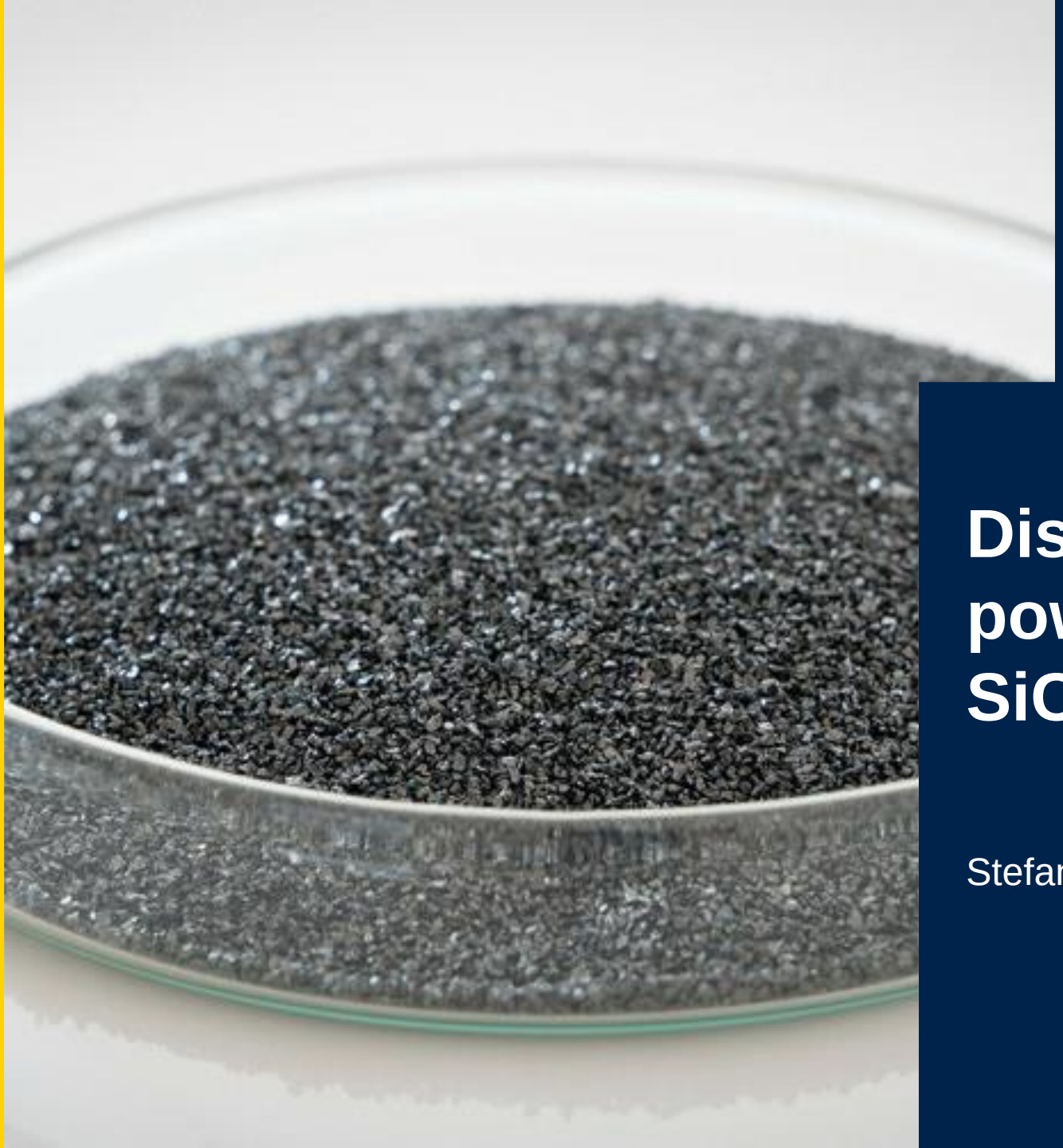

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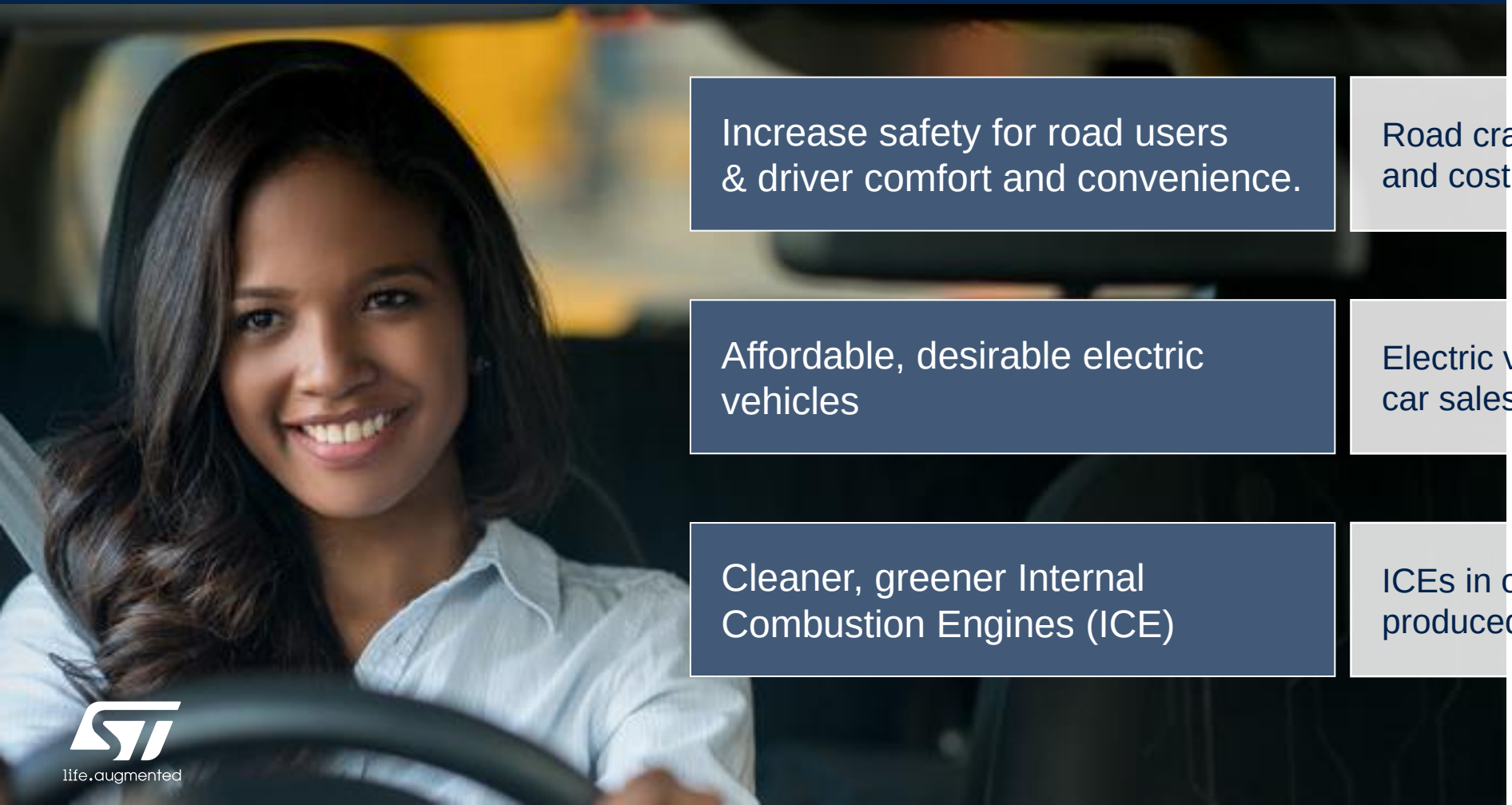
Discover ST electrifications powered by breakthrough SiC technology

Stefano La Rosa

ST mission for Electrification and Smart mobility

ST provides innovative solutions to help our customers make driving safer, greener and more connected for everyone



Increase safety for road users & driver comfort and convenience.	Road crashes carry a high human toll and cost **$500B+** every year
