\mu$ s (DM9)

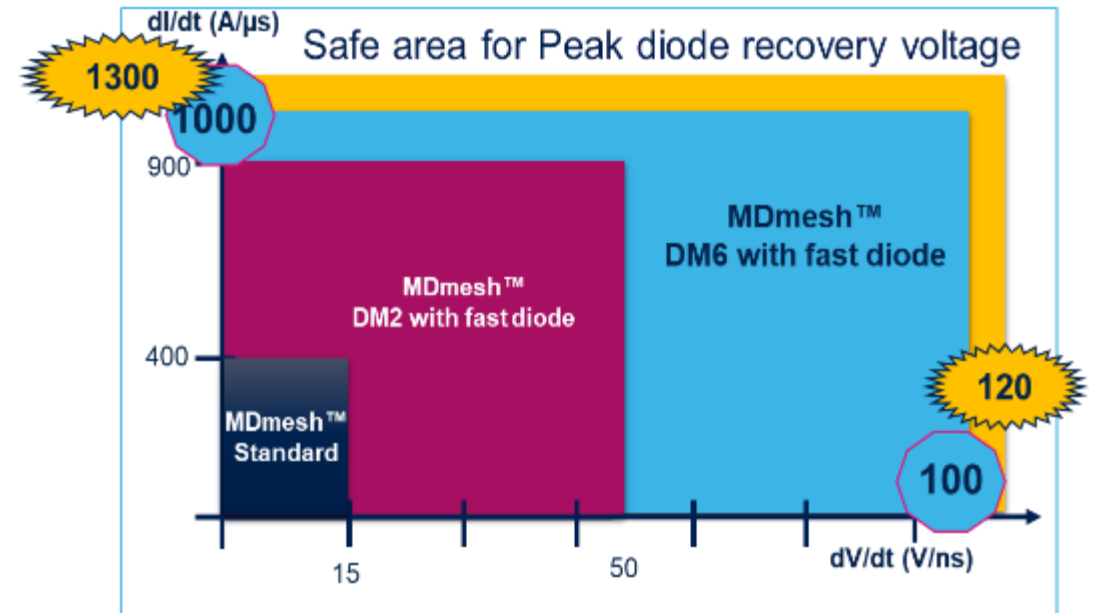


# MDmesh DM9 Fast Series

## 600 V - DM9 vs DM6 $R_{DS(on)}$ comparison

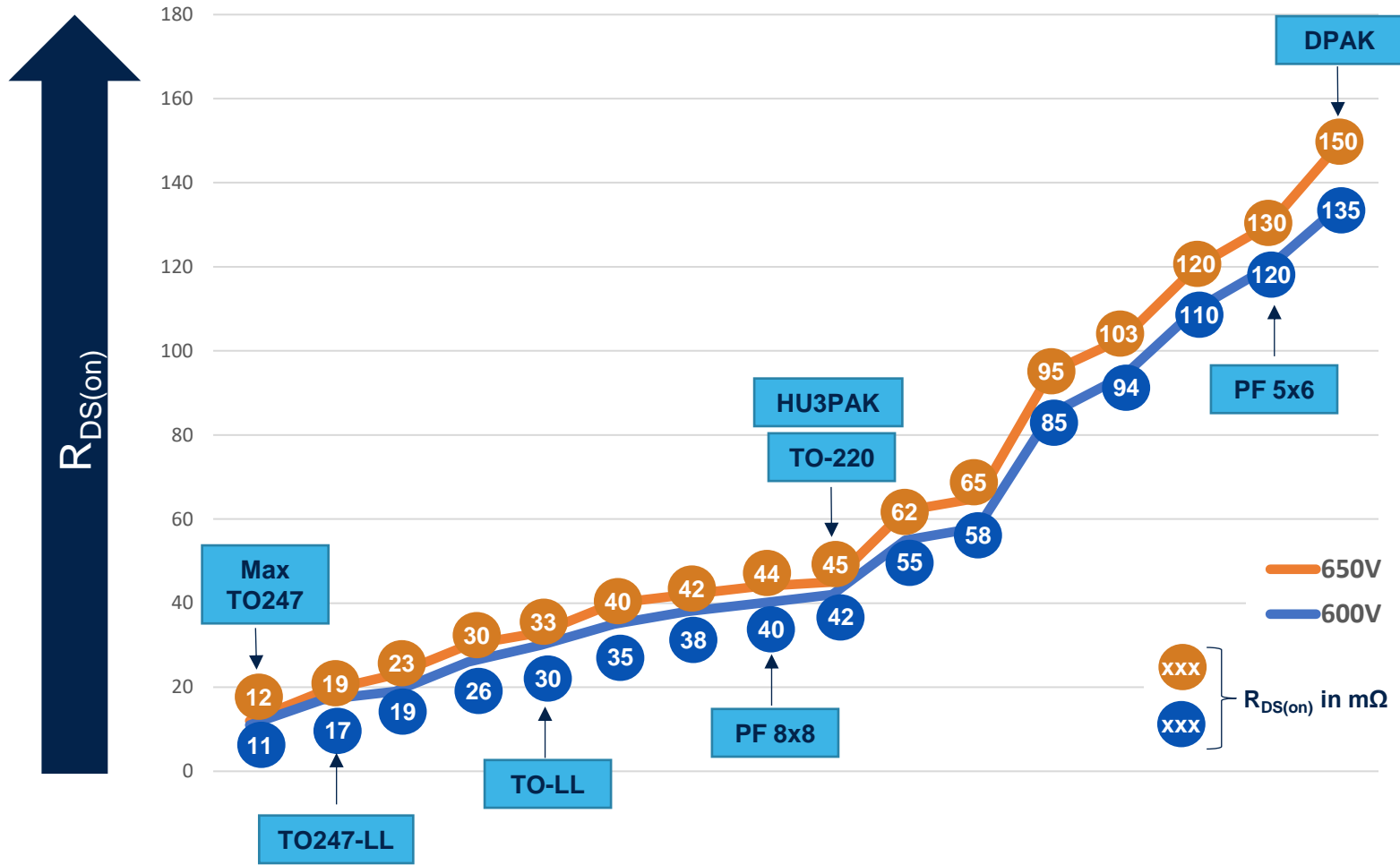


## Dynamic features



- **Fast device** (low trr) increases margins for critical electrical conditions.
- Diode recovery test performed setting **1300A/ $\mu$ s** and reaching **120 V/ns**
- **Wider safety area** for Peak diode recovery voltage

# MDmesh M9/DM9 Scalable RDS(on)



Best R<sub>DS(on)</sub> vs package

| package       | 600 V | 650 V |
|---------------|-------|-------|
| Max TO247     | 11    | 12    |
| TO247 LL      | 17    | 19    |
| TOLL          | 30    | 33    |
| HU3PAK        |       | 45    |
| TO-220        | 42    | 45    |
| PowerFLAT 8x8 | 40    | 44    |
| PowerFLAT 5x6 | 120   | 130   |
| DPAK          | 135   | 150   |



DM9 version approx. +10% R<sub>DS(on)</sub> vs M9



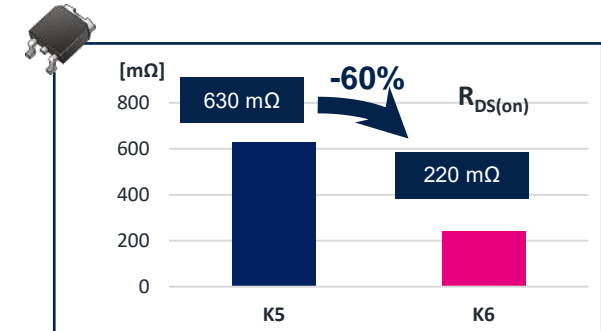
# 800–950 V\* MDmesh K6 series

## MDmesh K6 superjunction MOSFETs for very-high-voltage applications

Perfect for LED lighting applications and auxiliary SMPS based on flyback topology.

