pcim ASIA

Fusion switch concept addresses the cost-performance dilemma in EV powertrains

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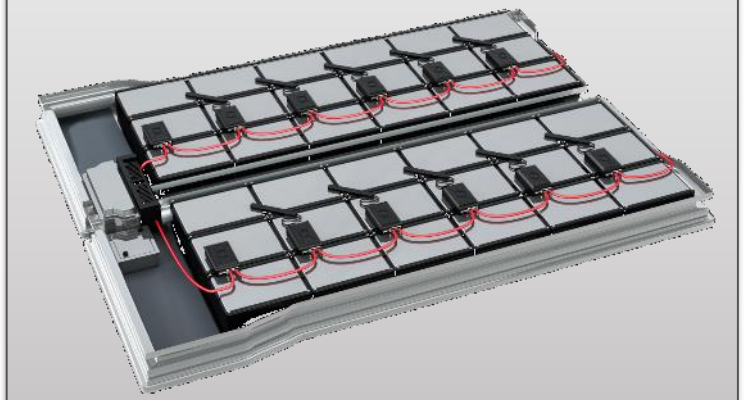
Motivation
The Cost-Performance Dilemma in EV powertrains

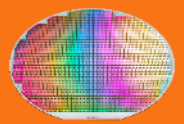
Cost *qualitative*
(not to scale)

Todays Cost Line

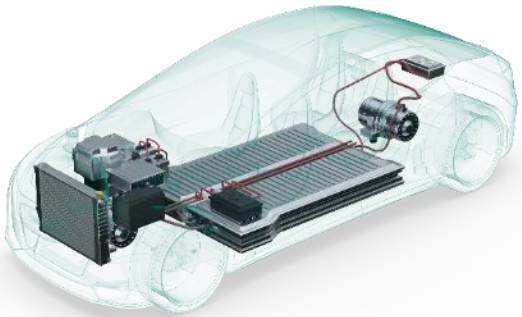
Battery Cost



SiC MOSFET power module



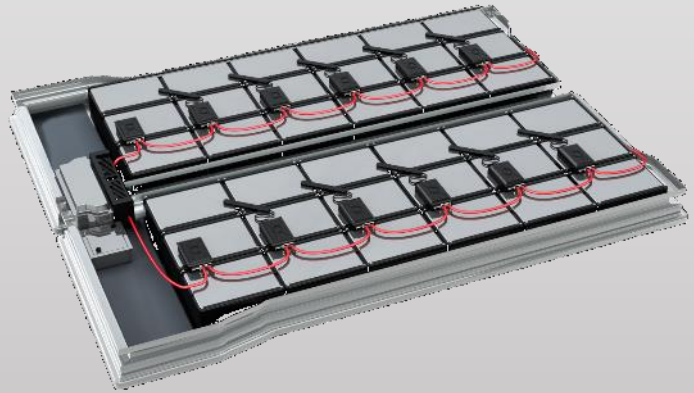
Electric Vehicles 470V
Compact to SUV class

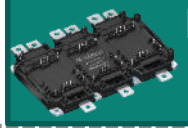


Driving Range 150 .. 600 km

Lower power module cost & performance has to be paid by additional battery cost!