Affordable, desirable electric vehicles	Electric vehicles to grow from ~15% of car sales in 2023 to ~40% by 2030
Cleaner, greener Internal Combustion Engines (ICE)	ICEs in over **70%** of new vehicles produced 2023-2027

Sources: asirt.org, TechInsights, IEA

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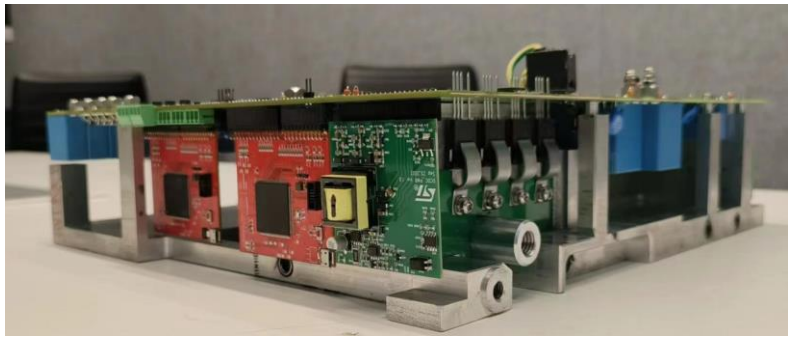
Smart mobility booth demos



Full traction inverter solution

- *Delivering very high-power capabilities thanks to SiC-power power module*
- *Compliant to ASIL-D safety requirements thanks to state-of-the-art gate driver and MCU*