Industry's best  $R_{DS(on)}$  for 800 V voltage range, enables designers to increase the power density system for more compactness solution

Lighting applications  
Auxiliary SMPS and e-metering



\* Under development

# MDmesh K6 Breakthrough on SJ technology

## Key features

$R_{DS(on)}$

### Benefits:

- More compactness solution
- Height board reduction

$V_{GS(th)}$

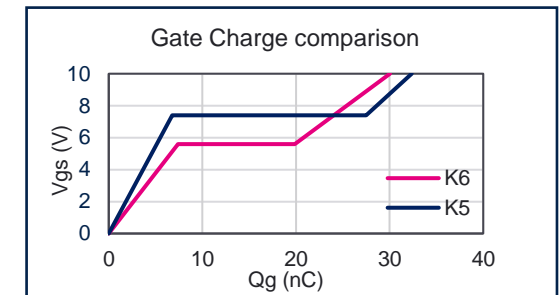
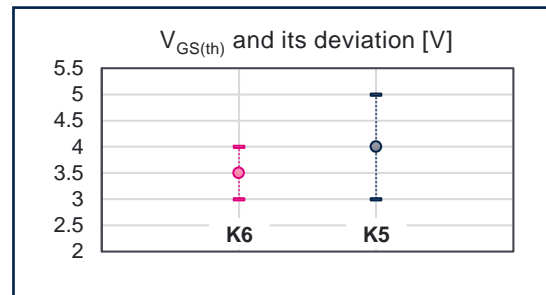
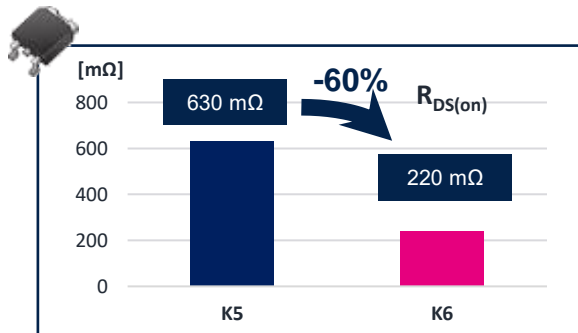
### Benefits:

- Lower driving voltage
- Idle reduced losses
- Tighter tolerance

$Q_g$

### Benefits:

- Higher efficiency
- Lower power losses



# MDmesh K6

## MDmesh K6

## STATUS

800 V



**42 P/Ns**

Product Range

- 42 P/Ns
- 6 packages

**9 P/N**

Full production

950 V

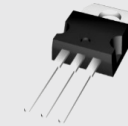


**36 P/Ns**

Product Range

- 36 P/Ns
- 7 packages

Developing



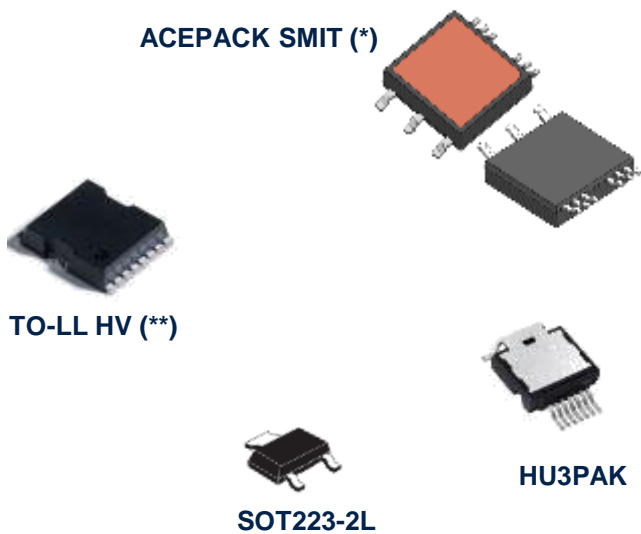
$R_{DS(on)} = 220, 340, 600, 900, 1100 \text{ m}\Omega$

STP80N240K6  
STD80N240K6  
STP80N340K6  
STD80N340K6  
STP80N450K6  
STD80N450K6  
STP80N600K6  
STP80N900K6  
STP80N1K1K6  
Full production

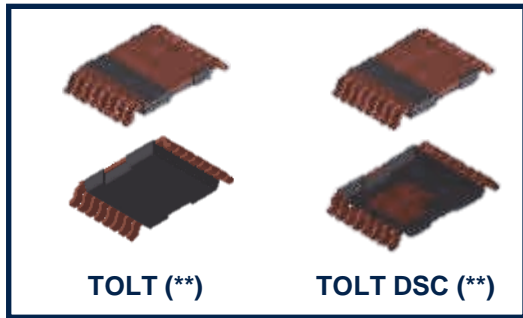
# Package roadmap

Continuously improving power density and thermal performance

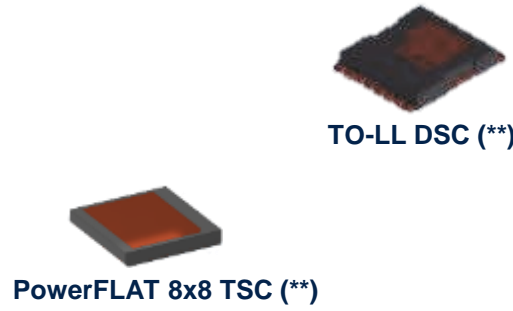
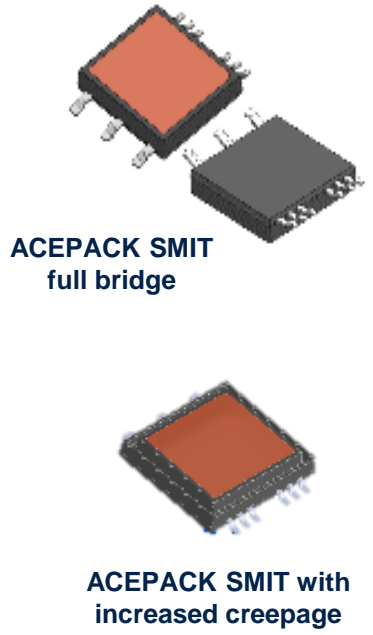
## Just now introduced



## What next



## Feasibility study and market survey



(\*) Different topologies (boost, half-bridge, etc.)  
(\*\*) HV single island (with source Kelvin contact)



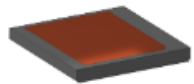
# New high thermal efficiency surface mounting packages

AEC-Q101 eligible; samples available soon

1

## PowerFLAT 8x8 TSC

- **Top side cooling**
- Very thin (<1 mm) with internal clip
- Well accepted in power conversion
- Kelvin source option for optimized driving
- Leadless



Samples available = March 24

2

## TOLT

- **Top side cooling**
- Leaded for best solderability
- Kelvin source option for optimized driving
- Industry standard



Samples available = Q4 24

3

## TOLT DSC

- **Bottom- & top-side cooling**
- Leaded for best solderability
- Kelvin source option for optimized driving
- Industry standard

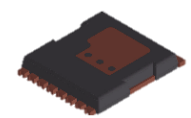


Samples available = Q4 25

4

## TOLL DSC

- **Bottom- & top-side cooling**
- Kelvin source for optimized driving
- Very good thermal dissipation
- Industry standard