Battery Cost



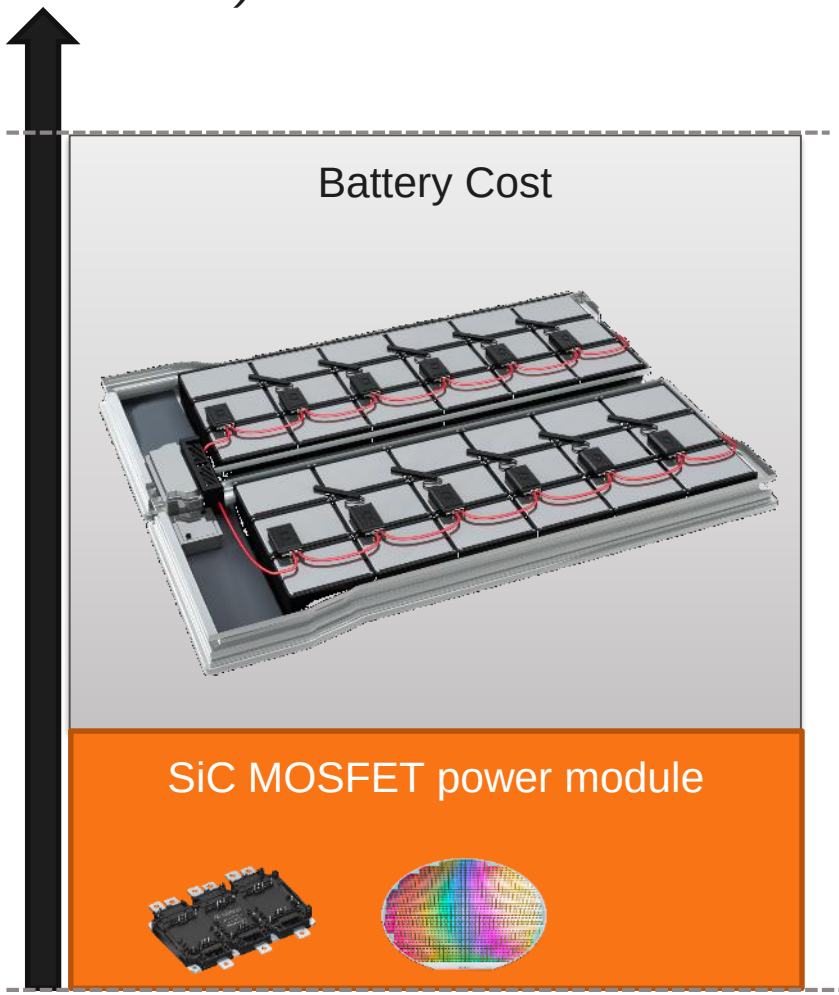


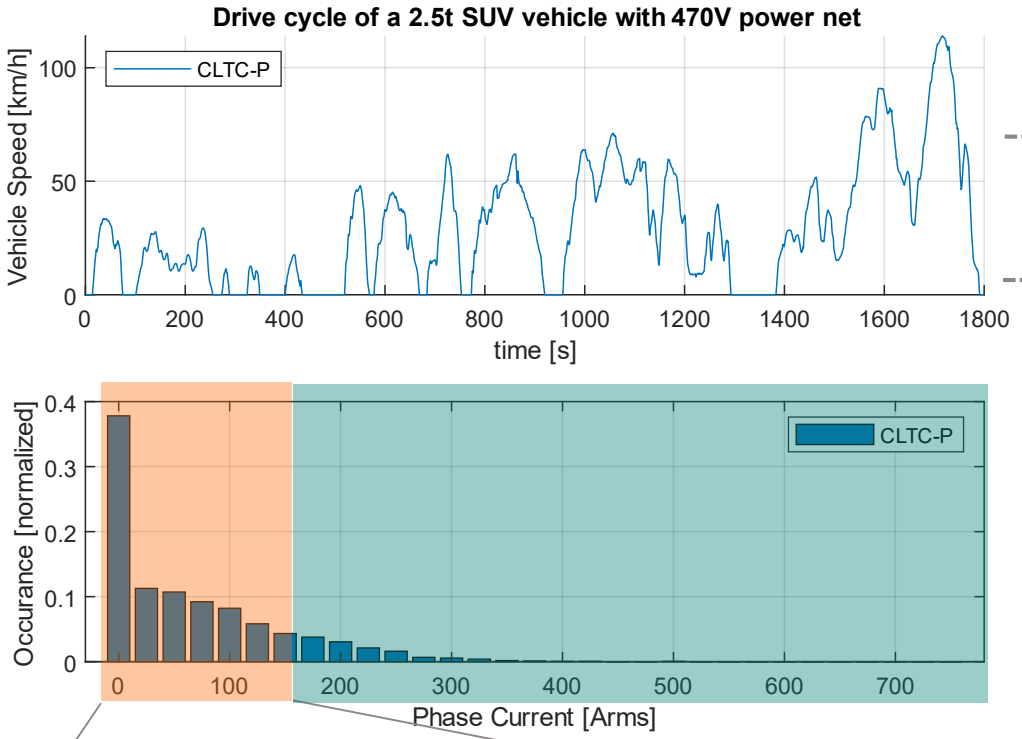
IGBT power module

Motivation
Fusion Concept to address cost savings at high efficiency

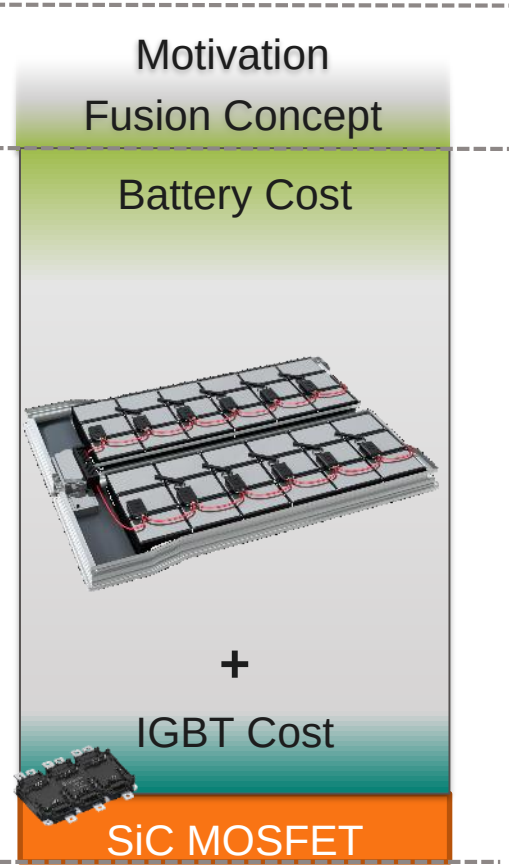
Cost *qualitative*

(not to scale)

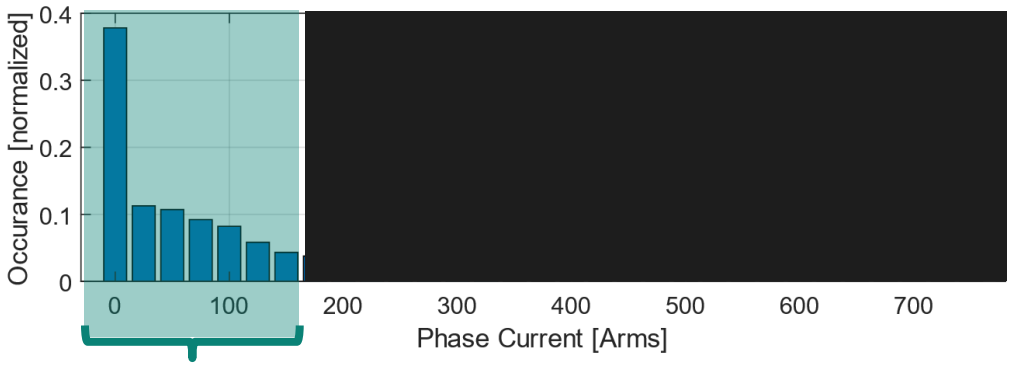


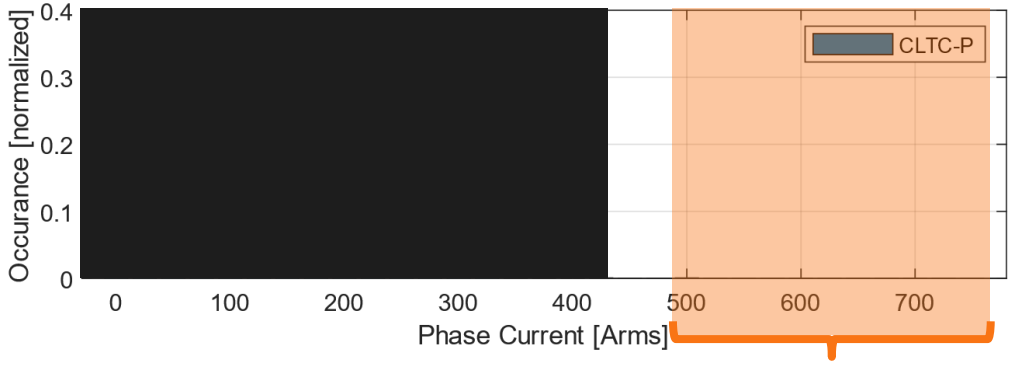


Only 30% of SiC chip content needed to drive the common operating conditions.

