Soft-Switching for Automotive Traction Inverter Applications

Dr. Ajay Poonjal Pai
Director, Head of WBG Innovation
Sanan Europe GmbH

Bodo's Wide Bandgap Event 2024

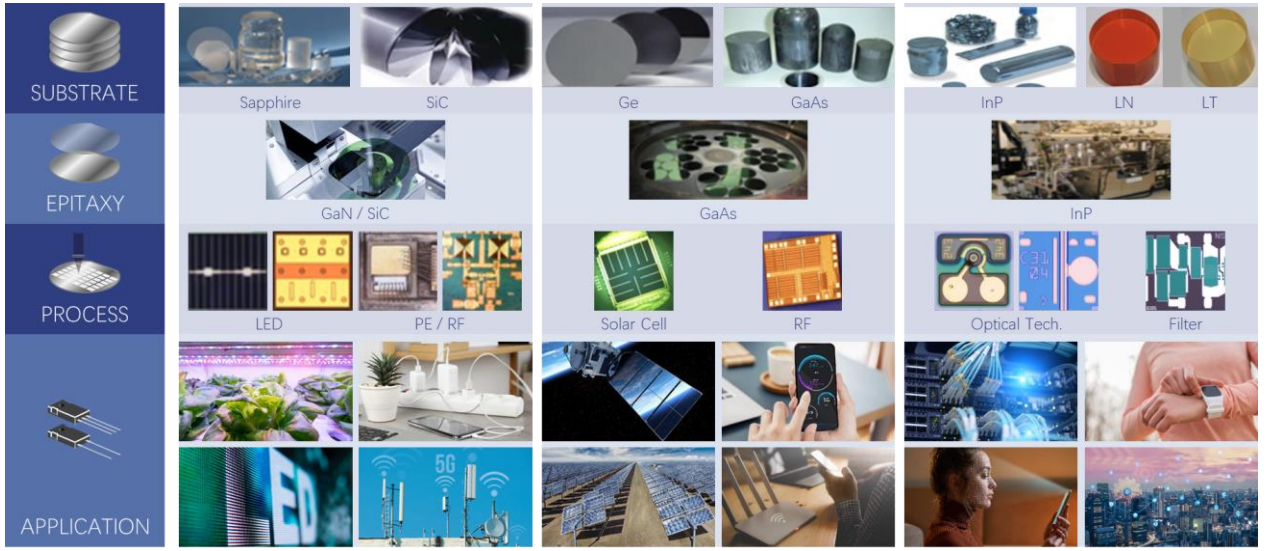
Making WBG Designs Happen

SiC

Committed to be a World-Class Compound Semiconductor R&D and Manufacturing Service Platform

Parent Company: Sanan Optoelectronics (SSE: 600703)

- Established in 2000, Xiamen, China
- ~$ 2B Revenue in 2023
- The largest LED Chip/Epitaxial Wafer Manufacturer in China
- >14,000 Employees
- Scale: >600 MOCVD Reactors
- Capacity: 12M Wafers/Year
- IP Portfolio: >3,000 patents and proprietary processes
- 1st in China as SAW Filter Vertical manufacturer
- Largest shipments in APAC of GaN RF foundry manufacturer
- Largest-scale of in-house developed GaAs wafer foundry manufacturer

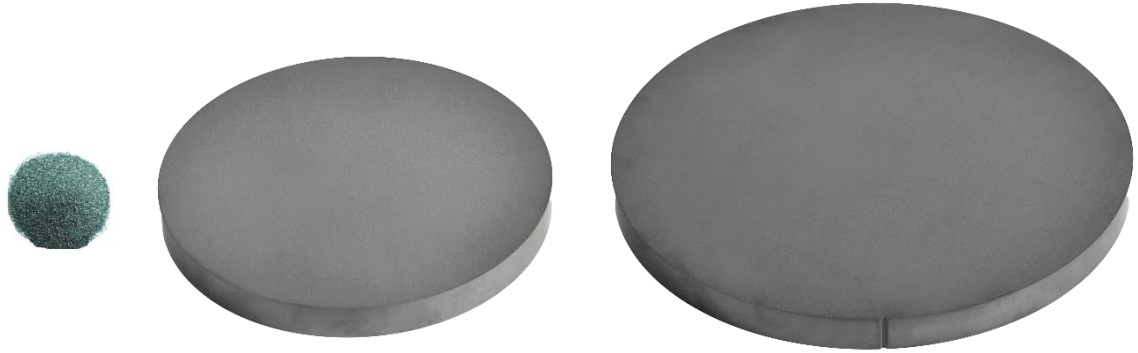


Sanan Semiconductor

- China's First Vertically Integrated SiC manufacturer
- Experience in SiC since 2014
- Mega Factory established in 2020, Changsha, China
- Capacity: ~500k Wafers/Year after ramp up
- IP Portfolio: >700 patents (granted and pending) and proprietary processes
- R&D in China (Xiamen & Changsha), Germany (Munich), Japan (Tokyo)
- 800+ Global Customers and Partners