22kW OBC + 3.5kW DC/DC

- *Combining all best ST technologies and skills to deliver high power density and superb efficiency*
- *Scalable and flexible approach to meet customer requirement*
- *Demonstrating how adaptable are ST's MCU*

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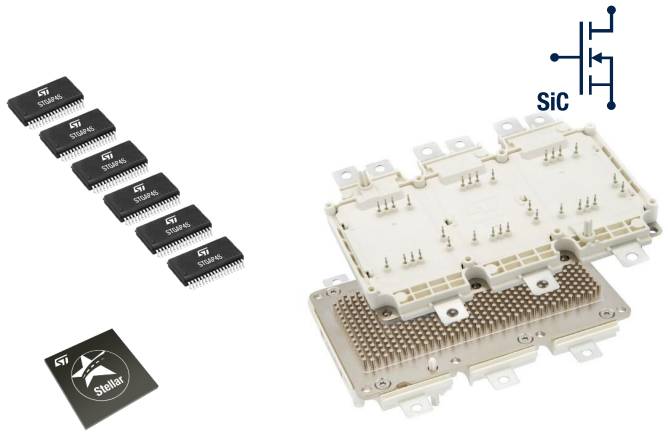
Main traction inverter

Full electric traction inverter solution

System solution for traction inverter based tested up to 200 kW

- SiC-MOSFET based power module
- Fully insulated driving section based on STGAP4S
- Liquid cooling compatible
- Based on the new Stellar E MCU family complemented by ST PMIC
- Featuring a resolver position feedback for ASIL-D compliancy



- Compatible with power module family for power scalability
- Galvanically insulated component, featuring embedded flyback, matching SiC perfectly
- Get the best performances from the power module
- Low CPU usage thanks to optimized driving strategies
- Extremely high-power density

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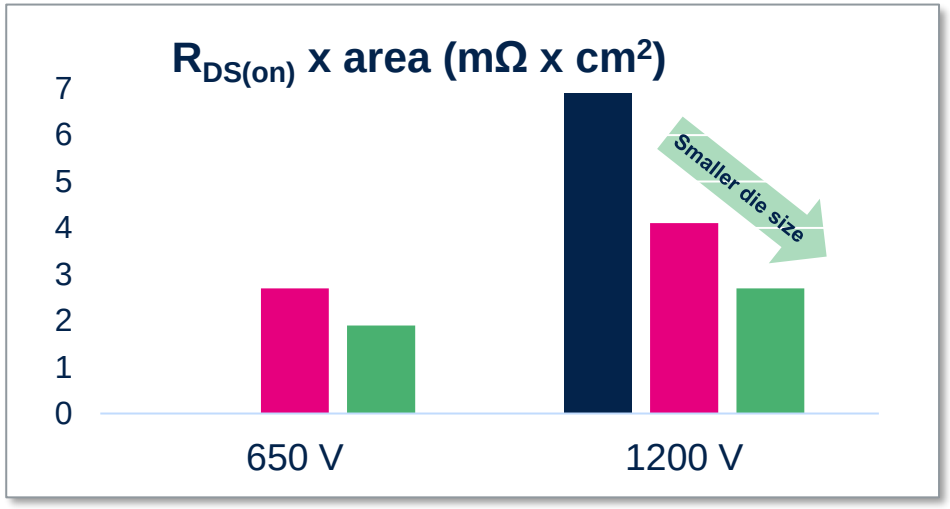
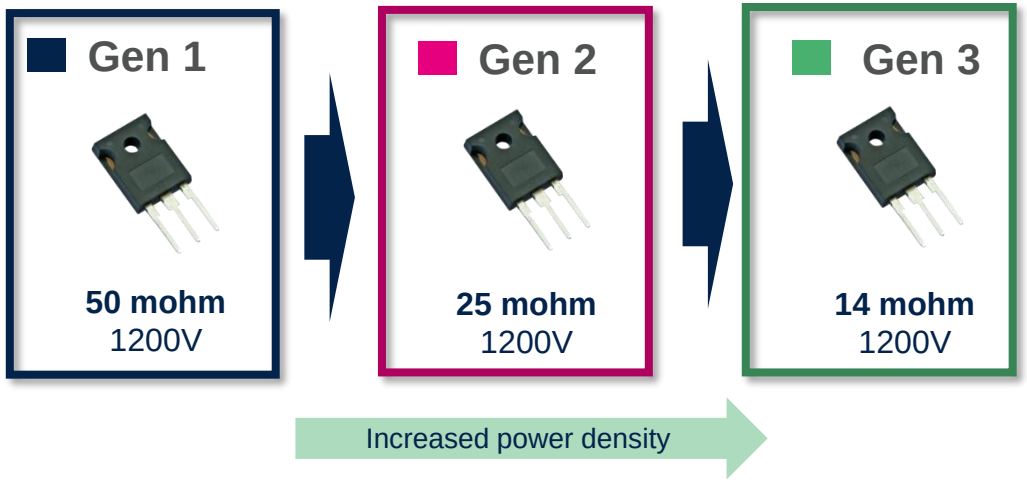
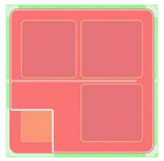
ST SiC MOSFET Gen3 for traction inverter

