

Robust SiC MOSFET Devices for Drive Train Applications

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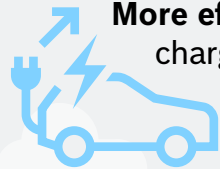
Advantages of SiC



Significantly less energy is lost in heat compared to comparable Si-components



More range due to higher efficiency

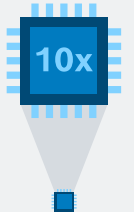


More efficient charging



Operation at higher voltages and temperatures **more economical** than with Silicon devices

Smaller installation space of SiC Power modules as comparable Si-module

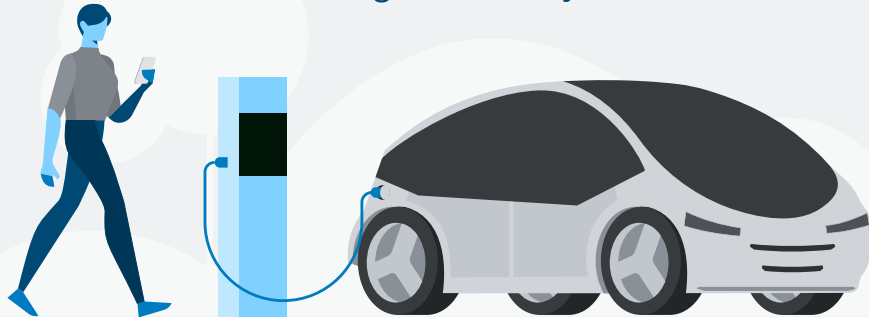


Smaller than conventional Si-semiconductors

SiC-components enable **3–5x** higher switching frequencies



Smaller batteries possible



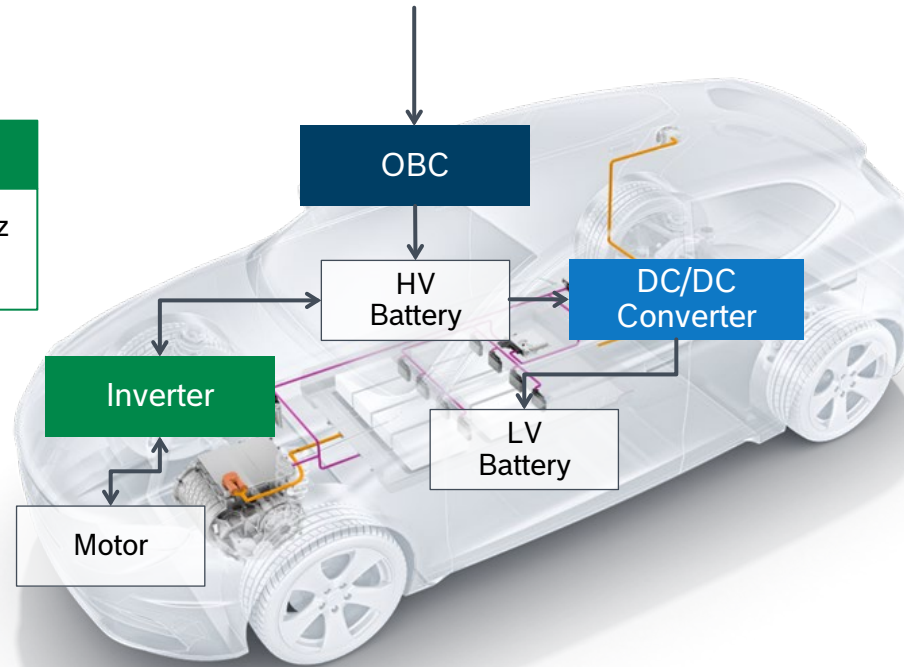
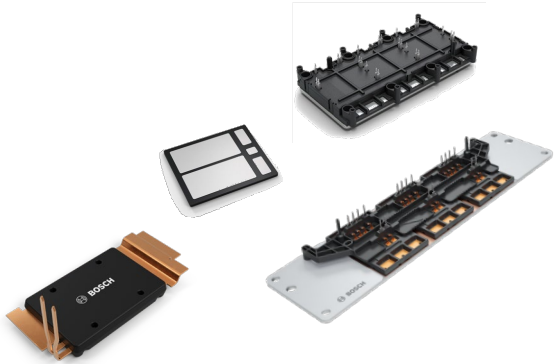
SiC chips are a key component for electrified mobility