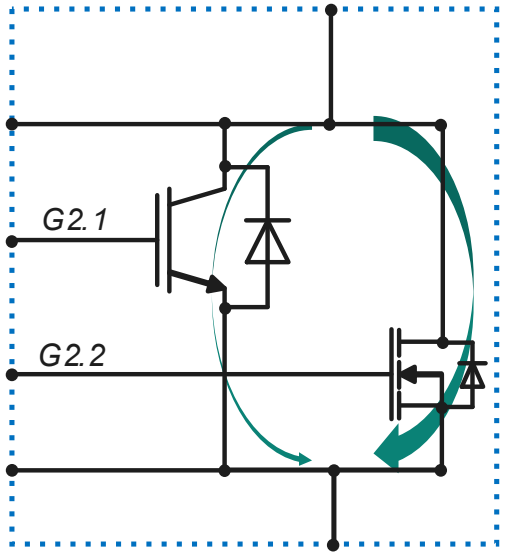


Fusion Switch Concept
Requirements for Current Sharing



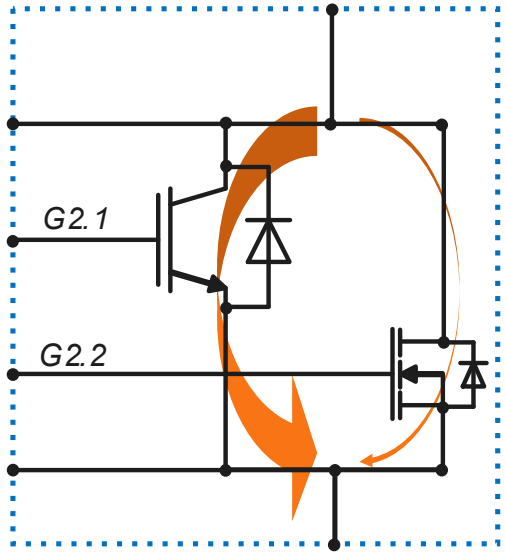


Light Load



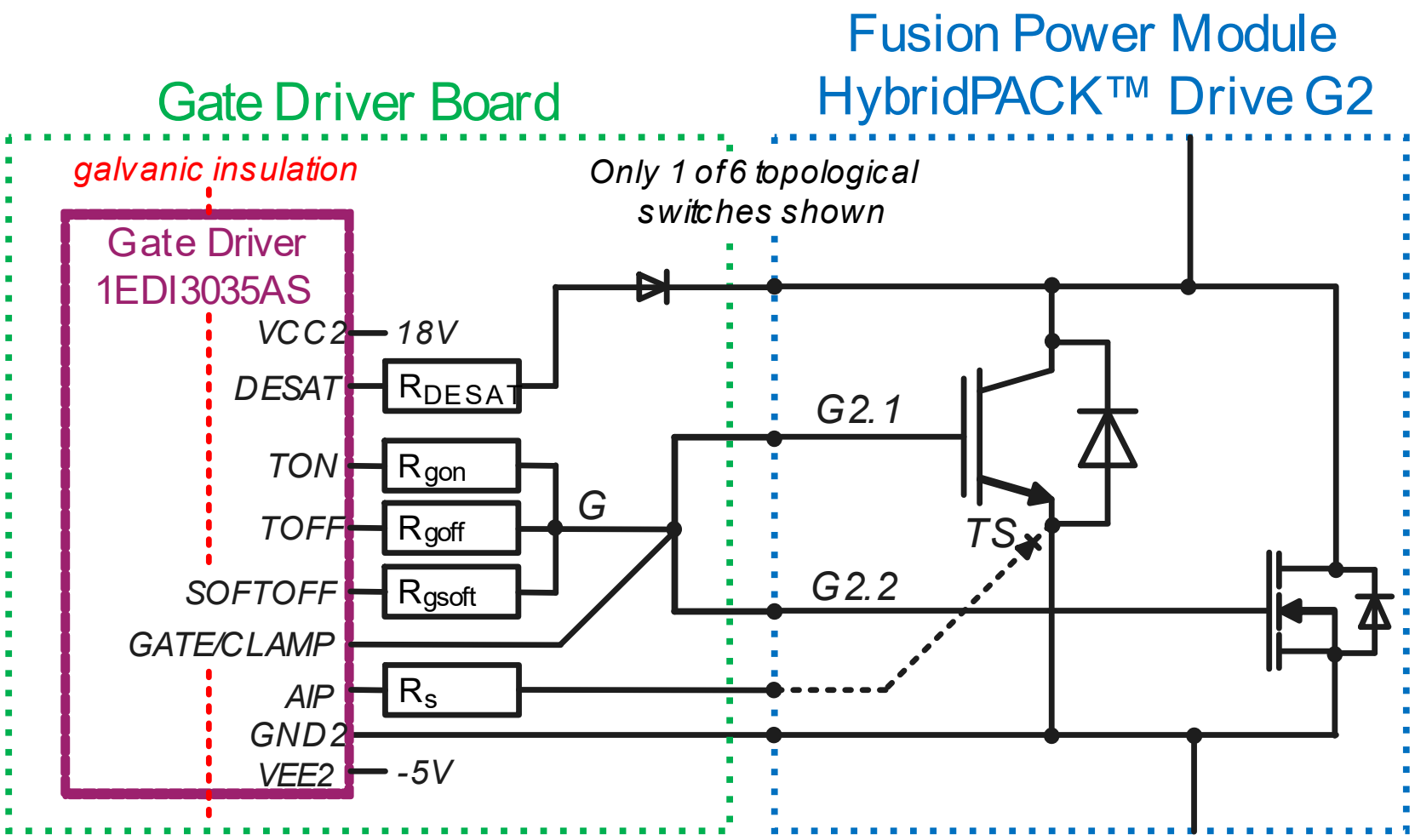
Boundary Condition:
A complex control is not intended in high volume automotive applications!

Full Load



Driving the full current via the small SiC MOSFET area can lead to failure!

Fusion Switch with Single Gate Drive
Makes it ready for high volume automotive applications

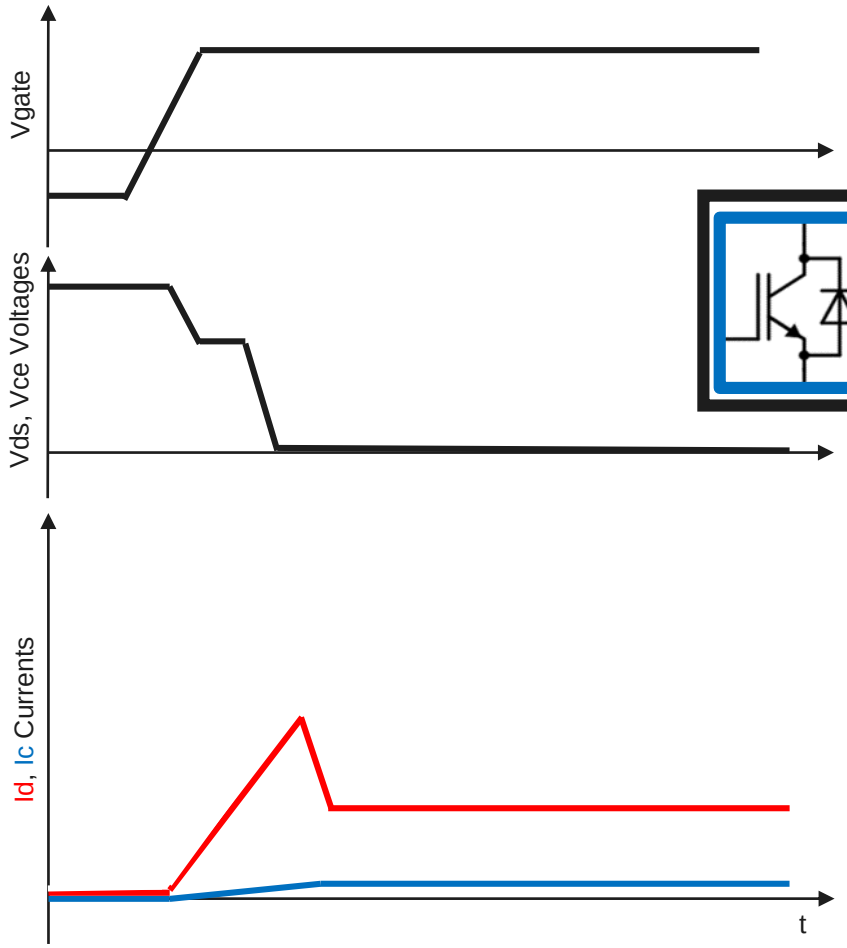


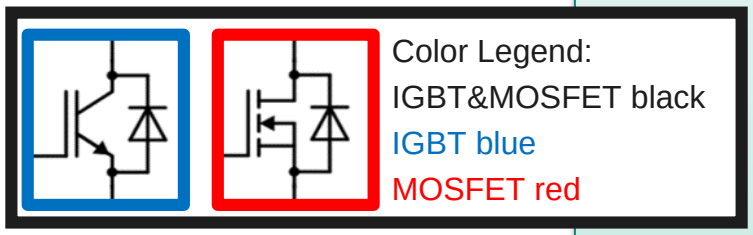
The Fusion switch concept is motivated by using a standard single gate drive.

The IGBT | Diode | SiC MOSFET characteristics and power module layout has to support the required current sharing task.