20+ YEARS IN COMPOUND SEMICONDUCTOR INNOVATION (2000 / 2020)

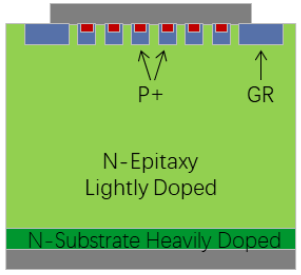
Sanan powers the SiC Revolution with Vertical Integration

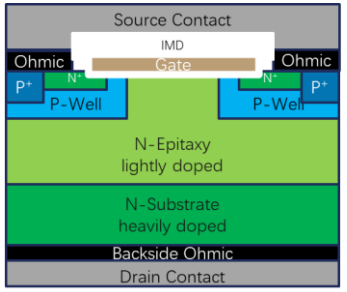


SiC Crystal/Substrate Growth

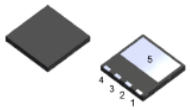
SiC Epi-wafer / Epi –growth

Device Fabrication



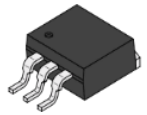


Packaging



DFN

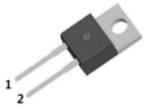
TO-252



TO-263

SOT-277

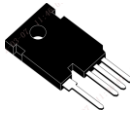
and Customer-specific packages



TO-220

TO-247-2

TO-247-3

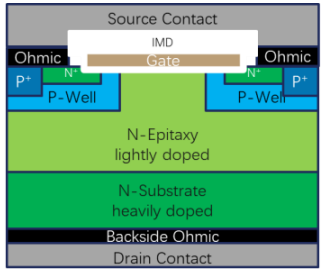


TO-247-4

Due to **Vertical Integration**, Sanan Semiconductor maintains control of the complete supply chain including capacity, cost and qualification of all materials including wafers and devices

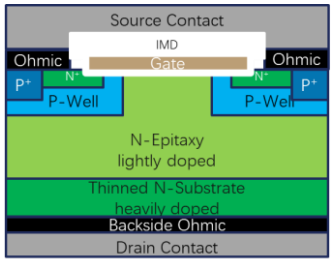
Note: Dimensions Not to scale

SiC MOSFET Technology Development is on track, lead version has been released



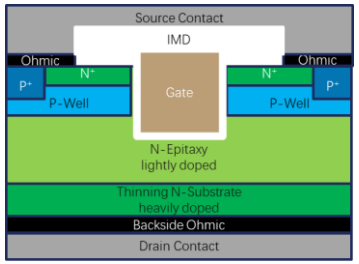
SiC MOSFET Gen1

- Planar structure
- Driving voltage (-5V ~ +20V)
- JEDEC standard



SiC MOSFET Gen2

- Planar structure
- Driving voltage (-5V ~ +15/18V)
- Chip thinning
- AEC Q101 standard



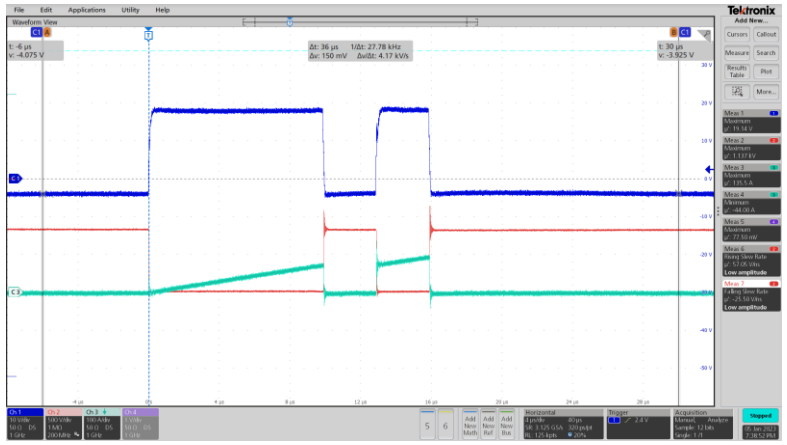
SiC MOSFET Concept

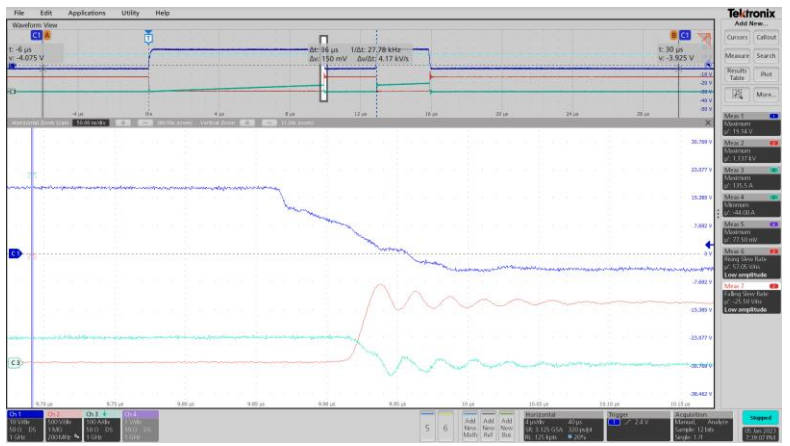
- Trench structure
- Chip thinning
- AEC Q101 standard