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Applications of SiC

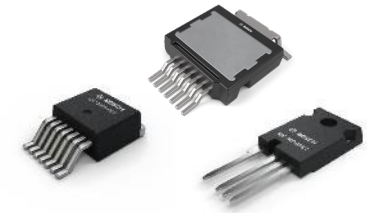
Inverter to drive the motor

- Switching frequency between 10kHz and 40kHz
- Power range between 50kW and 400kW



OBC to convert power from grid to HV battery

- Switching frequency >100kHz
- Power range between 3.3kW and 22kW



DC/DC converter from HV to LV battery

- Switching frequency >100kHz
- Power range between 1kW and 5kW



Additional AUT applications + industrial applications

Robust SiC MOSFET Devices for Drive Train Applications

Bosch's history of SiC MOSFETs

More than

57 Mio.

SiC MOSFETs delivered worldwide since 2021

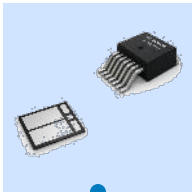


Installation SiC line Reutlingen



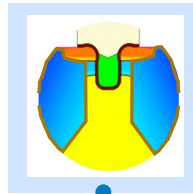
Reutlingen (DE)

SOP Gen1
6"/150 mm



Reutlingen (DE)

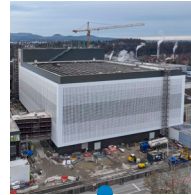
SOP Gen 2
6"/150 mm



Reutlingen (DE)

Samples Gen 2
8"/200 mm

Extension
Reutlingen Fab



Reutlingen (DE)

Samples Gen 3
8"/200 mm



Reutlingen (DE)

Samples Gen 2
8"/200 mm

New U.S. Fab
in Roseville



Roseville (U.S.)