Samples available = Q4 25

# SiC MOSFET



# Wide-bandgap (WBG) figures of merit

Higher breakdown voltage: x10  
Lower on-resistance & losses

**SiC**

**Si**

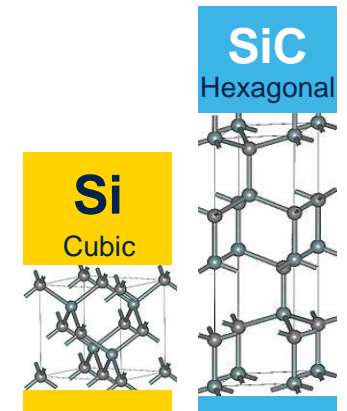
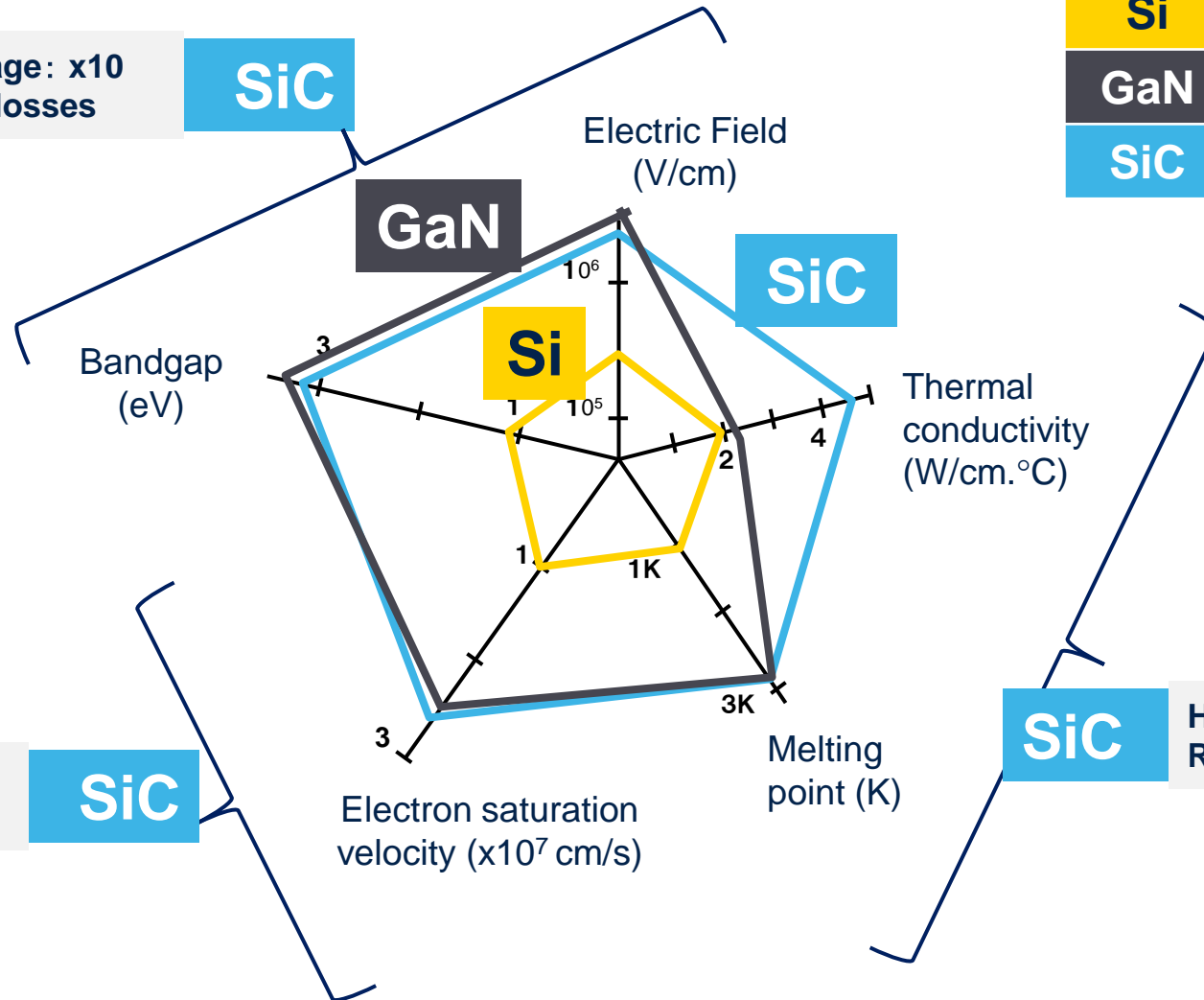
conventional silicon

**GaN**

gallium nitride (WBG)

**SiC**

silicon carbide (WBG)



Higher switching frequency  
Lower switching losses

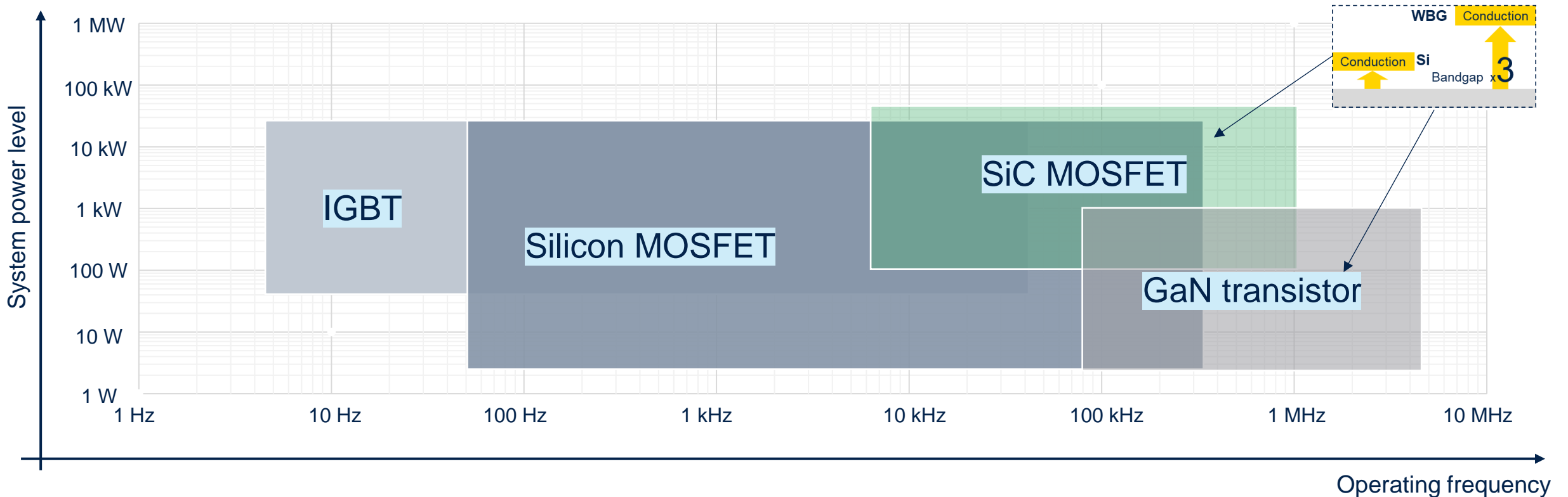
**SiC**

**SiC**

Higher temp. (operation & endurance)  
Reduced cooling requirements

# Silicon, SiC, and GaN power semiconductor positioning

Higher power levels can be achieved with modules or paralleling





# SiC MOSFET range

## High voltage and fast switching for high density applications

**Gen1**

Optimized **R<sub>on</sub>** and **T<sub>j</sub>** for motor drive applications

1200–1700 V

**Gen2**

Balanced **R<sub>on</sub>** and **Q<sub>g</sub>** for a broad range of automotive & industrial applications

650 V, 1200 V, 2200 V

**Gen3**

Ultrafast series optimizing **R<sub>on</sub>** and **Q<sub>g</sub>** for very high frequency applications