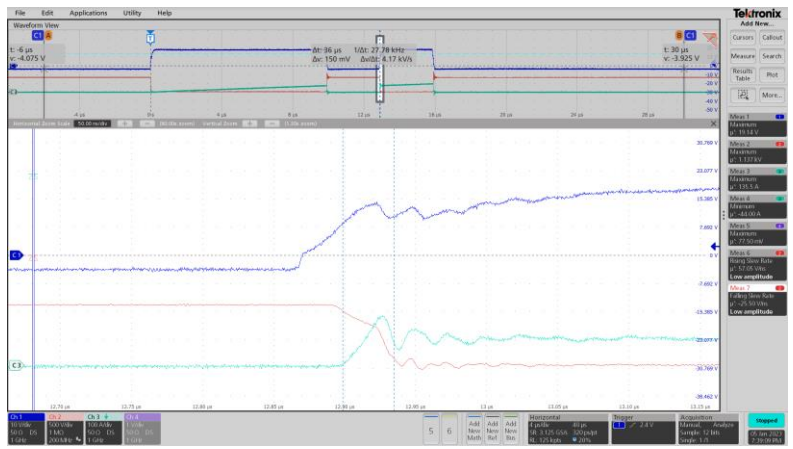
SiC MOSFET

- Voltage Classes: 650V, 1200V, 1700V and 2kV
- Rdson Classes: 13-1000 mΩ
- JEDEC and Automotive Qualified
- Packages: Bare Die, TO247, TO263

DPT Measurement of 1200V 16mΩ SiC Mosfet. Condition: Vdc=800V, Vgs=+18V/-4V, Id=75A, Ron/Roff=4.3Ω, 25℃

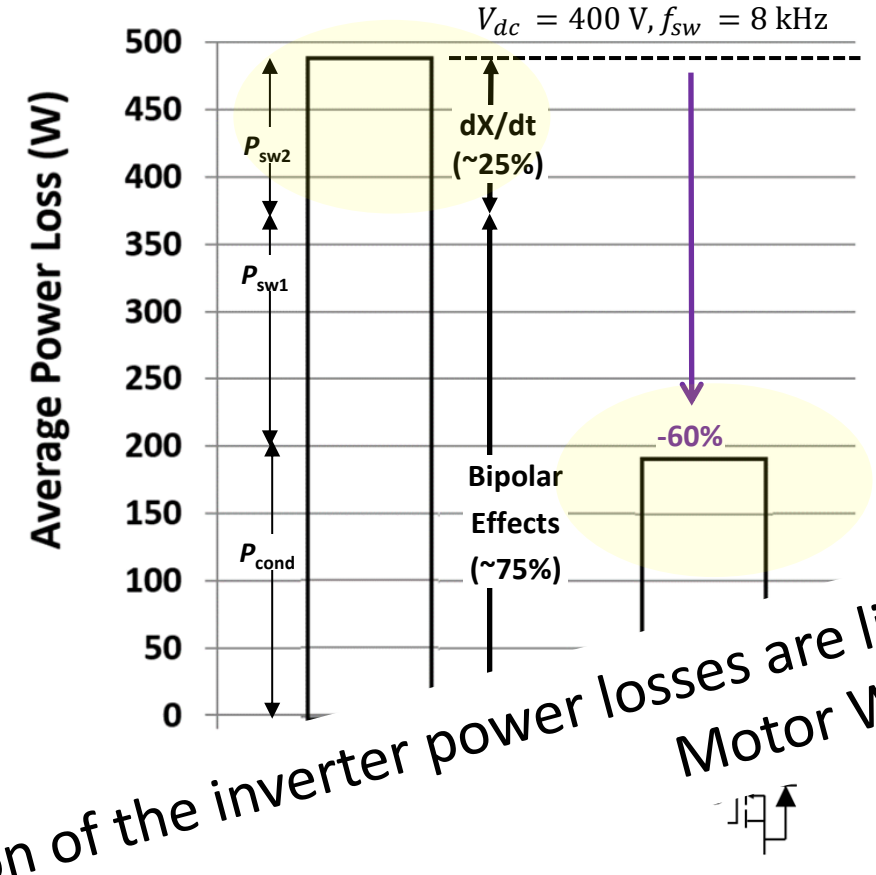


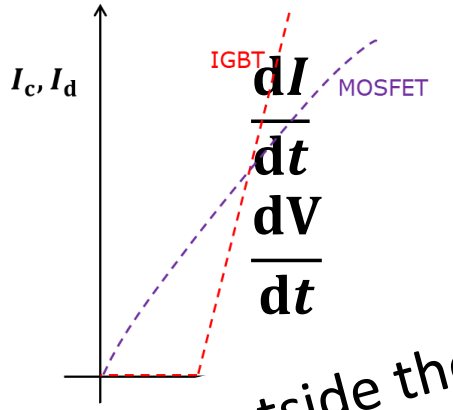




Note: Dimensions Not to scale

SiC enables upto 60% reduction in power losses in Automotive Traction Inverters (Artemis Highway Mission Profile)