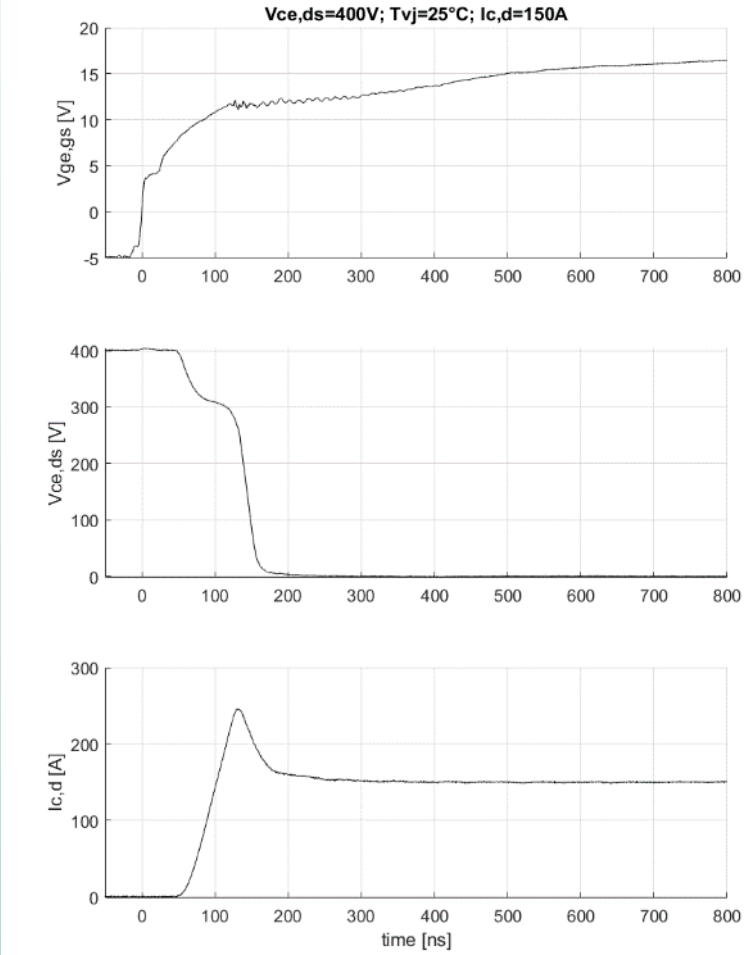
Fusion Switch with Single Gate Drive
Turn-on at light load

Basic Principle (simplified)



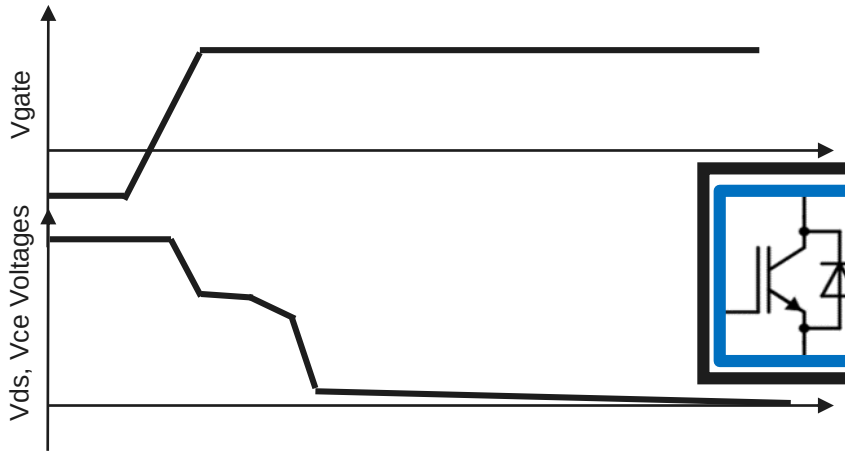


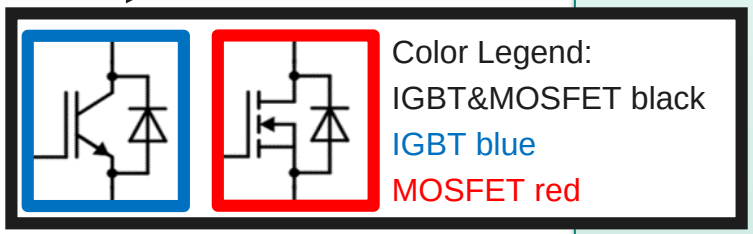
Measured

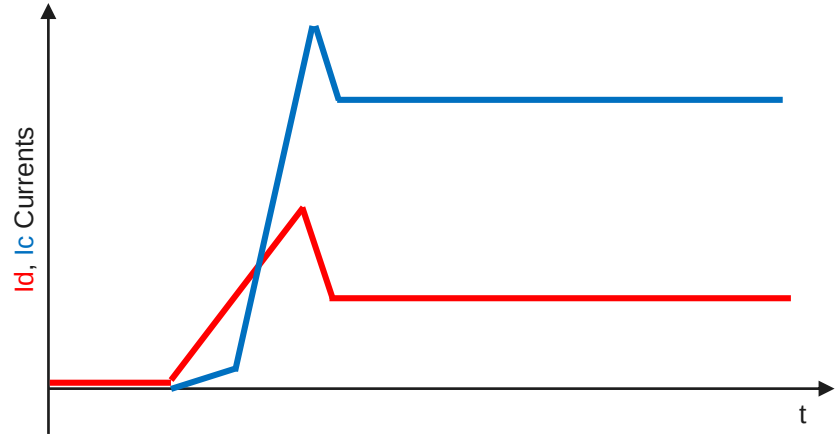


Fusion Switch with Single Gate Drive
Turn-on at full load

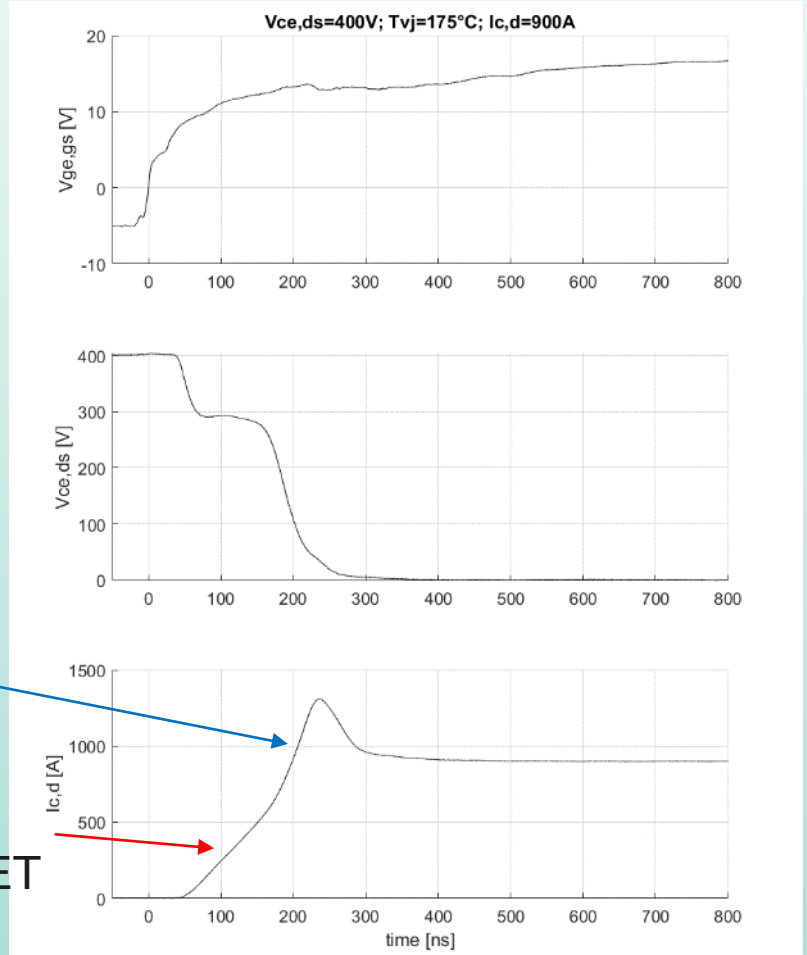
Basic Principle (simplified)