2019

2021

2023

2024

2025

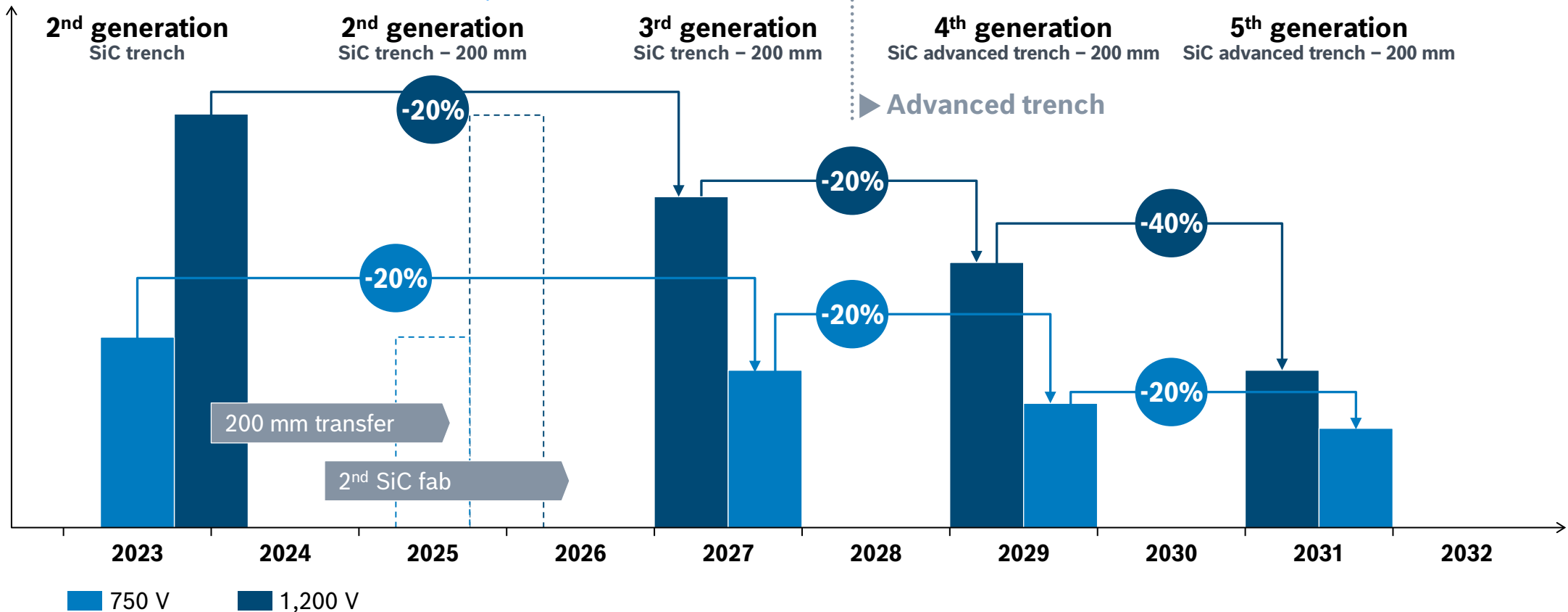
2026

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Bosch's roadmap of SiC MOSFETs

$R_{on}A$ at 175 °C

▶ 1,400-1,700 V variants

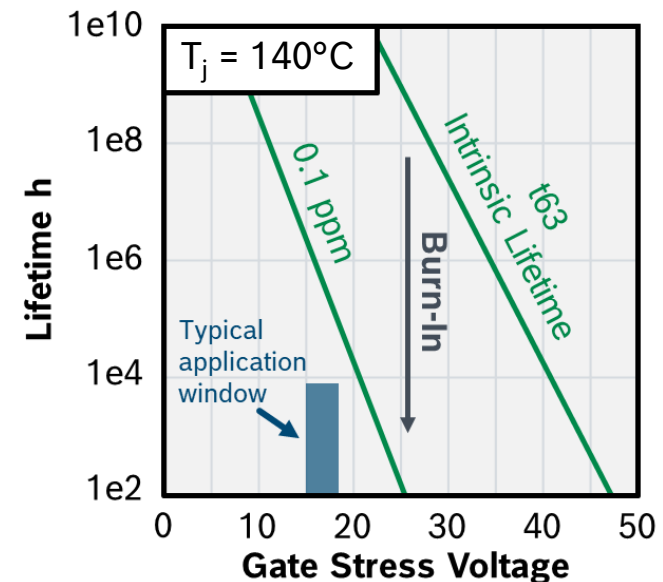
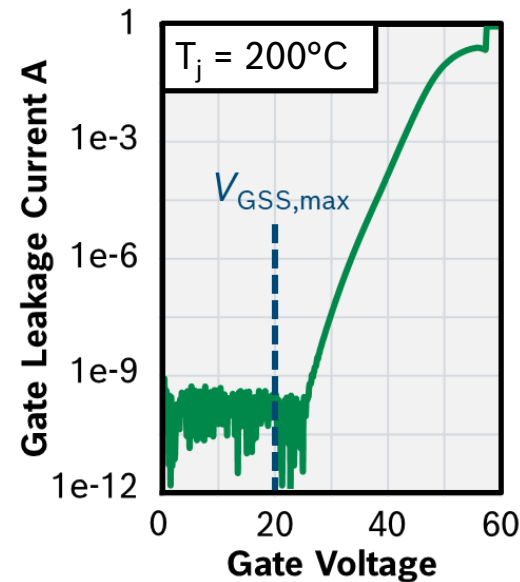
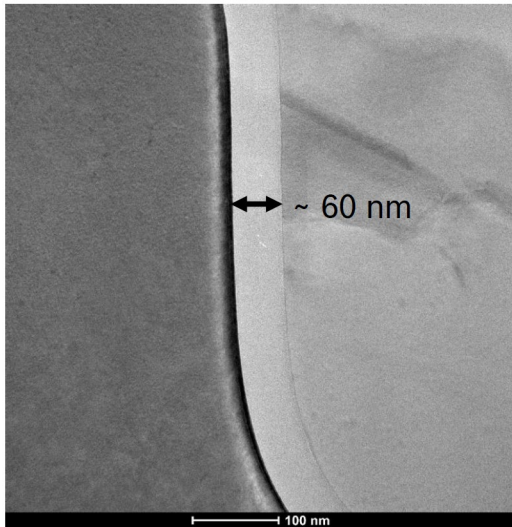