A big portion of the inverter power losses are limited by the System outside the inverter (e.g., Motor Windings)!

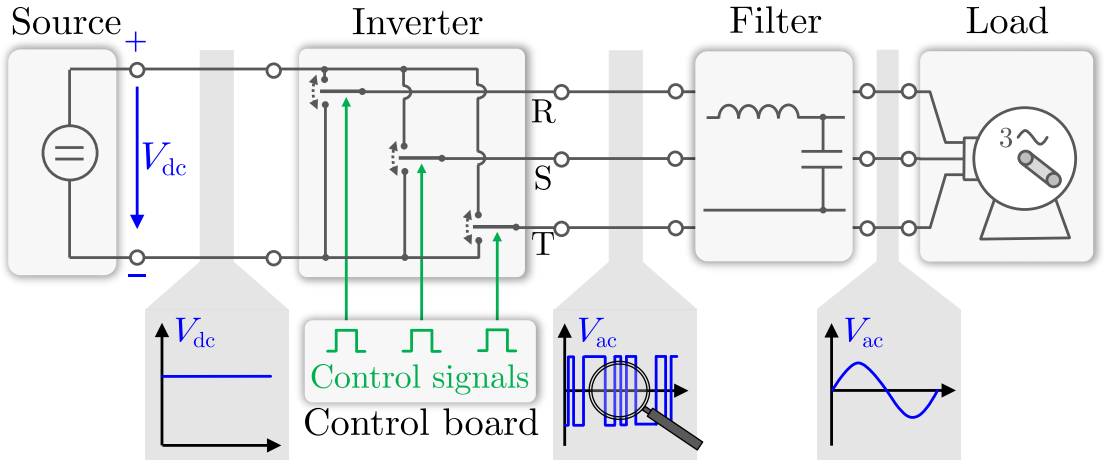
...verter power losses by around 60% compared to IGBT, at similar di/dt, dv/dt

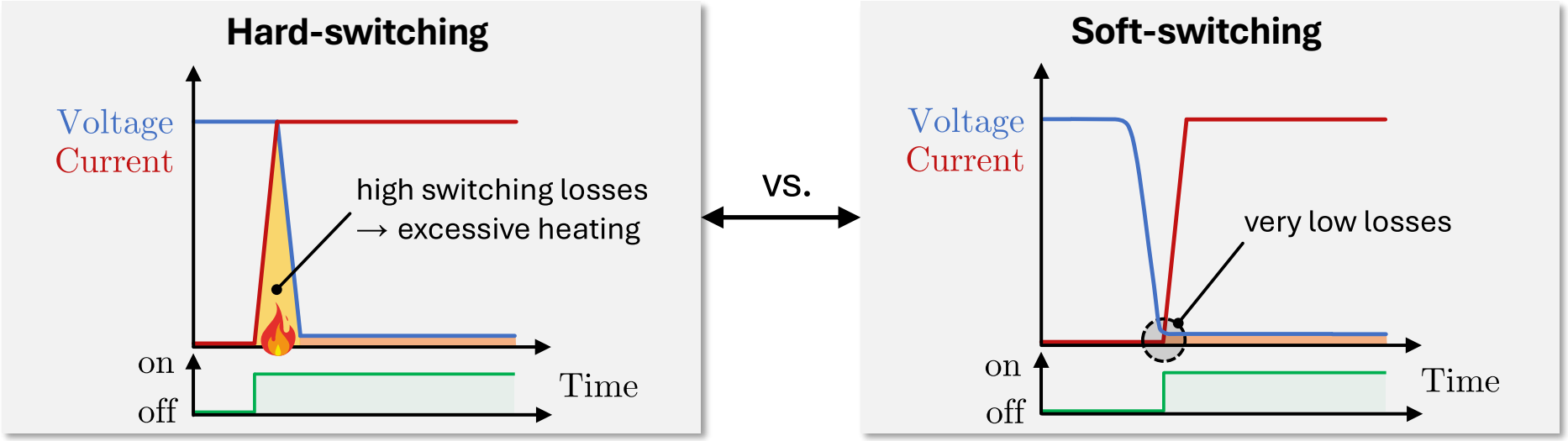
...nts of SiC Mosfets are actually coming due to going from bipolar behaviour to unipolar behaviour