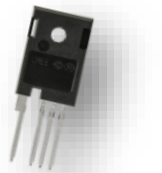




SiC MOSFET Gen3.				
BV	650V	750V	900V	1200V
$R_{DS(on)}$	14 - 21 mΩ	11 mΩ	12 mΩ	15 – 20 mΩ
Packages	Bare die, HiP-247 family, STPAK, ACEPACK SMIT			

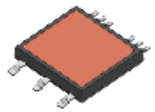


Maximum flexibility



Standard discrete approach
200°C rated

Advanced discrete approach
200°C rated



Modular approach
SMD device

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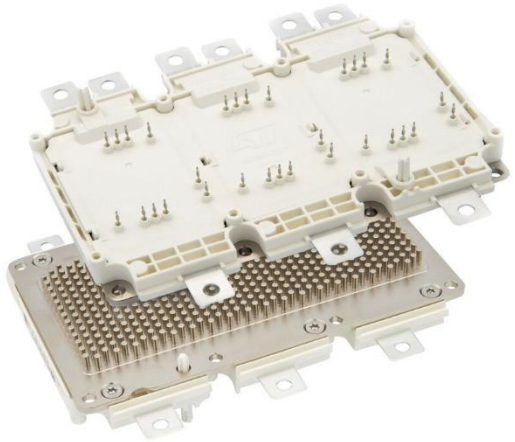
Direct liquid cooled high-performance module

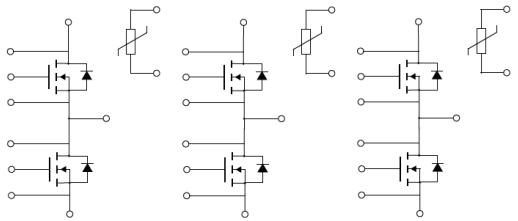
Traction inverter for (H)EV, trucks, and buses

Main traction inverter

- Press fit connections for high reliable and long-lasting connection
- AQG-324 qualified
- Pin-fin base plate for direct liquid cooling
- Dedicated NTC for each single substrate
- Best-in-class $R_{DS(on)}$

ACEPACK DRIVE
based on
SiC MOSFET Gen 3
1200V & 750V





- Internal layout optimized for minimized stray inductance
- High reliability and robustness: dice sintered to substrate for SiC-based power modules
- Different bus bar available to fit welding or screwing connection methods
- AMB substrates for better thermal management for SiC-based power modules
- Extremely high-power density

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Power modules for traction inverter

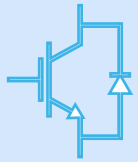
IGBT & diode based

SiC-MOSFET based

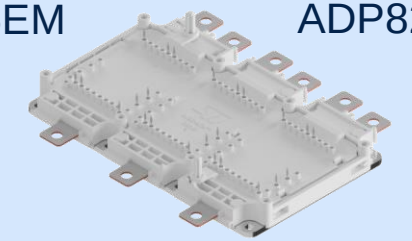
120kW **150kW** **175kW** **220kW**

750V BV

ADP660S75EM

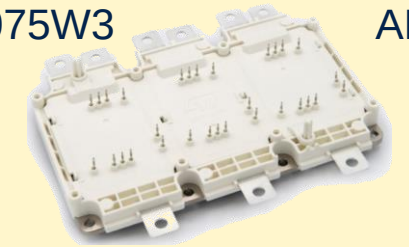


Under development



ADP820S75EM

ADP46075W3

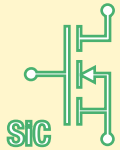


ADP61075W3

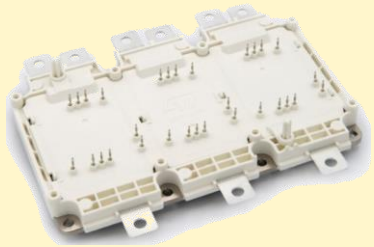
750V BV

Mass production

1200V BV



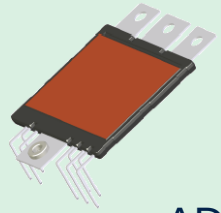
ADP280120W3



ADP360120W3

ADP480120W3

Under development



1200V BV

ADDH900120W3

180kW **230kW** **300kW** **>400kW**

SiC-MOSFET based

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How to drive a power module: STGAP

Multiple options to address a variety of applications in Industrial and Automotive markets

Vehicle Electrification		**EV Inverter & OBC/DCDC** applications must **be extreme robust**
Power management		**Power conversion** applications must **be more and more efficient**
Industrial motor drives		**Industrial** applications require **safer** and more **efficient** devices