650 V, 750 V, 900 V, 1200 V

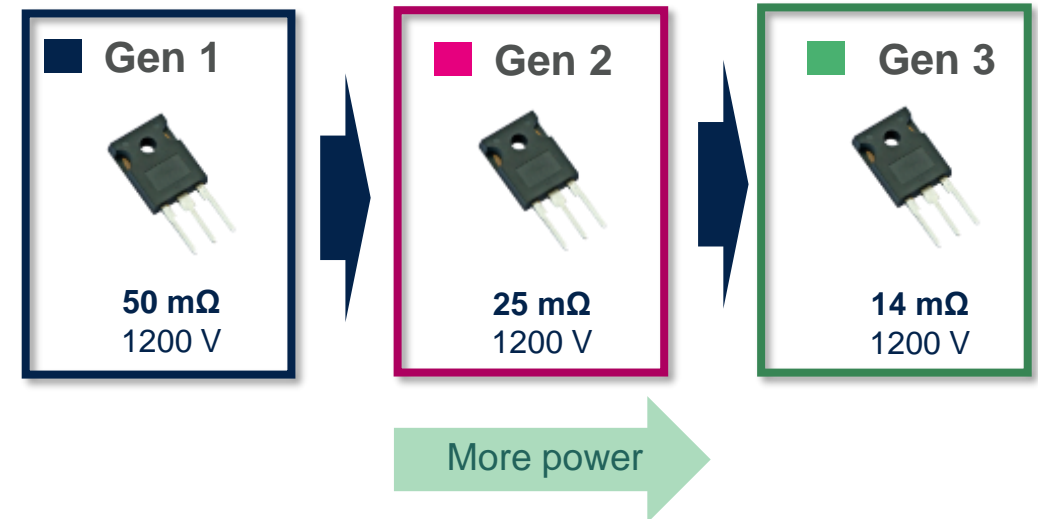
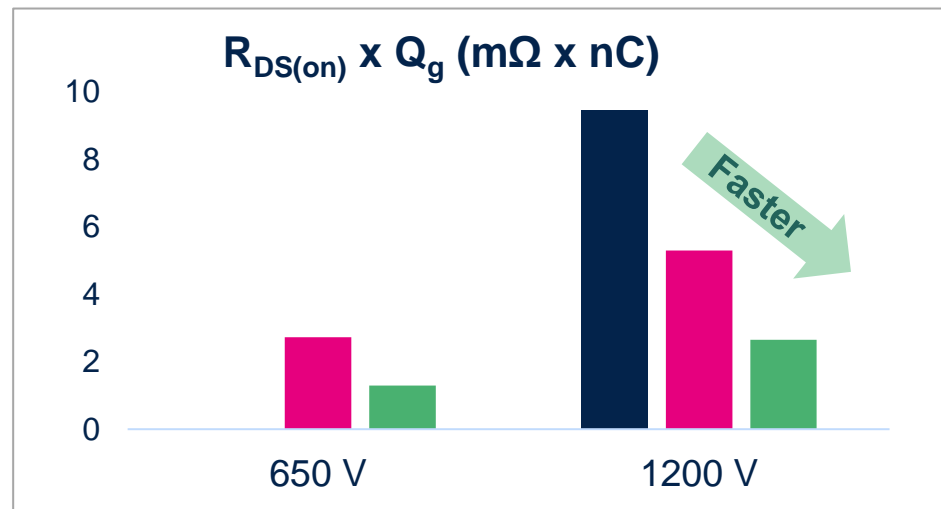
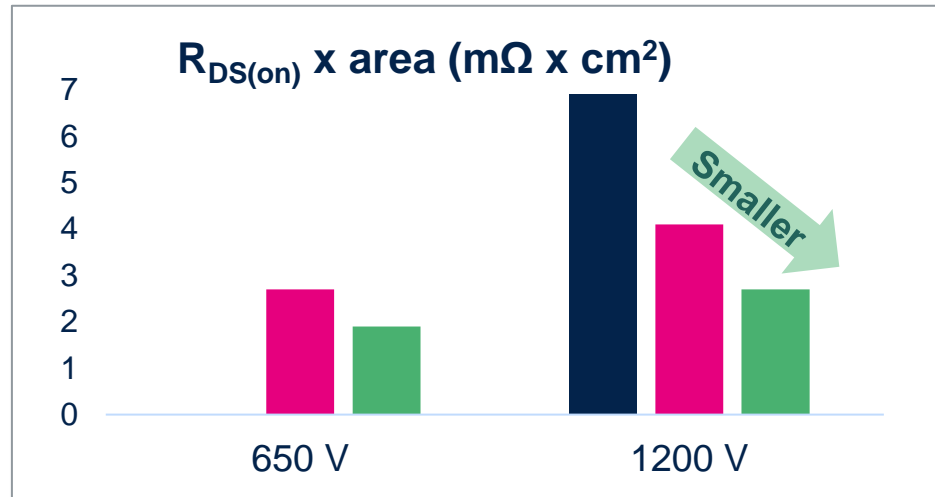
**SiC VHV**  
2200 V\*

Very high voltage SiC extend the advantages of SiC technology to higher voltage ranges

2200 V

\* industrial grade

# SiC MOSFET advances in figures of merit



## Improvement in MOSFET generations

- **Lower  $R_{on} \times \text{area}$  → lower  $R_{on}$  for a given chip size or smaller chip size for a given  $R_{on}$ , higher current capability, lower conduction losses → higher power achievable in power module with the same form factor**
- **Lower  $R_{on} \times Q_g$  → lower switching losses, higher frequency (reduced board)**

# STPOWER SiC MOSFET

## Product families and applications

### Breakdown voltage

650 V

750 V/900 V

1200 V

1700 V

2200 V

### Series

G2

G3

G3

G1

G2

G3

G1

VHV

### On-state resistance

18 mΩ to  
67 mΩ

14-55 mΩ

11 mΩ

52 mΩ to  
520 mΩ

25 mΩ to  
75 mΩ

15 mΩ to  
70 mΩ

1 Ω and  
65 mΩ

31 mΩ

### Focus applications

OBC & DC-DC  
Renewable energy  
Power supply  
Industrial drives

Traction  
OBC & DC-DC  
High density  
power supply

Traction inverter  
OBC & DC-DC  
High density power  
supply

Photovoltaic  
Power supply


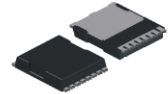


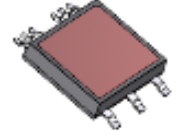
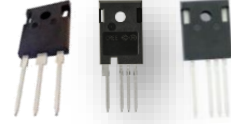


OBC & DC-DC  
Inverter  
Charging stations  
Industrial drives

Traction inverter  
OBC & DC-DC  
HF power supply

DC-DC  
Power  
supply  
Renewable  
energy

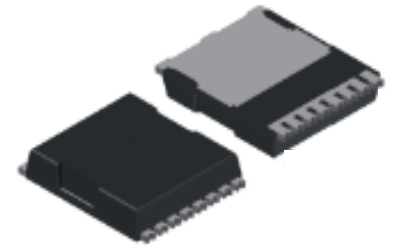
DC-DC  
Power  
supply  
Renewable  
energy

# SiC MOSFET package technologies

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

# SiC Gen 3 MOSFETs in TO-LL

Designed for high-speed phase, high power, and more efficient server and telecom power systems



| $V_{DS}$ [V] | $R_{DS(on)}$ typ @ 25°C [ $\Omega$ ], $V_{GS}=18$ V | Package | P/N          | Eng. Samples | MAT 30   |
|--------------|---|---------|--------------|--------------|----------|
| 650 V        | 0.040   | TO-LL   | SCT040TO65G3 | Available    | Achieved |
|              | 0.055   | TO-LL   | SCT055TO65G3 | Available    | Q4 2024  |
|              | 0.027   | TO-LL   | SCT027TO65G3 | Available    | Q4 2024  |
|              | 0.014   | TO-LL   | SCT014TO65G3 | Available    | Q4 2024  |