In contradiction to literature, switching speed (di/dt, dv/dt) does not bring down the power losses drastically

Source: A. Pai, PhD Thesis „Impact of SiC based semiconductors on the mission profile efficiency of Automotive traction inverters“

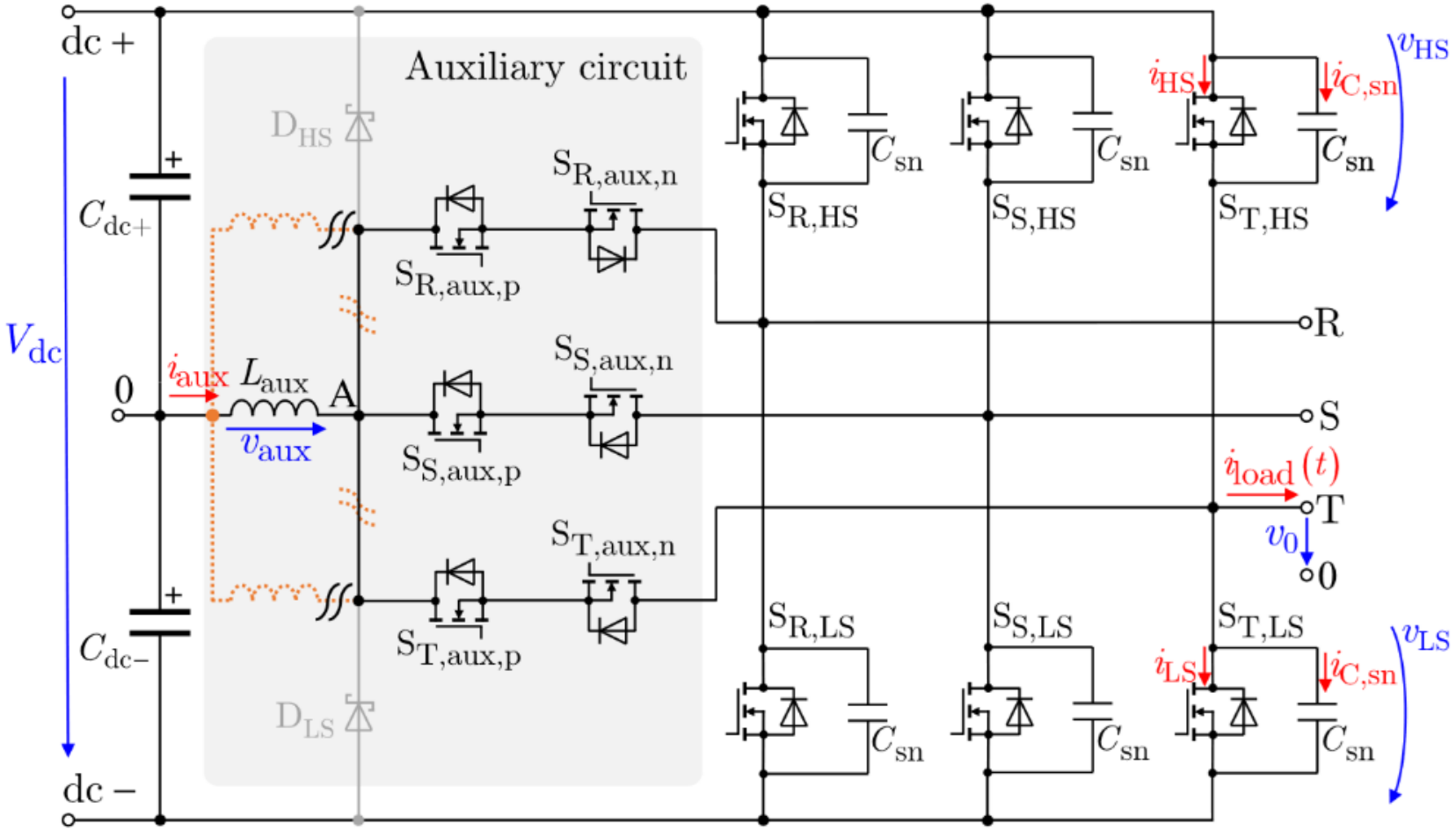
Why should you choose Soft-Switching?