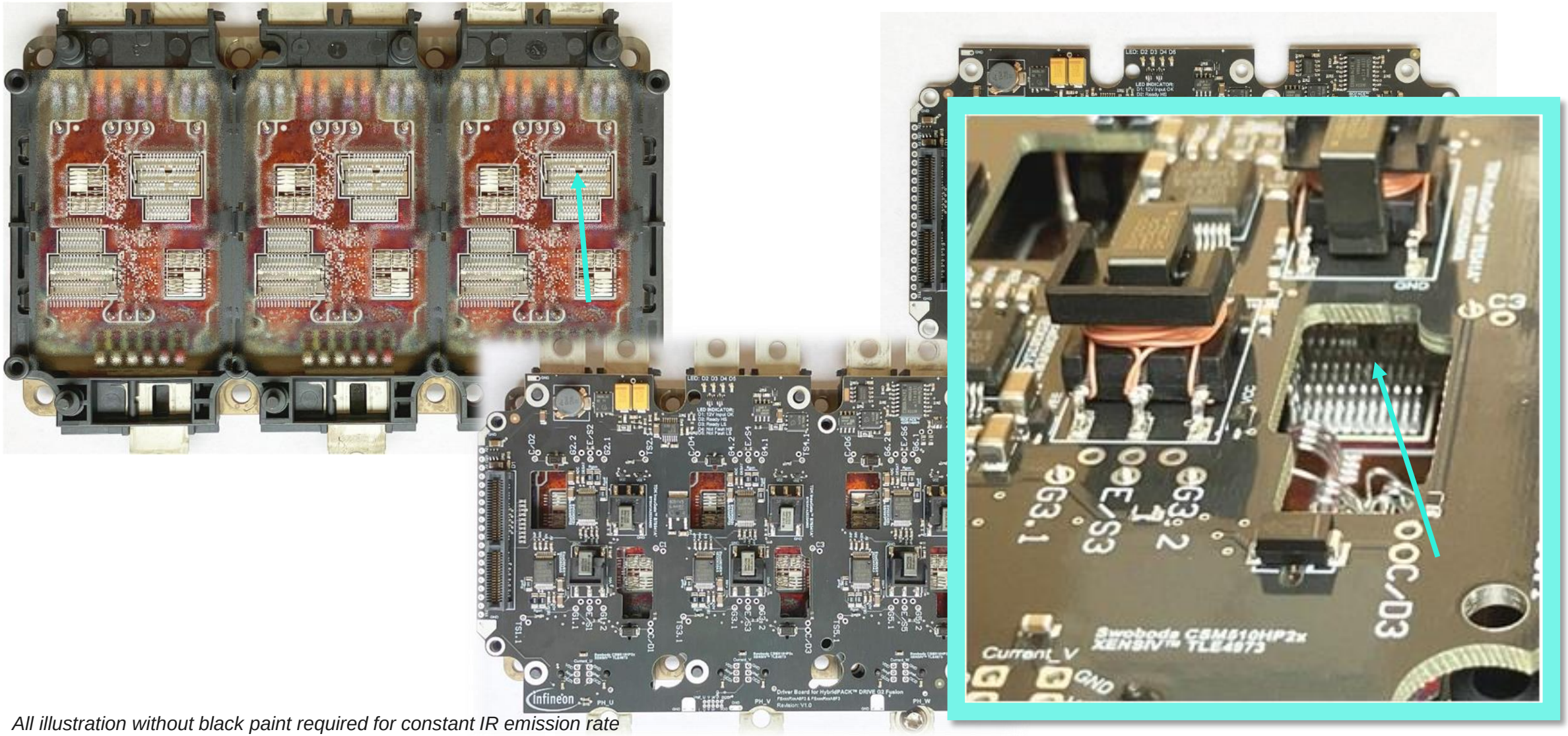




Measured



Fusion Switch Concept Thermal Testing
Setup for Thermal IR Testing during Inverter Operation

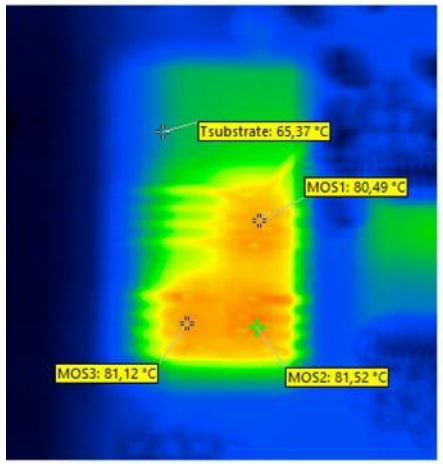


All illustration without black paint required for constant IR emission rate

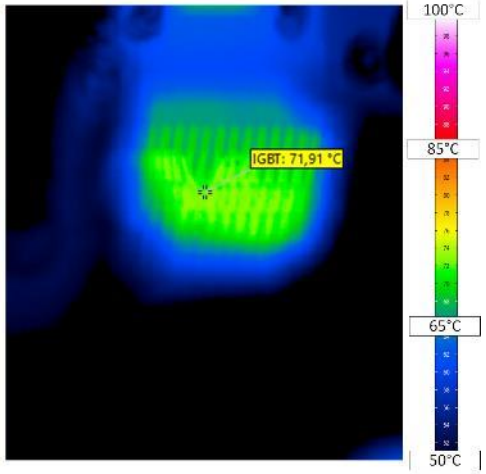
Fusion Switch Concept Thermal Testing
Inverter Thermal IR Testing @400V, 10kHz and 65°C coolant fluid