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STGAP best fit for SiC

Why STGAP selection for SiC driving

> 4A sink / source driving current	→	Matches the needs of SiC power switches gate driving
High CMTI > 100 V/ns	→	Robustness and high rejection to common mode transients
Embedded Miller Clamp function	→	Enhance driving performance enabling high system efficiency
Galvanically insulated	→	Ensuring fully compliancy with safety requirement and separation between power and control signals

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AEC-Q100 qualified gate driver: STGAP4S

Advanced galvanic isolated gate driver for SiC FETs

SO-36W

- High voltage rail up to 1200 V with 6.4 kVpk galvanic isolation
- >100 V/ns CMTI
- Fully protected Integrated **isolated flyback** controller
- VH supply rail between 10 and 32 V
- **Negative gate drive ability**, VL supply rail between 0 V and -10 V
- **Programmable input deglitch filter**
- Programmable **deadtime**, with violation error
- Two **Diagnostic** status outputs
- **SPI** interface for parameter programming and extended diagnostics
- Gate level monitoring
- Embedded functions & **Self Diagnostic routines** support ASIL-D system certification

- **Programmable UVLO and OVLO** functions on VH and VL
- VCC flyback supply and 3.3V supply UVLO
- Active Miller clamp driver
- **Programmable Desaturation** detection
- **Programmable SENSE** overcurrent detection
- **Adjustable** Soft-TurnOff for **effective** and **optimized** short-circuit protection
- **VCE-Clamp**
- Asynchronous stop command (ASC)
- **Optimized ADC for temperature monitoring.**
- **Synchronized ADC sampling-time (Sample in noiseless period)** with current source for Power Module T_J measurement
- Temperature warning and shutdown protection

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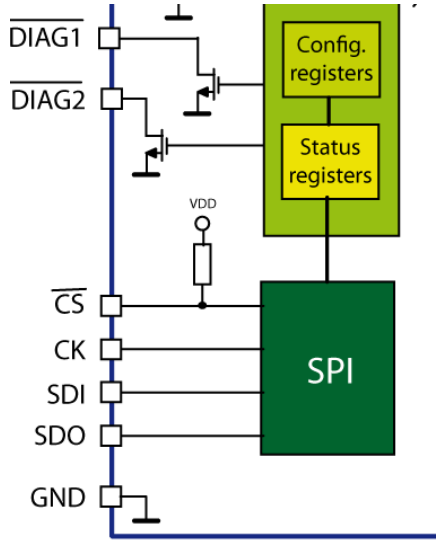
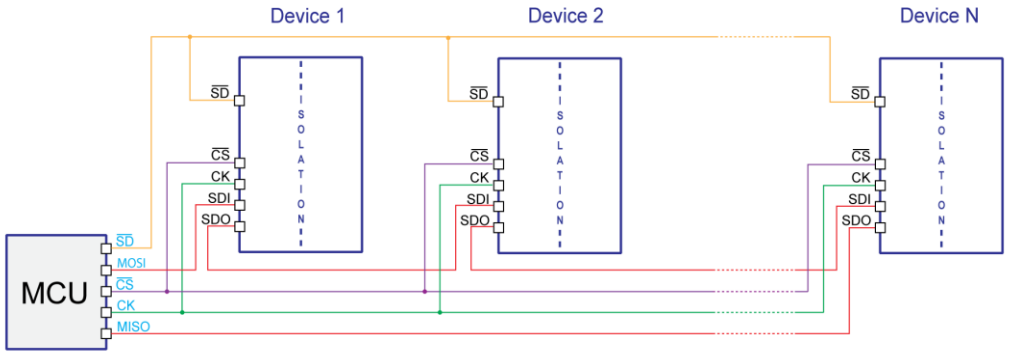
STGAP4S – Programmability and Diagnostic

SPI Interface for parameters setting and advanced diagnostic

- Communication with MCU by means of 16-bit SPI, CRC Protected
- Parameters configured in dedicated Registers
- Customization for different Applications
- Diagnostic information stored in Status Registers accessible by MCU
- Status Registers data can trigger 2 configurable diagnostic pins to inform the MCU
- Daisy-chain configuration for multiple drivers management by 4 wires