Robust SiC MOSFET Devices for Drive Train Applications

Robust Gate-Oxide as core of device design

- Special shielding structures reduce stress under high-voltage blocking
- Thicker oxide (at least 10% thicker compared to planar devices)
 - Very low leakage w/ high margin between recommended limit and breakdown
 - High intrinsic lifetime allows more efficient screening/burn-in with higher test voltage levels

TEM of Bosch Gate Oxide



Robust SiC MOSFET Devices for Drive Train Applications

Robust Gate-Oxide demonstrated with extended tests

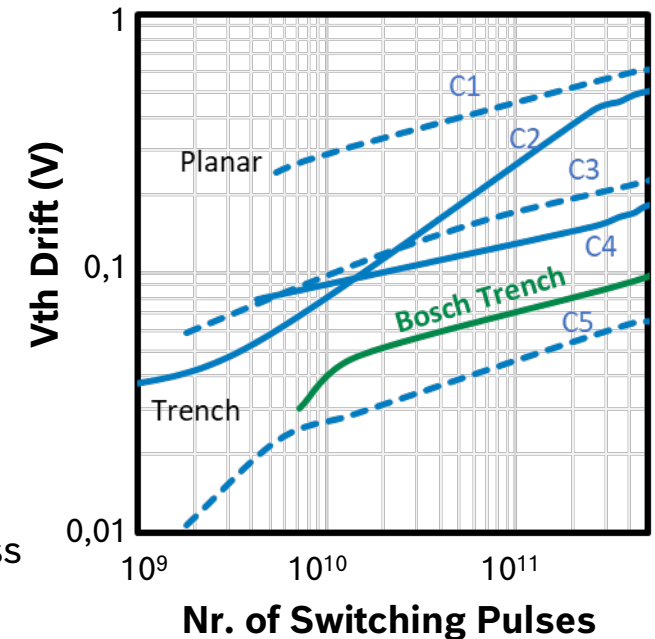
- Static Tests performed with extended stress and 3x longer than industry standard (AEC-Q101)

- HTGB (High Temp. Gate Bias)
 - max gate voltage for 2500h @ 175°C and 100h @ 200°C, finalized with extended gate voltage for 24h @ 175°
 - **Result** : less than 12% drift
- HTRB (High Temp. Reverse Bias)
 - 1200V , -5-5V 2500h @ 175°C and 110h @ 200°C, followed by 1350V, -5,5V during 24h @ 175°
 - **Result**: Less than 10%

Continuous temperature to be increased to 185°C

- Dynamic tests demonstrate stability under extreme conditions

- Scope of tests covers highest stress factors, switching transients in the range of 10^{11} (traction inverter) up to 10^{14} (board net converter)
- **Dynamic H³TRB** at 80% of $V_{DS,max}$ for 1000h @ 85°C/85RH, $f = 15\text{kHz}$ with voltage overshoot $> 80\%$ of $V_{DS,max}$
- **Extreme dv/dt** (up to 300V/ns) demonstrated without issues thanks to robust edge termination
- **Dynamic Gate Stress** Test show one the lowest drifts in the industry
- **HTFB** to ensure device robustness against bipolar degradation



Robust SiC MOSFET Devices for Drive Train Applications

High avalanche capability for robust overvoltage ruggedness

- **Key parameter for robust design**

Avalanche capability ensures fault-free operation if voltage rating is exceeded depending on design margin or due to abnormal transients