150 Arms

SIC MOSFET

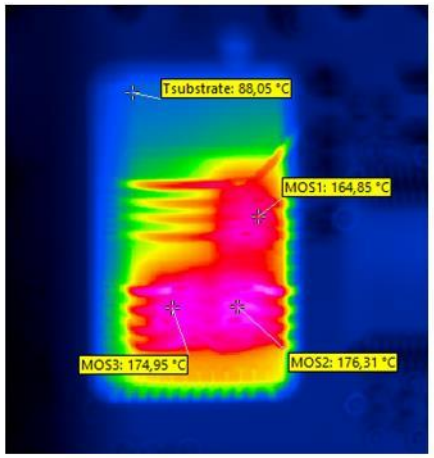


IGBT

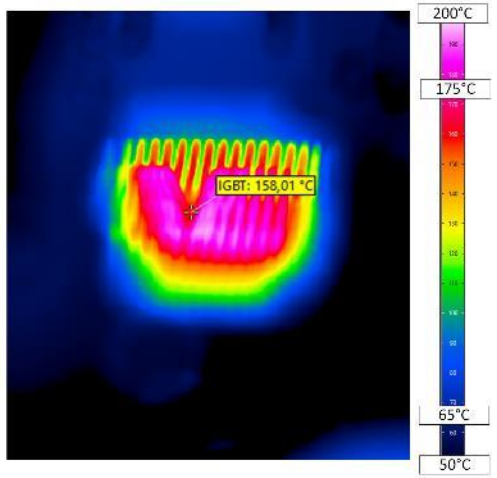


725 Arms

SIC MOSFET

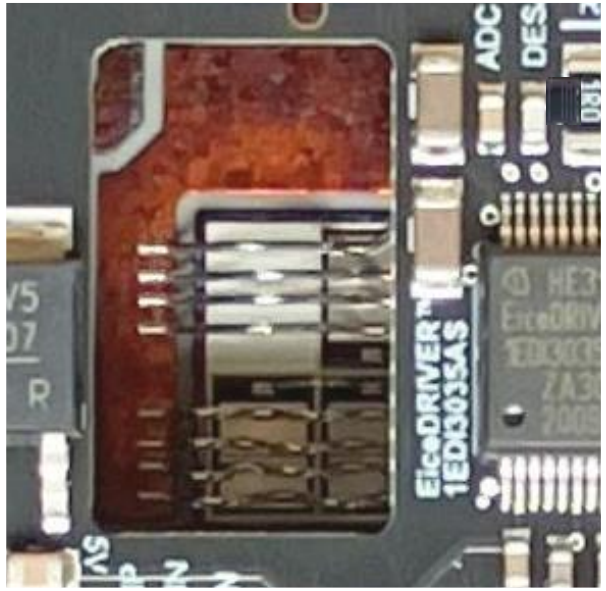


IGBT



Real View

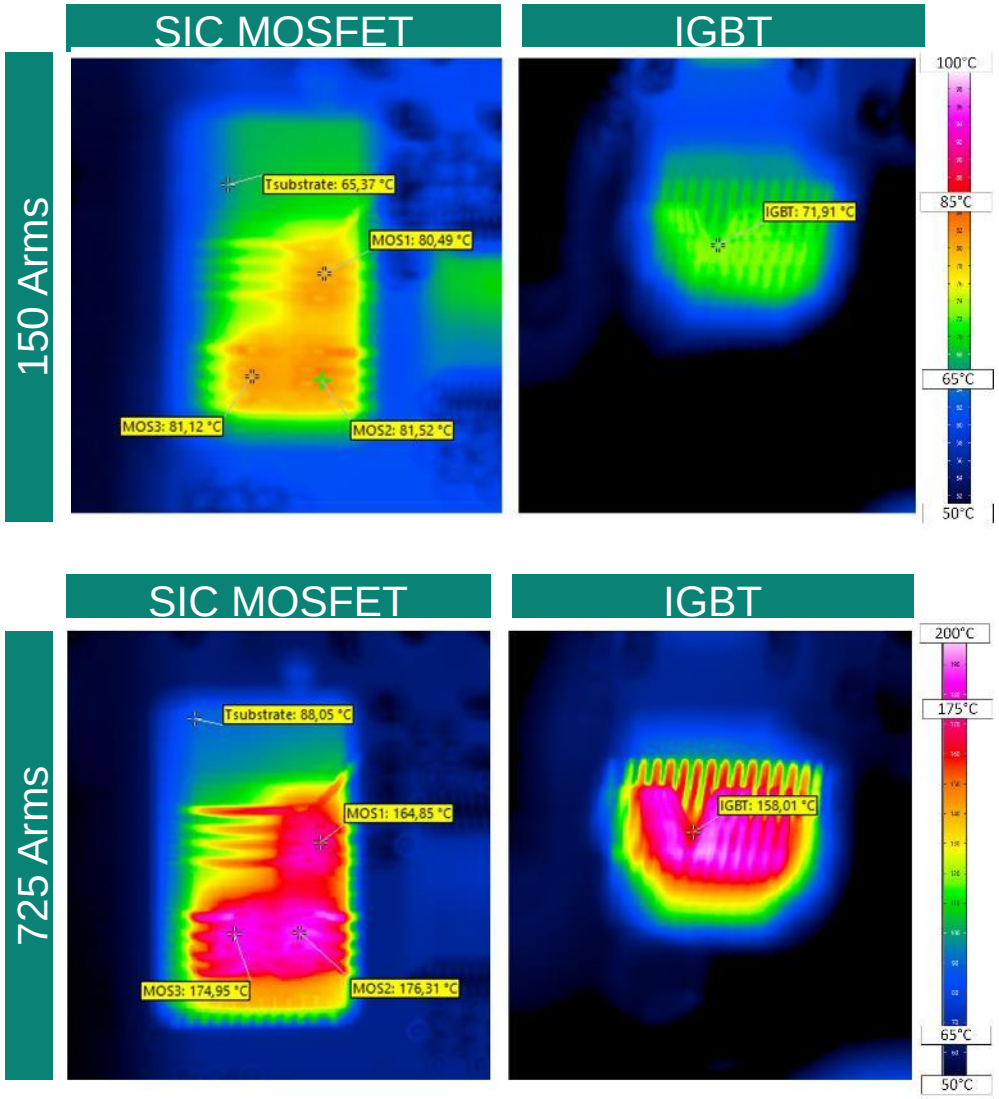
SIC MOSFET

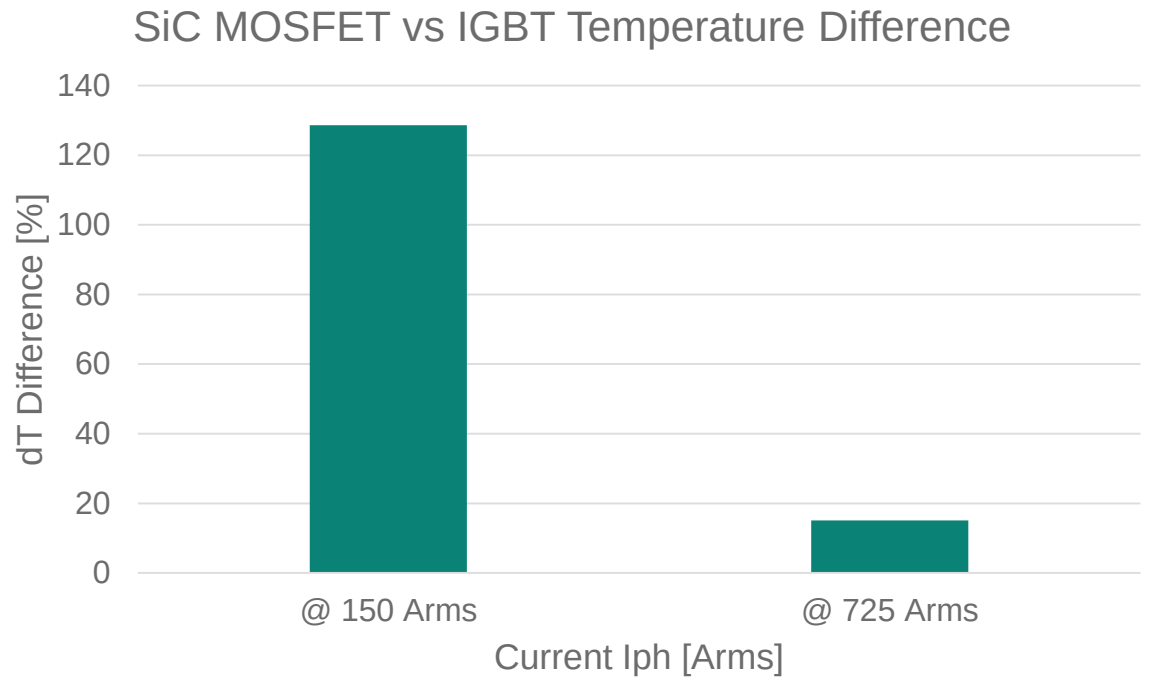


IGBT

Illustration real view without black paint required for constant IR emission rate