With Kelvin source

Suitable to be driven at  $V_{GS}=15$  V

# STPOWER GaN products

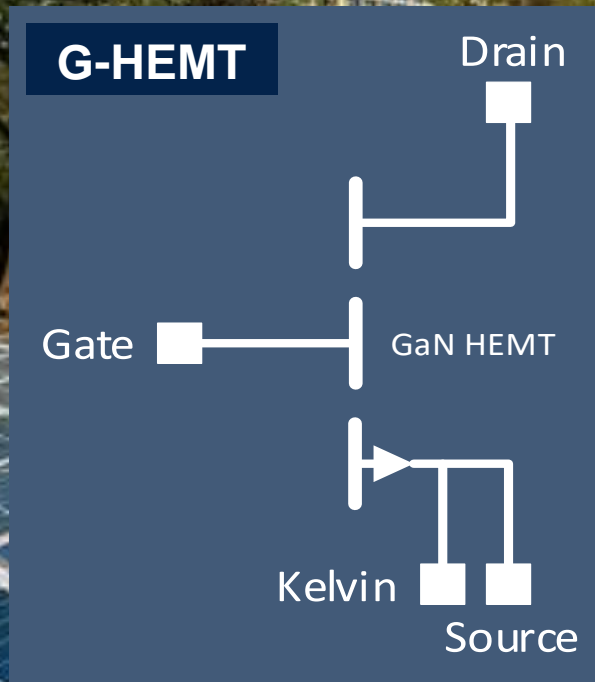


life.augmented



# PowerGaN range for various applications

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



| 100 V | Rds(on) typ - mΩ |     |     |     |      |
|-------|------------------|-----|-----|-----|------|
|       | 1.2              | 1.8 | 4.5 | 7.5 | 11.5 |

| 650 V | Rds(on) typ - mΩ |    |    |    |     |     |
|-------|------------------|----|----|----|-----|-----|
|       | 14               | 30 | 49 | 75 | 125 | 290 |

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

# 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

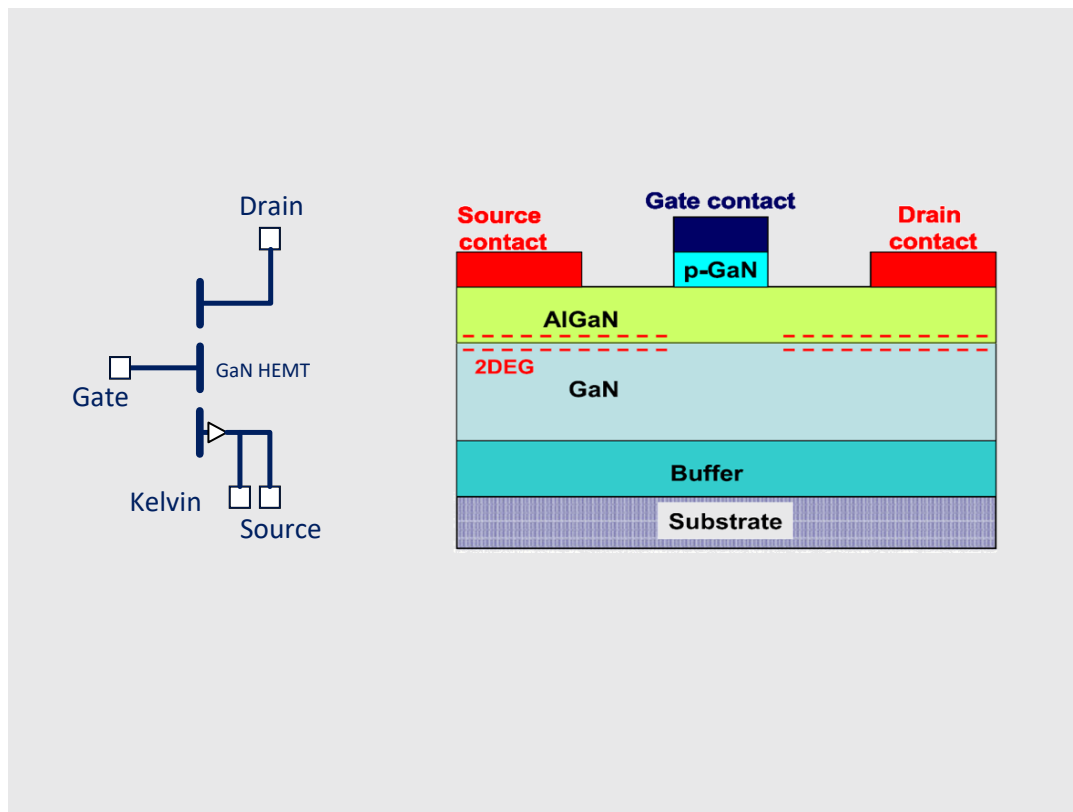
Maximizing efficiency & consolidating renewable energy generation



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

# ST GaN technology platforms

## PowerGaN G-HEMT: e-mode HEMTs (intrinsically normally-off devices)



### Partnership

- GaN power discrete & GaN IC platform
- 6-inch wafers GaN-on-Si
- 650 V normally-off based on p-GaN process for industrial

### ST proprietary

- Tours (France) manufacturing
- 8-inch wafers GaN-on-Si
- 100 & 650 V normally-off based on p-GaN process for automotive

# PowerGaN 650 V industrial product plan

| Series | MPN          | Target electrical specifications |                          |           |         | Package           | Eng Samples | Qual Samples | SOP    |
|--------|--------------|----------------------------------|--------------------------|-----------|---------|-------------------|-------------|--------------|--------|
|        |              | I <sub>D</sub> [A]               | R <sub>DS</sub> typ [mΩ] | Coss [pF] | Qg [nC] |                   |             |              |        |
| G-HEMT | SGT440R65BL  | 5                                | 290                      | 14        | 1       | PowerFLAT 5x6     | Q3 '24      | Q4 '24       | Q1 '25 |
|        | SGT190R65BL  | 12                               | 125                      | 20        | 2.2     | PowerFLAT 5x6     | Q3 '24      | Q4 '24       | Q1 '25 |
|        | SGT120R65AL  | 15                               | 75                       | 50        | 3       | PowerFLAT 5x6     | ✓           | ✓            | ✓      |
|        | SGT110R65ALB | 15                               | 75                       | 50        | 3       | PowerFLAT 8x8     | Q1 '24      | Q2 '24       | Q3 '24 |
|        | SGT65R65AL   | 25                               | 49                       | 85        | 5.4     | PowerFLAT 5x6     | ✓           | ✓            | ✓      |
|        | SGT65R65ALB  | 25                               | 49                       | 85        | 5.4     | PowerFLAT 8x8     | Q1 '24      | Q2 '24       | Q3 '24 |
|        | SGT65R65AKT  | 25                               | 49                       | 85        | 5.4     | LFPACK 12x12 TSC  | ✓           | Q1 '24       | Q3 '24 |
|        | SGT65R65AK   | 25                               | 49                       | 85        | 5.4     | LFPACK 12x12 BSC  | Q2 '24      | Q3 '24       | Q4 '24 |
|        | SGT40R65ALB  | 40                               | 30                       | 130       | 9.3     | PowerFLAT 8x8     | Q2 '24      | Q3 '24       | Q4 '24 |
|        | SGT40R65ALD  | 40                               | 30                       | 130       | 9.3     | PowerFLAT 8x8 DSC | Q4 '23      | Q2 '24       | Q4 '24 |
|        | SGT40R65AKT  | 40                               | 30                       | 130       | 9.3     | LFPACK 12x12 TSC  | ✓           | Q2 '24       | Q3 '24 |
|        | SGT40R65AK   | 40                               | 30                       | 130       | 9.3     | LFPACK 12x12 BSC  | Q2 '24      | Q3 '24       | Q4 '24 |
|        | SGT20R65AKT  | 40                               | 14                       | 258       | 23      | LFPACK 12x12 TSC  | ✓           | Q2 '24       | Q3 '24 |

# Packages for PowerGaN

## PowerFLAT 5x6 HV



Qualified

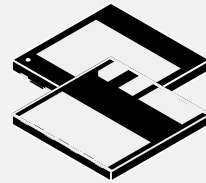
- In-house manufacturing
- Established package solution
- Flexible solution
- Multiple sources



Gaming & adapters

LED lighting

## PowerFLAT 8x8 BSC/DSC

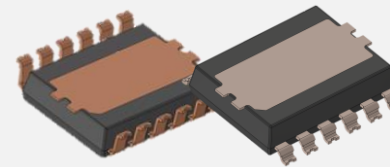


- Exposed metal on top side and bottom side
- Low package profile
- Cu clip technology
- Low operating temperature
- Creepage >3.5 mm
- 8 x 8 mm
- Kelvin source for optimized driving