- **Avalanche Capability**

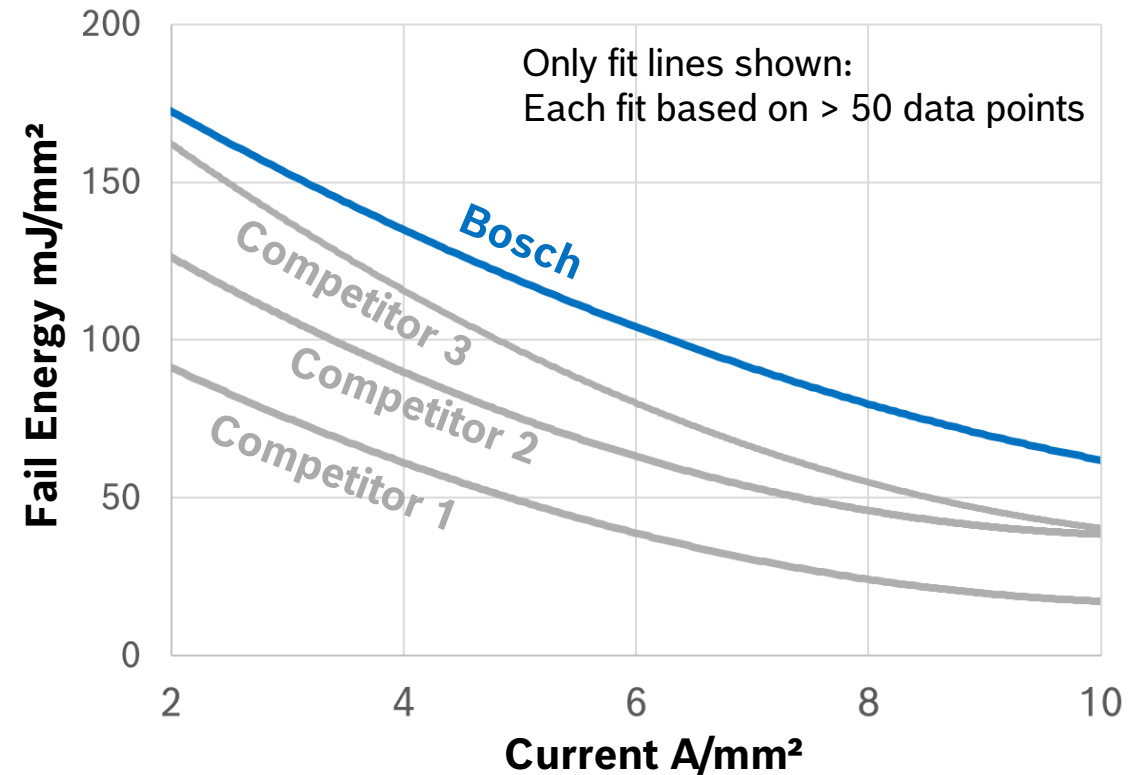
All Bosch SiC devices in all voltage classes have intrinsic avalanche capability through targeted design

- **Comparison**

Bosch SiC devices sustain higher energies in comparison to competitor devices

- **Avalanche Rating**

Currently not specified in data sheet for bare dies
→ Activity on-going to include avalanche rating