Fusion Switch Concept Thermal Testing
Inverter Thermal IR Testing @400V, 10kHz and 65°C coolant fluid



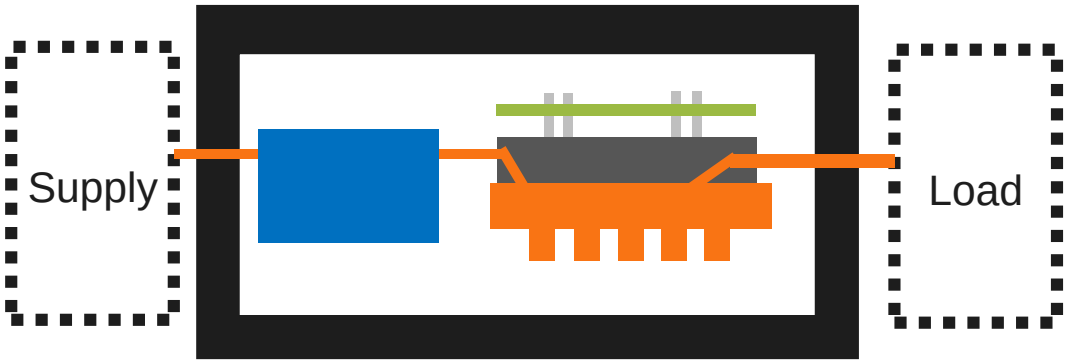


The SiC MOSFET mainly drives the light load currents.

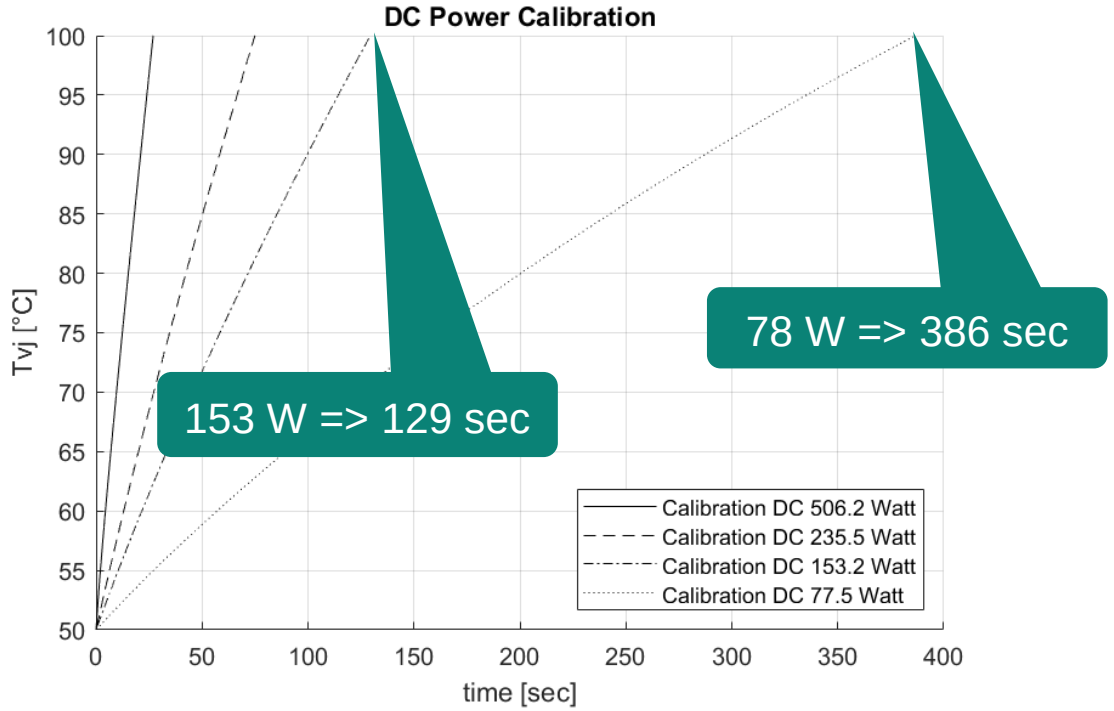
The full load currents are shared on SiC MOSFET and IGBTs for a balanced thermal/electric stress.

Fusion Switch Concept
Adiabatic Calorimeter Testing

Complete Inverter in thermally insulated package!



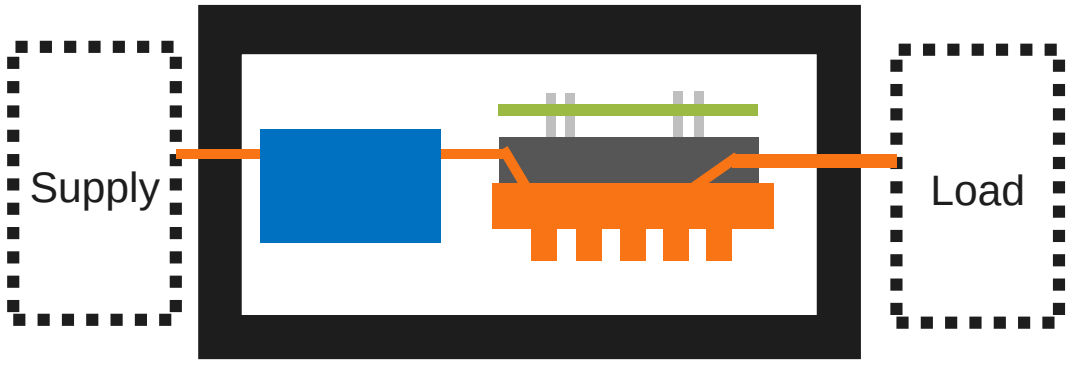
1st Step Calibration:
Supply with DC Power and measure temperature rise within this thermal isolated package.



More detailed information: A. Pai, T. Reiter, O. Vodyakho, M. Maerz, "Mission Profile Analysis of a SiC Hybrid Module for Automotive Traction Inverters and its Experimental Powerloss Validation with Electrical and Calorimetric Methods" in Advances in Science, Technology and Engineering Systems Journal Vol. 3, No. 1, 329- 341, 2018.