Server and telecom power

## LPAK 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

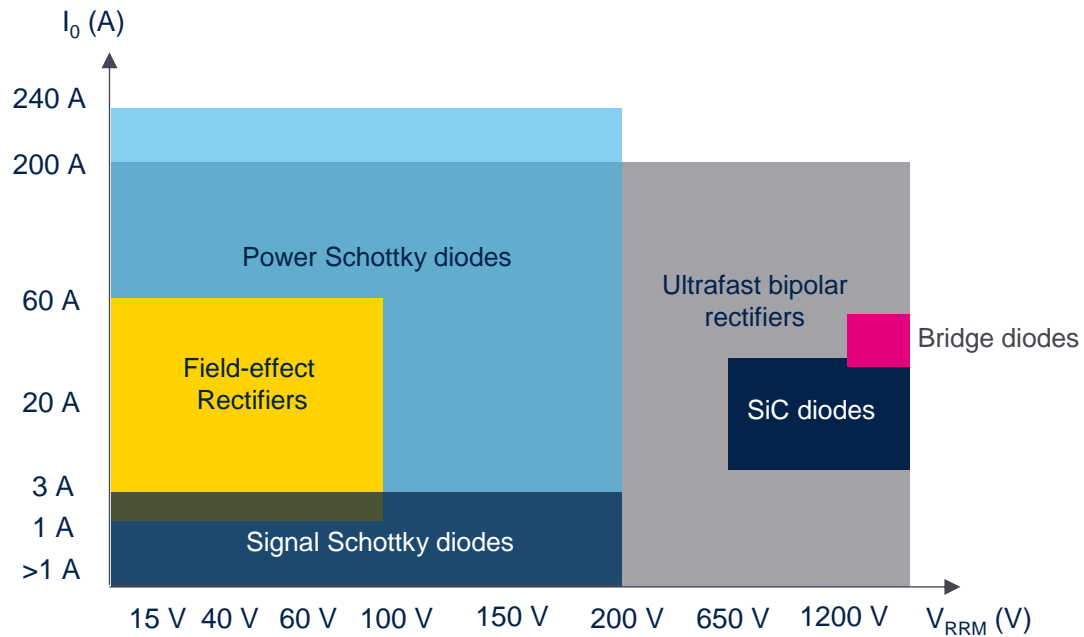


OBC & DC-DC converters, server and telecom power

# Diodes and rectifiers

# Diodes and rectifiers

## Product families for industrial applications

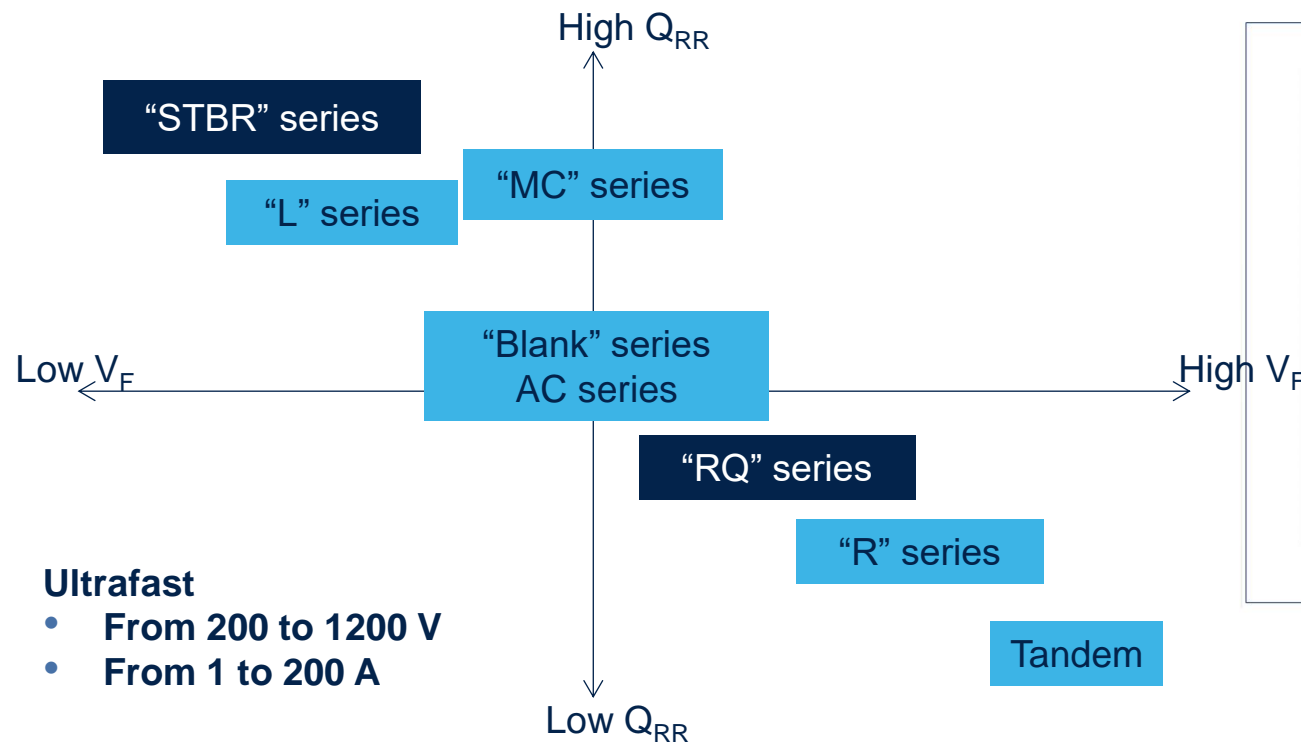


### Industrial power conversion

- Digital power supply
- Server & storage power supply
- LED lighting
- Motor control in home/automation
- Medical
- Solar
- Charging stations
- UPS

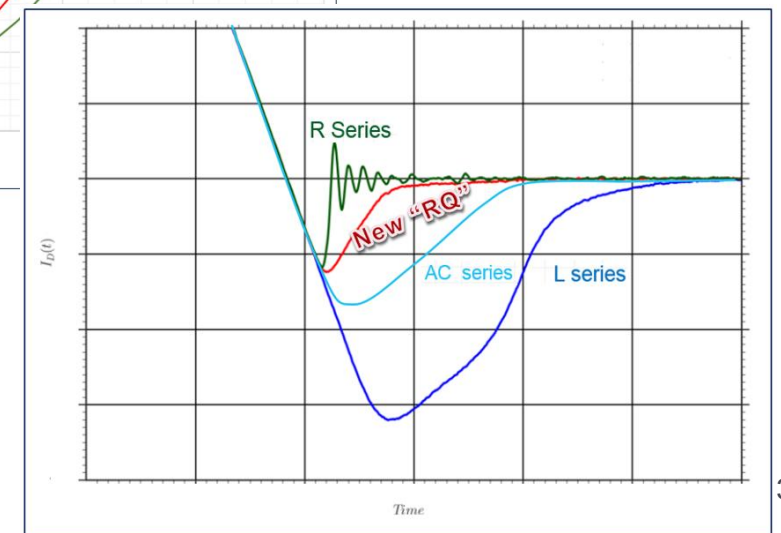
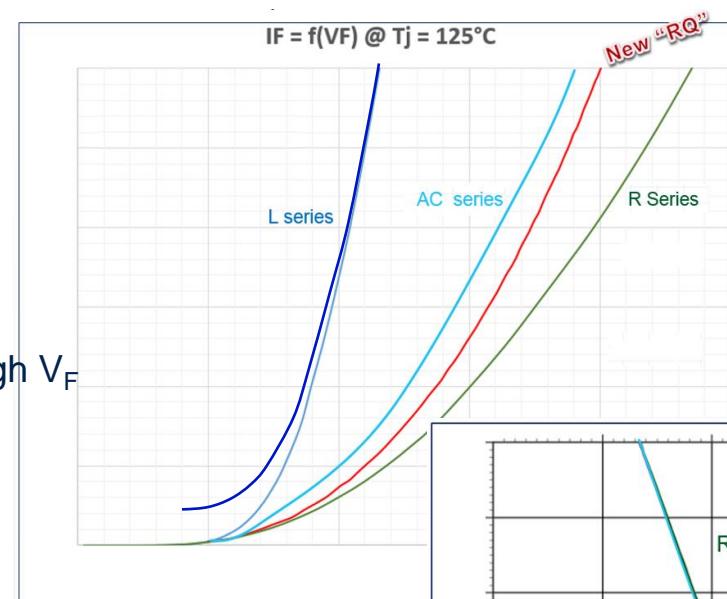
# Ultrafast rectifiers