Soft-switching resolves the trade-off between switching speed (dv/dt) and Switching Losses

Soft-switching is Achieved by introducing an Auxiliary branch in a Standard Two Level (B6) Inverter



Conv. ARCP

S²I-ARCP

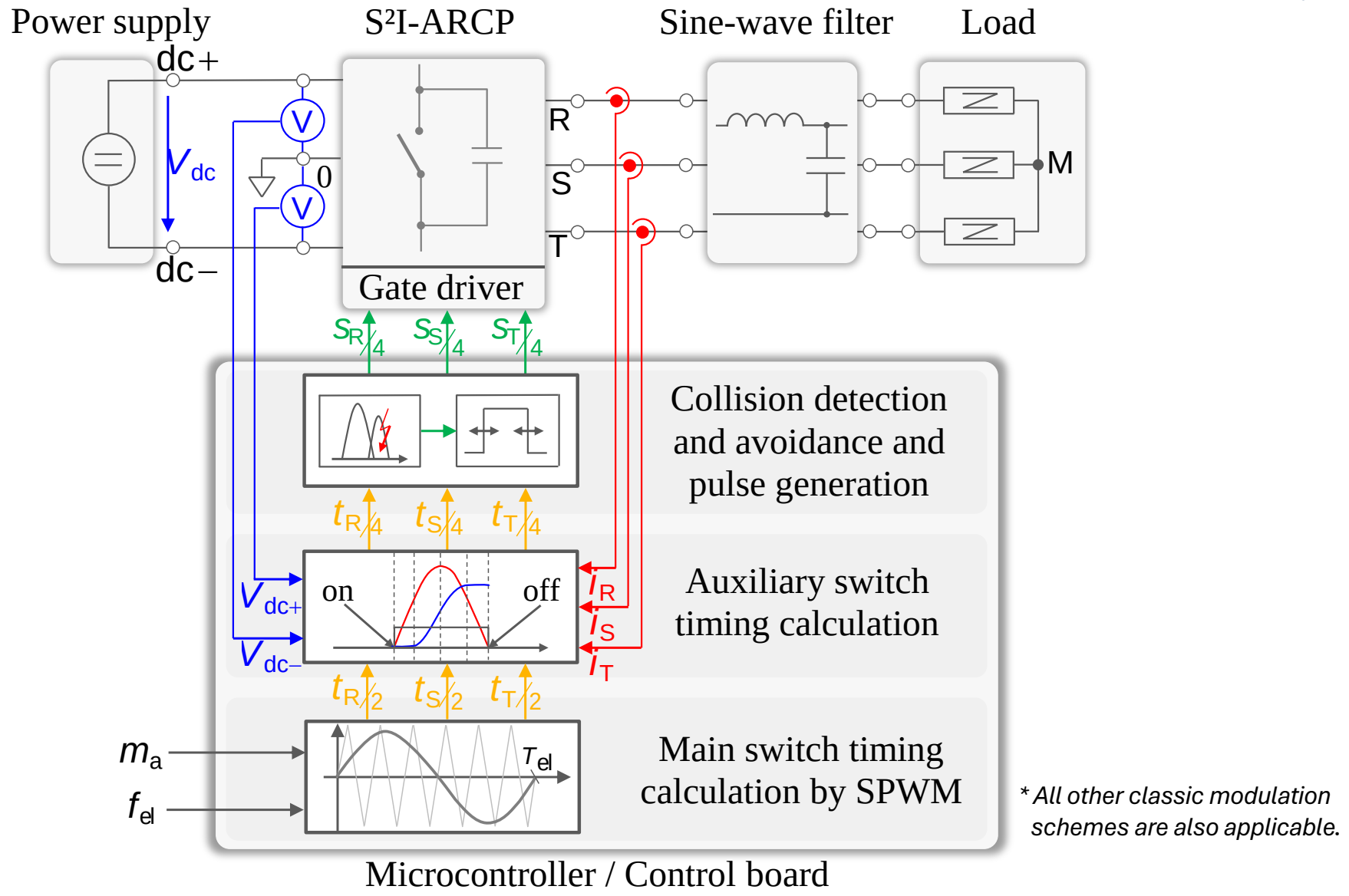
Benefits:

- Savings in size, weight, and material costs
- Better utilization of the shared auxiliary inductor

Challenges:

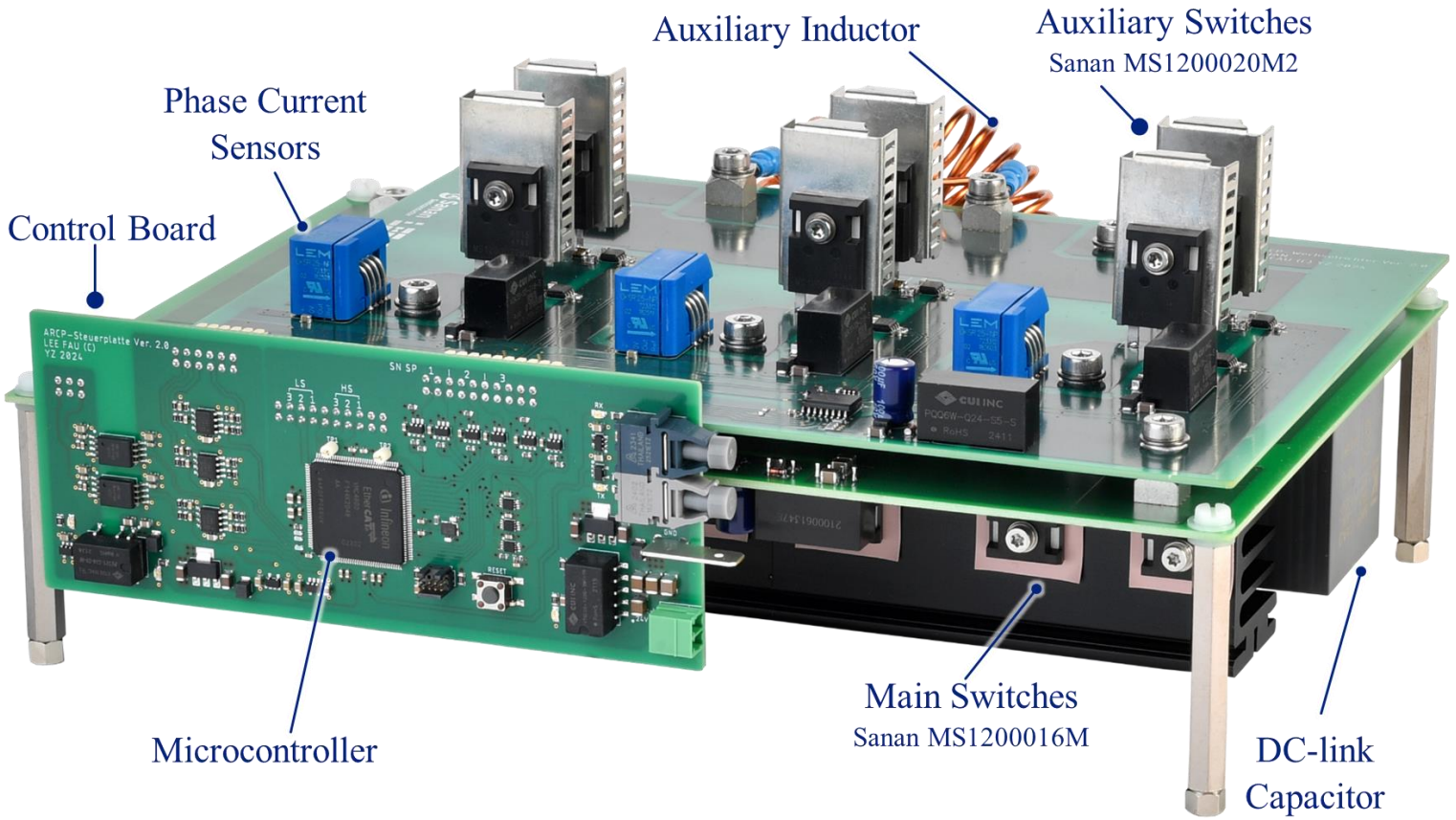
- Avoid simultaneous use of the auxiliary circuit by several phases
- Intelligent control strategy required

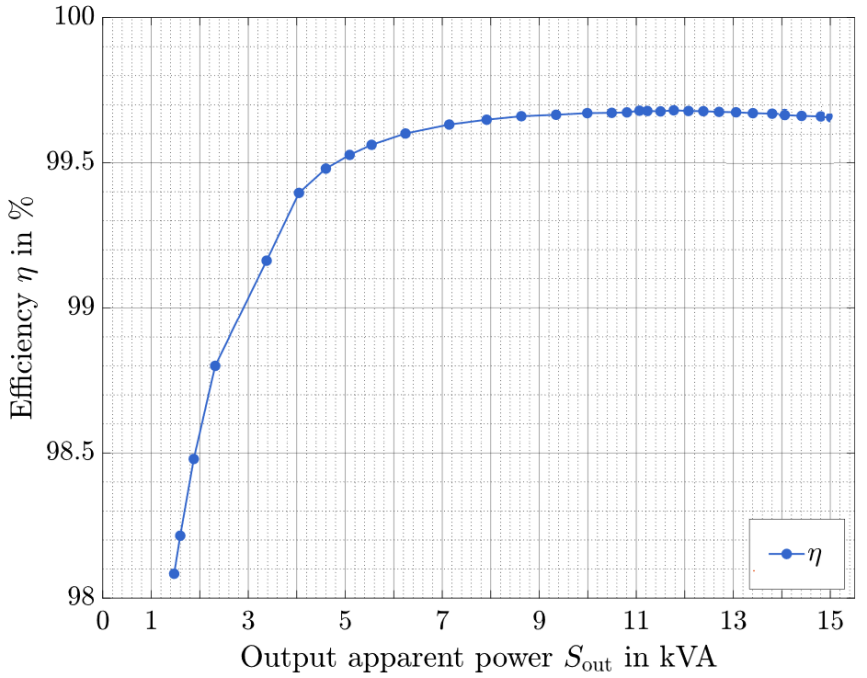
Setup and Stages of Pulse Generation



*All other classic modulation schemes are also applicable.