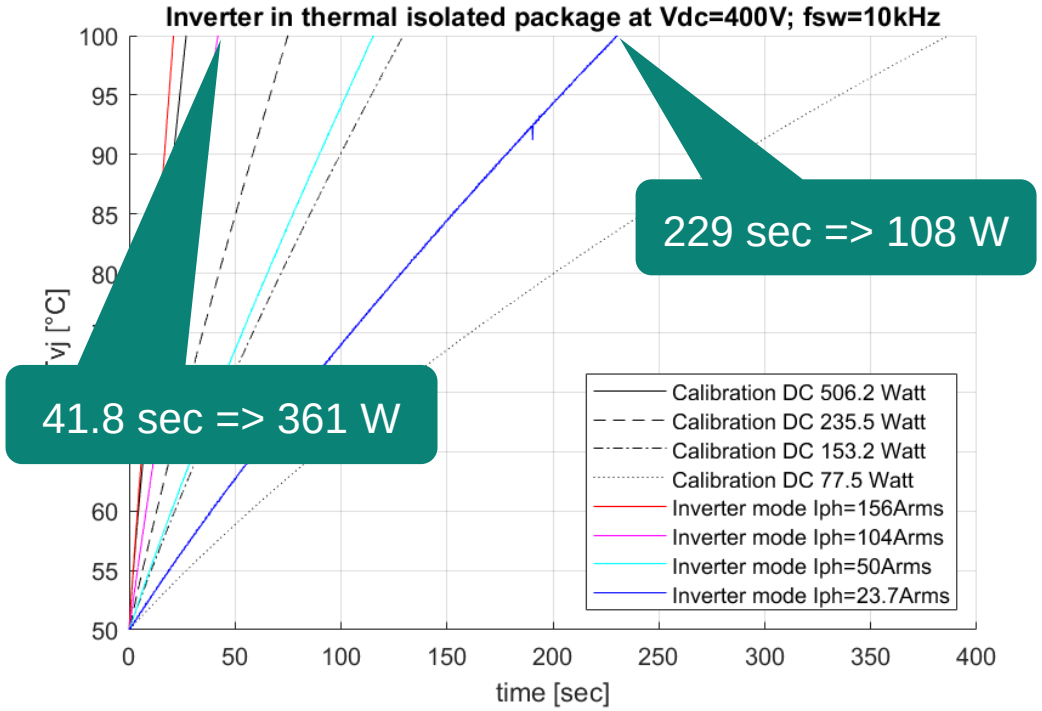
Fusion Switch Concept
Adiabatic Calorimeter Testing

Complete Inverter in thermally insulated package!



2nd Step Inverter Operation:

3rd Step Correlation of Power Losses



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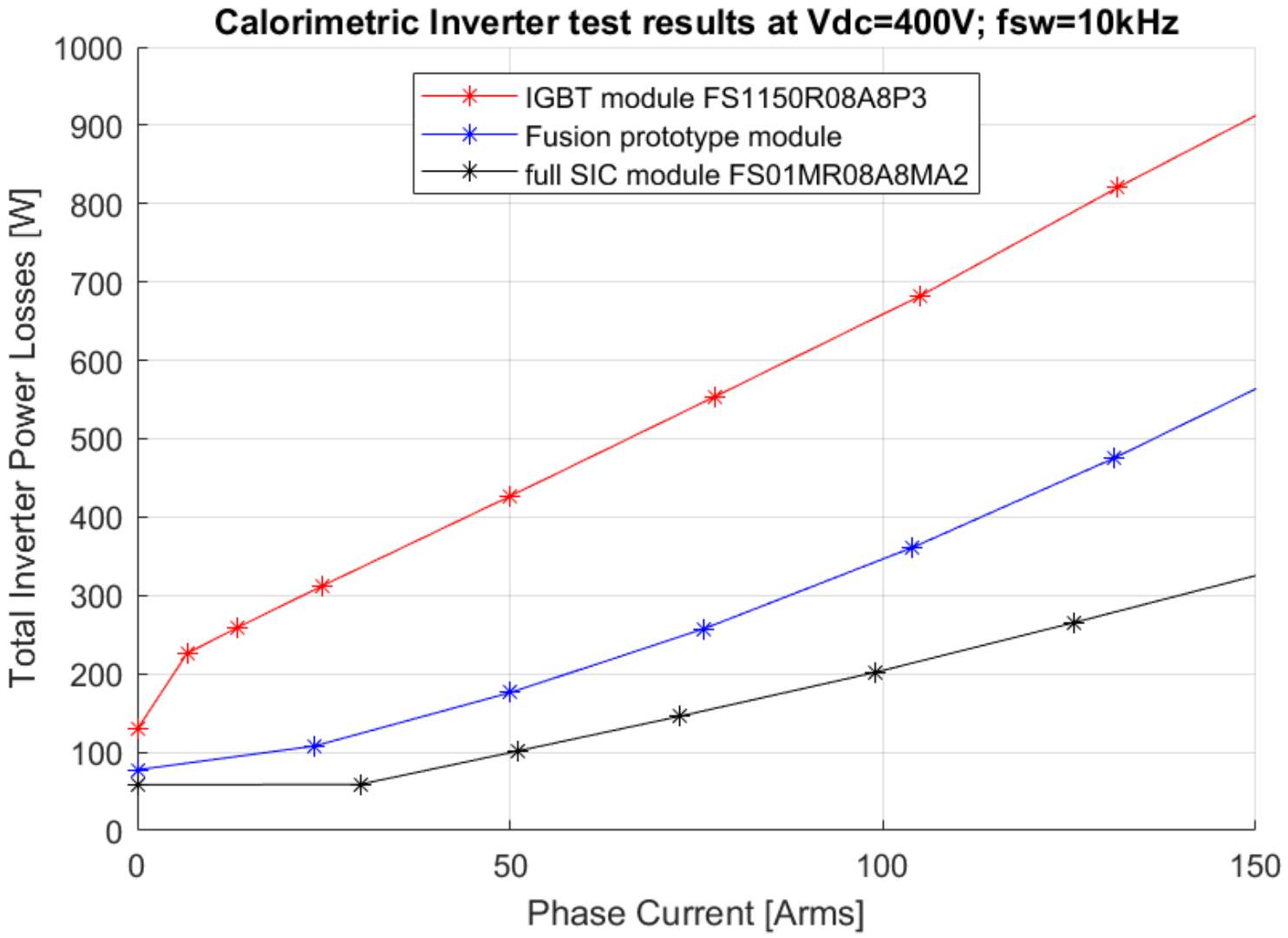
Fusion Switch Concept
Power Loss Comparison



With just 30% of SiC MOSFET die content we achieve more than 70% of the efficiency gain of a Full SiC MOSFET power module.

Nomenclature:

$$\text{"Efficiency Gain"} = \frac{P_{\text{loss,Fusion}} - P_{\text{loss,IGBT}}}{P_{\text{loss,SiC}} - P_{\text{loss,IGBT}}}$$

Fusion Switch Concept
Summary & Conclusion

- **Fusion switch adresses the „Cost/Performance Dilemma“ in EV powertrains.**
  Just 30% of SiC MOSFET area lead to more than 70% of the efficiency gain of a full SiC MOSFET module.

- **Fusion switch can be designed for a simple „Single Gate Drive“.**
  The SiC MOSFETs, IGBTs as well as the power module layout can provide the required current sharing.
  This reduces customer design efforts and risk.

- **The switching slopes are extremely fast & smooth.**
  The IGBT/Diodes provide an active „snubber“ effect for the SiC MOSFET chips.
  Switching overshoots and oscillations are damped without compromise on switching efficiency.


Infineon