Stellar MCUs
The Most Scalable MCUs Series

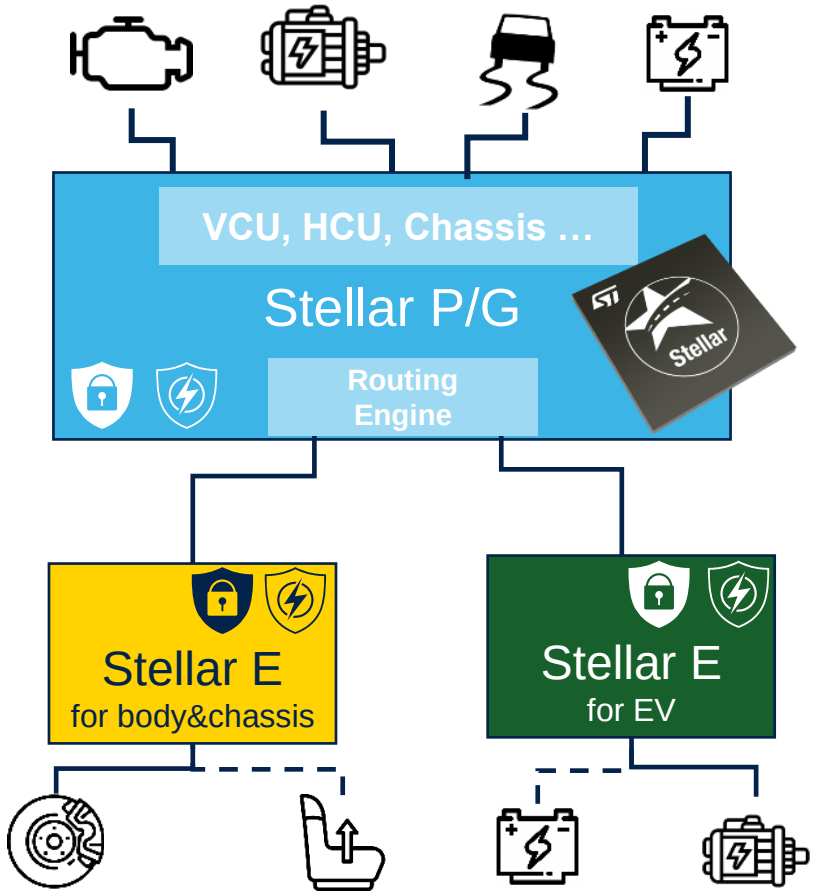
Two Stellar Series for best coverage of future challenges

Stellar P & G “Apps Integration”

Premium performances for **ECU consolidations** and advanced **vehicle dynamics control**

Stellar E “Smart Actuation”

Best in class performance, low latency, advanced analog, SecOC support, for **fast, precise** control strategies



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Stellar E: Electrification Domain MCUs

Applications for dynamic, energy storage and power conversion

Traction Inverter: safety and math computational requirements

Battery management system: memory and AI potential

On-board charger: fast analog and SiC/GaN enablement

DCDC converters and power distributions: efficiency and safety

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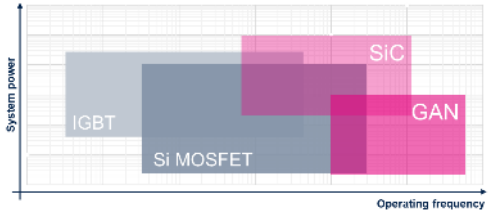
Stellar E MCU Series