Ongoing R&D progress in our bipolar ultrafast rectifier diodes, illustrated by the latest 'RQ' soft diode series for resonant converters



## Ultrafast

- From 200 to 1200 V
- From 1 to 200 A







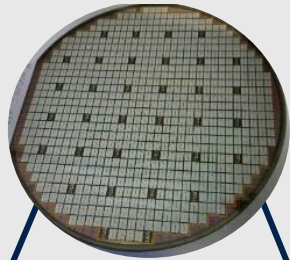
# SiC diode technology

## Increase power conversion efficiency

### Si-based ultrafast diodes



Power losses



Recovery losses

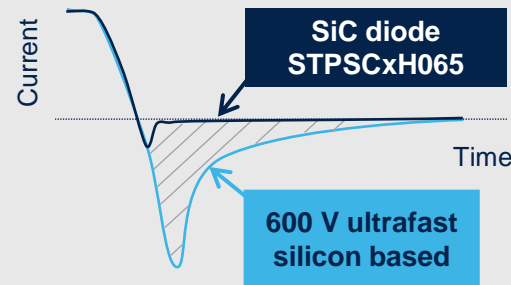
Conduction losses

### SiC based diodes



Eliminate recovery losses

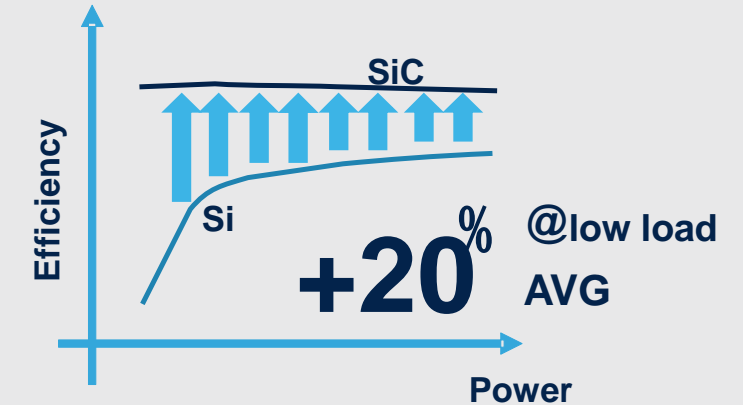
Switching performance comparison



### More efficient power conversion

Reduced dimensions

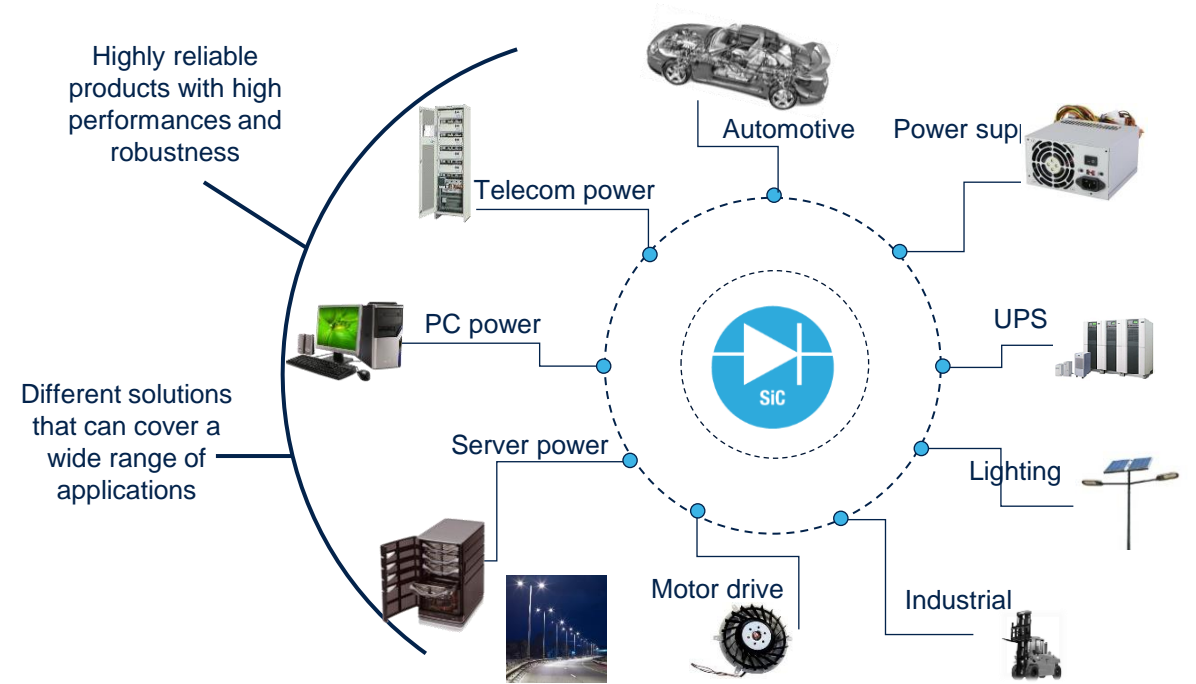
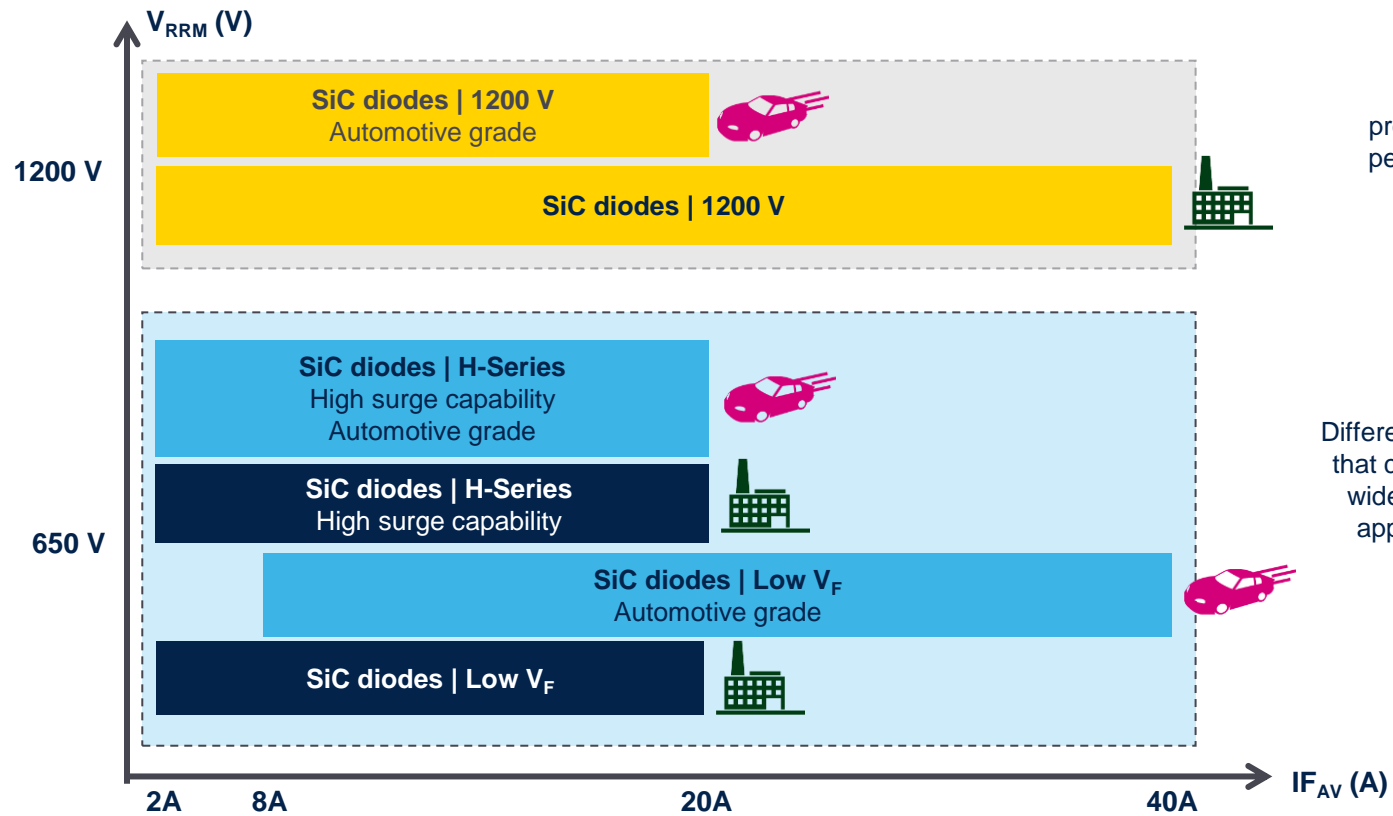
- 60%