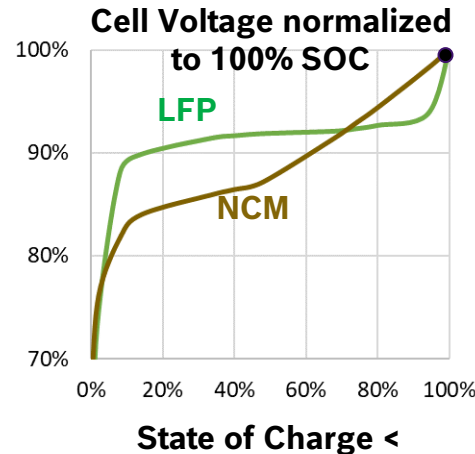
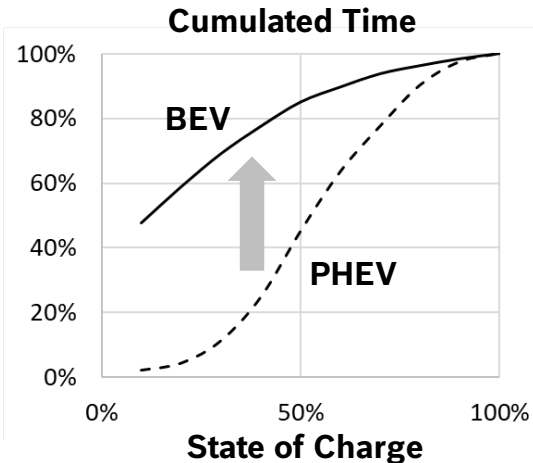


Competitor 1: Trench
Competitor 2 and 3: Planar

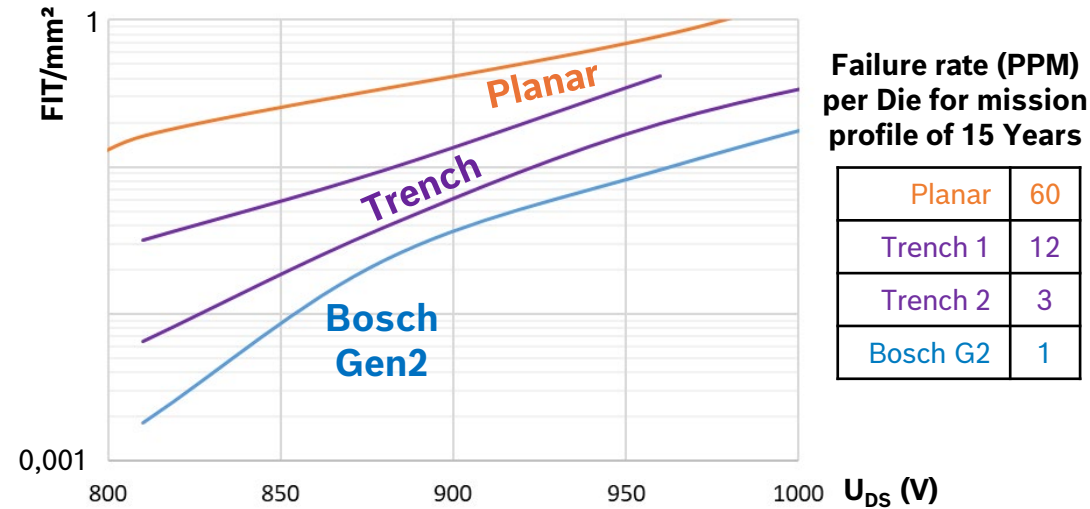
Robust SiC MOSFET Devices for Drive Train Applications

Cosmic Ray

- BEV often operate with almost fully-charged batteries, with higher voltages being more common
- Trend towards LFP cells (stable voltage), longer range (larger batteries) and fast charging (higher system voltage) will further increase amplitude of voltage stress



- Higher voltage increases failure-rate due to cosmic ray induced single event burnout (SEB)
- Bosch Gen2 is one of the most robust devices, with 65% lower failure rate than next best competitor



Outstanding robustness against cosmic ray induced failures for future-proof high-voltage concepts

Robust SiC MOSFET Devices for Drive Train Applications

Summary

- Bosch's SiC MOSFETs have a robust gate oxide
- Bosch's SiC MOSFETs pass qualification tests beyond industry standard
- Bosch's SiC MOSFETs exhibit a high avalanche capability
- Bosch's SiC MOSFETs have a high robustness against cosmic radiation induced failures

Bosch's SiC MOSFETs offer a high robustness designed for reliable operation in automotive applications

Thank You!



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SACHSEN



Bayerisches Staatsministerium für
Wirtschaft, Landesentwicklung und Energie

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