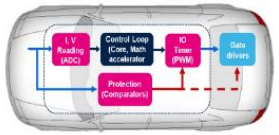
Innovation with Value

Designed for Car Electrification

FAST Acquisition Actuation Protection

For **SiC** and **GaN** wide band technology





Entire system control in ONE MCU

- HRTimer
- SD-ADC
- Analog Comp

300 MHz Control Loop

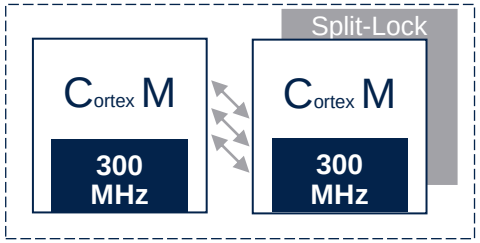
Tailored for

OBC
DCDC
Traction Inverter

Stellar E MCU

Electrification, control & actuation

Unique Scalable Performance



ARM Cortex-M

Split-Lock flexibility

ISO 26262 ready

Safe and Secure

ASIL-D

Low Latency HSM

ISO 21434 ready

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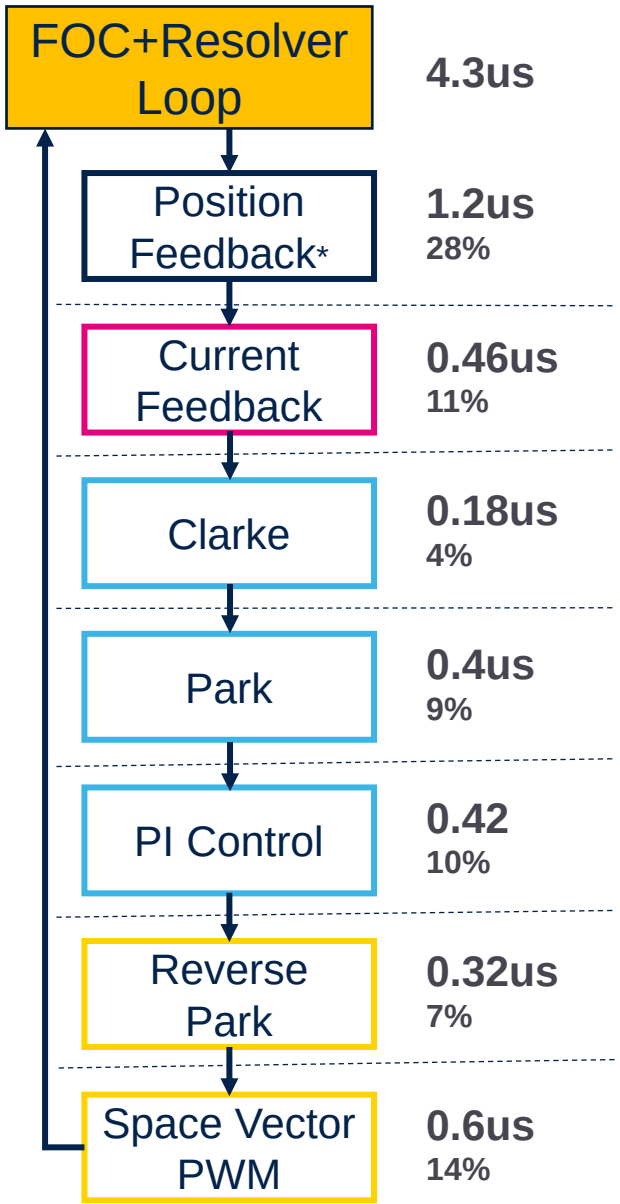
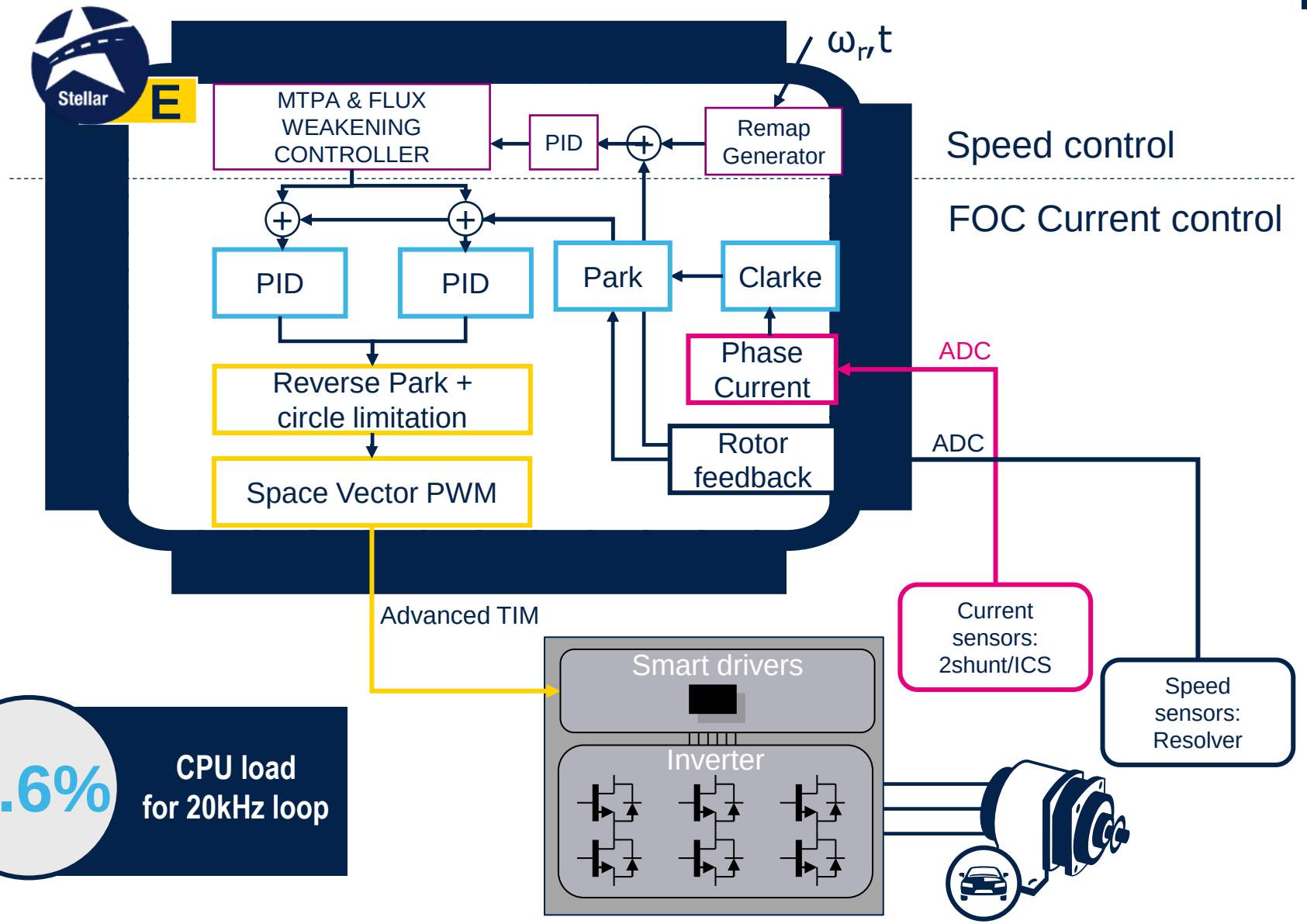
Stellar E1 benchmark for MTCK