# SiC diode families

Extended range

Where to place SiC diodes?



Highly reliable products with high performances and robustness

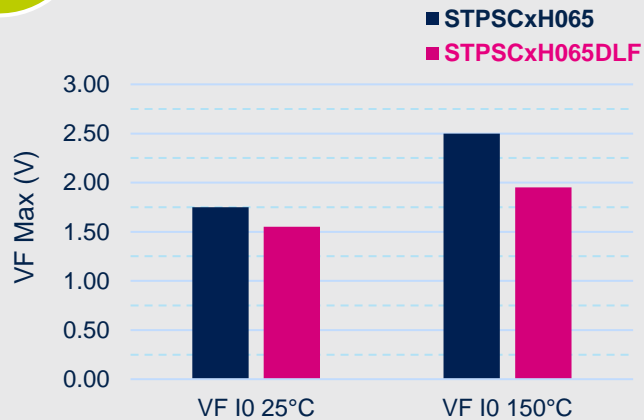
Different solutions that can cover a wide range of applications

# PowerFLAT 8x8 package 4, 6, 8, & 10 A (12 & 20 A in development)

## PowerFLAT8x8: a less-than-1-mm thick package

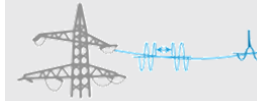


The ultimate improvement in watts

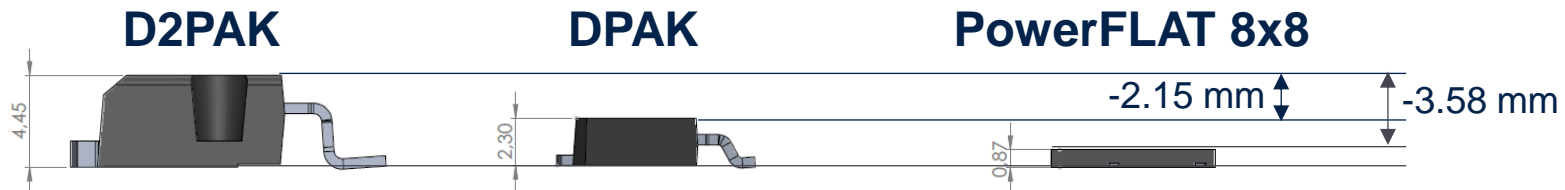
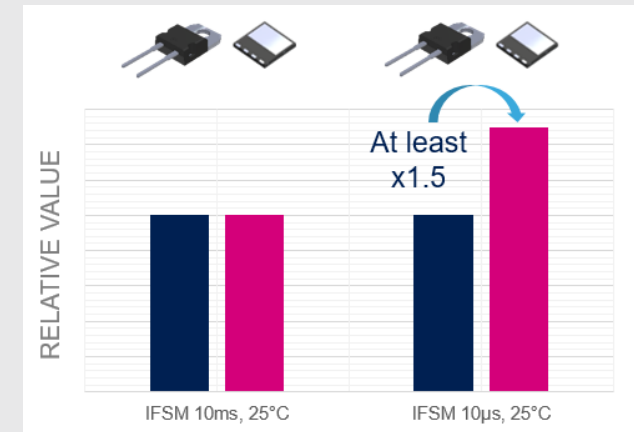


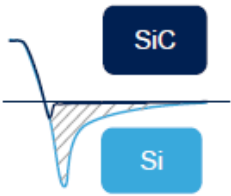
Every mV grants efficiency toward 97%, 98%, 99%

&

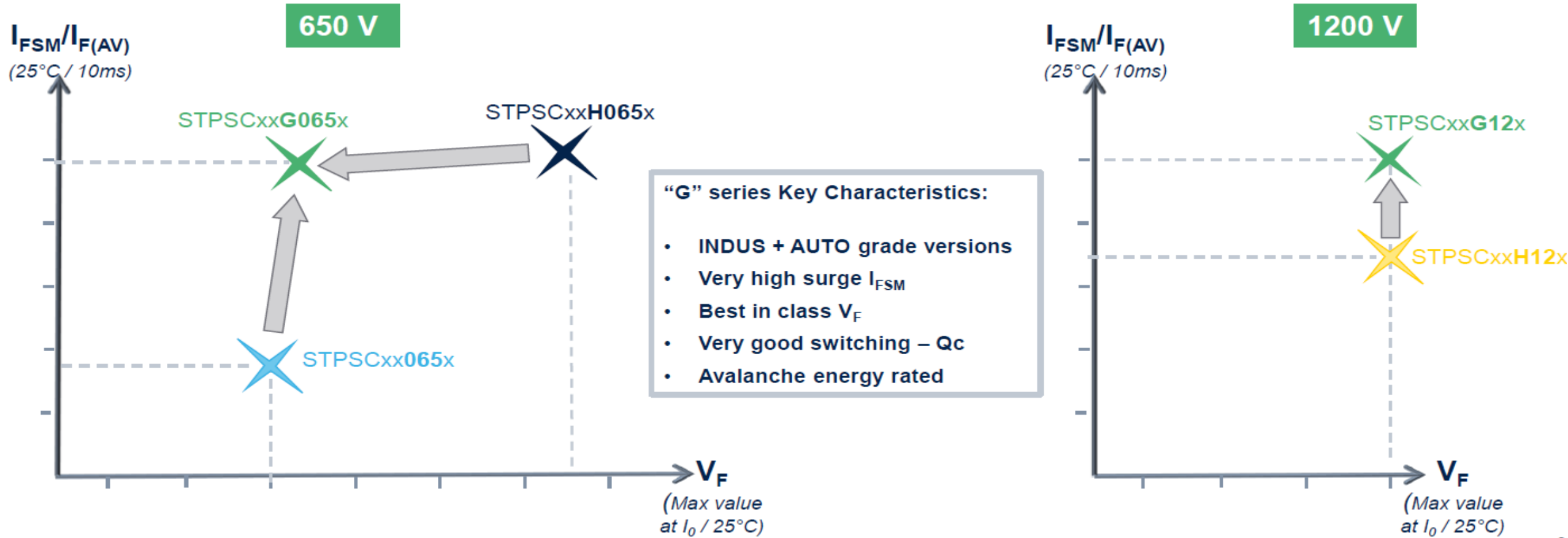


More guard band to grid disturbances





# G series: enhanced SiC diode performance



# Key takeaways



- Very wide range of power discrete products
- SiC market leadership
- Comprehensive SiC options (bare die, discrete, STPAK, and power modules)
- Advanced package technology
- Continuous product development



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