The Soft Switching Inverter Topology achieves 99.7% Efficiency with Sanan SiC Mosfets





Joint Development with FAU Erlangen University

Boundary Conditions:
V_{dc}= 800 V, $V_{0,rms}$= 230 V, f_{el} = 50 Hz, f_{sw} = 30 kHz.

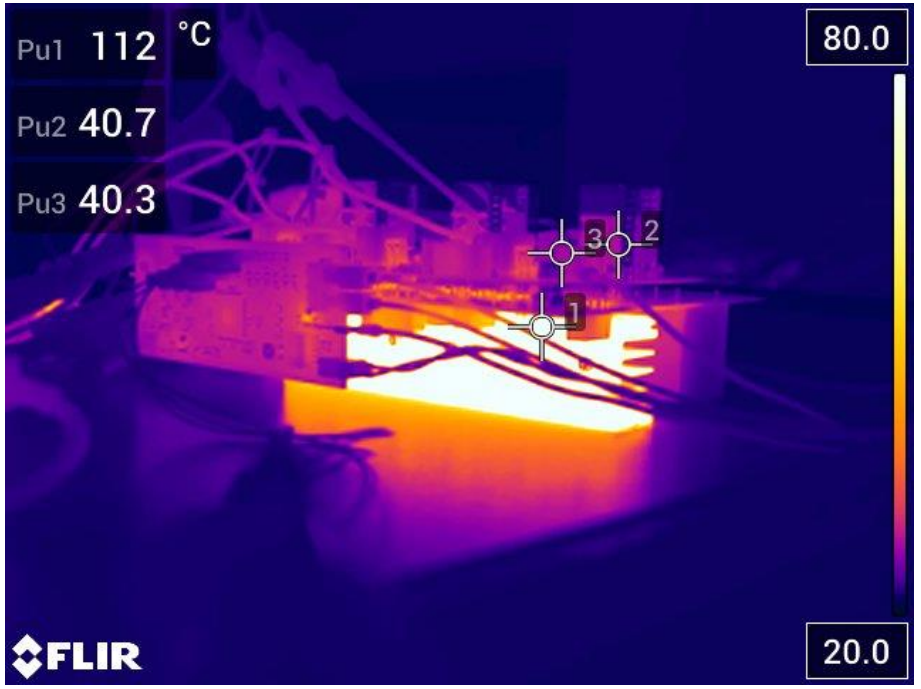
NOTE: Filter losses as well as driver and control losses are not included in Efficiency measurement

Paper Planned

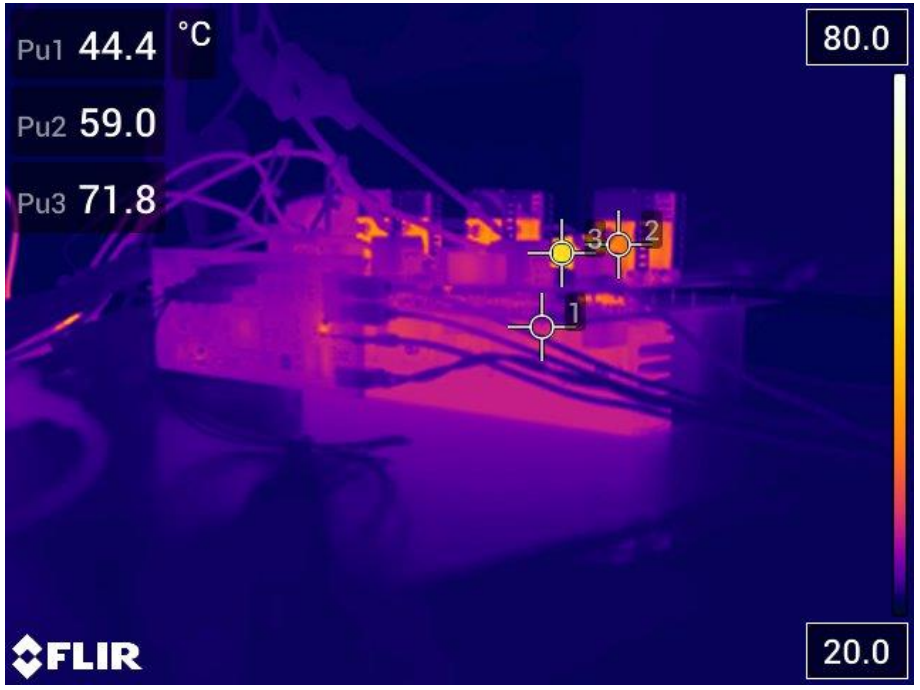
Thermographic Comparision @ 10 kW and 30 kHz

The recordings were made in steady state with natural convection:

Hard-Switching



Soft-Switching with S^2I-ARCP



- Lower cooling effort with S^2I-ARCP due to loss reduction and better heat spread
- Reduces inverter's volume and weight and therefore increases power density

Paper Planned

THANKS

Committed to becoming a world-class
compound semiconductor R & D, manufacturing and service company