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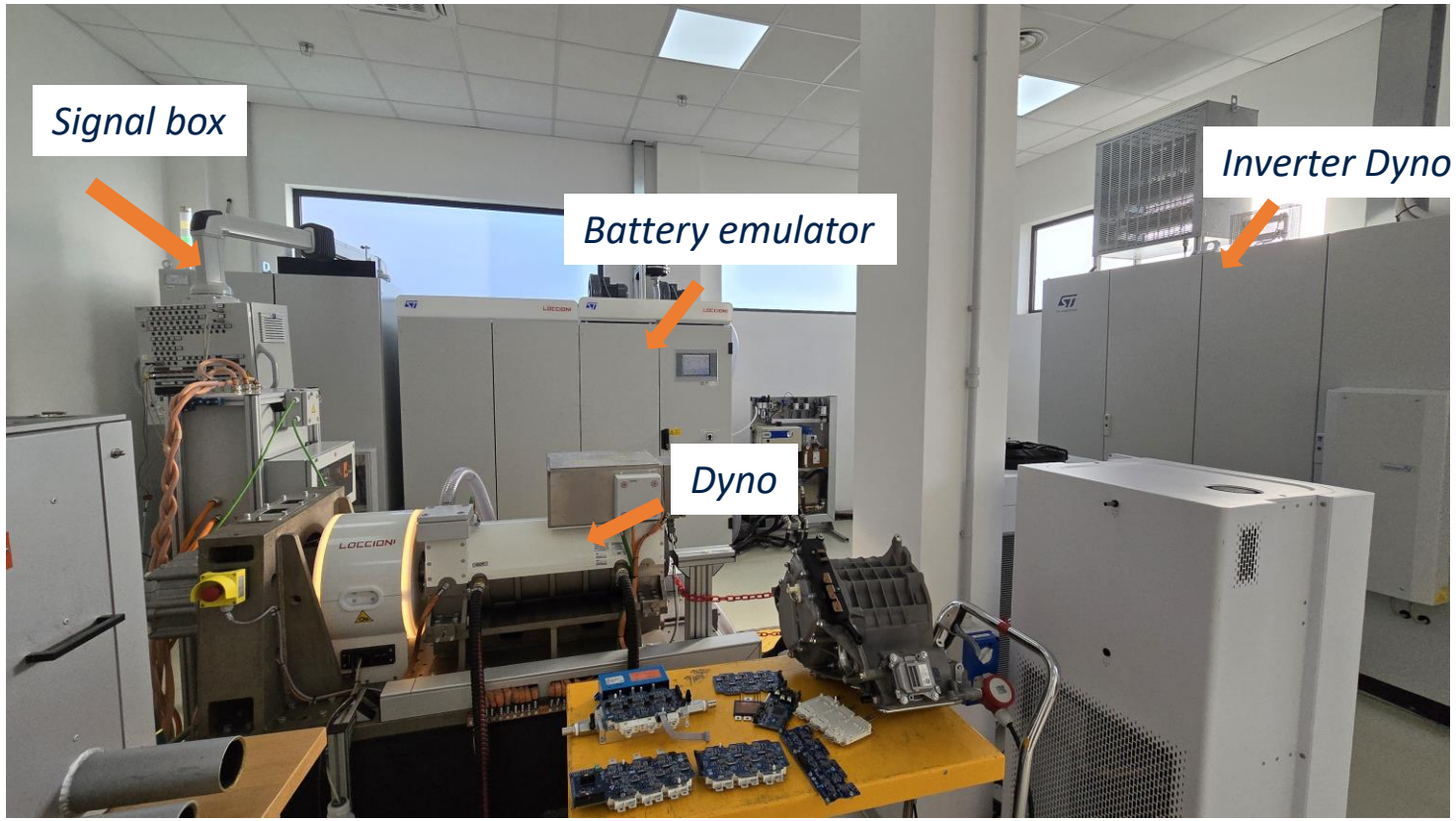
*17% ISR and function calls overhead

240 kW New Power lab, in System lab ST Italy



Control station

- *System validation done by running an active dynomontric bench*
- *Equipped to host different kind of traction motors*
- *Able to replicate mission profile and aging tests*
- *Up to 1000V Battery Emulator*
- *Up 20,000 RPM*
- *Up to 240 kW*

Same capability of a car maker

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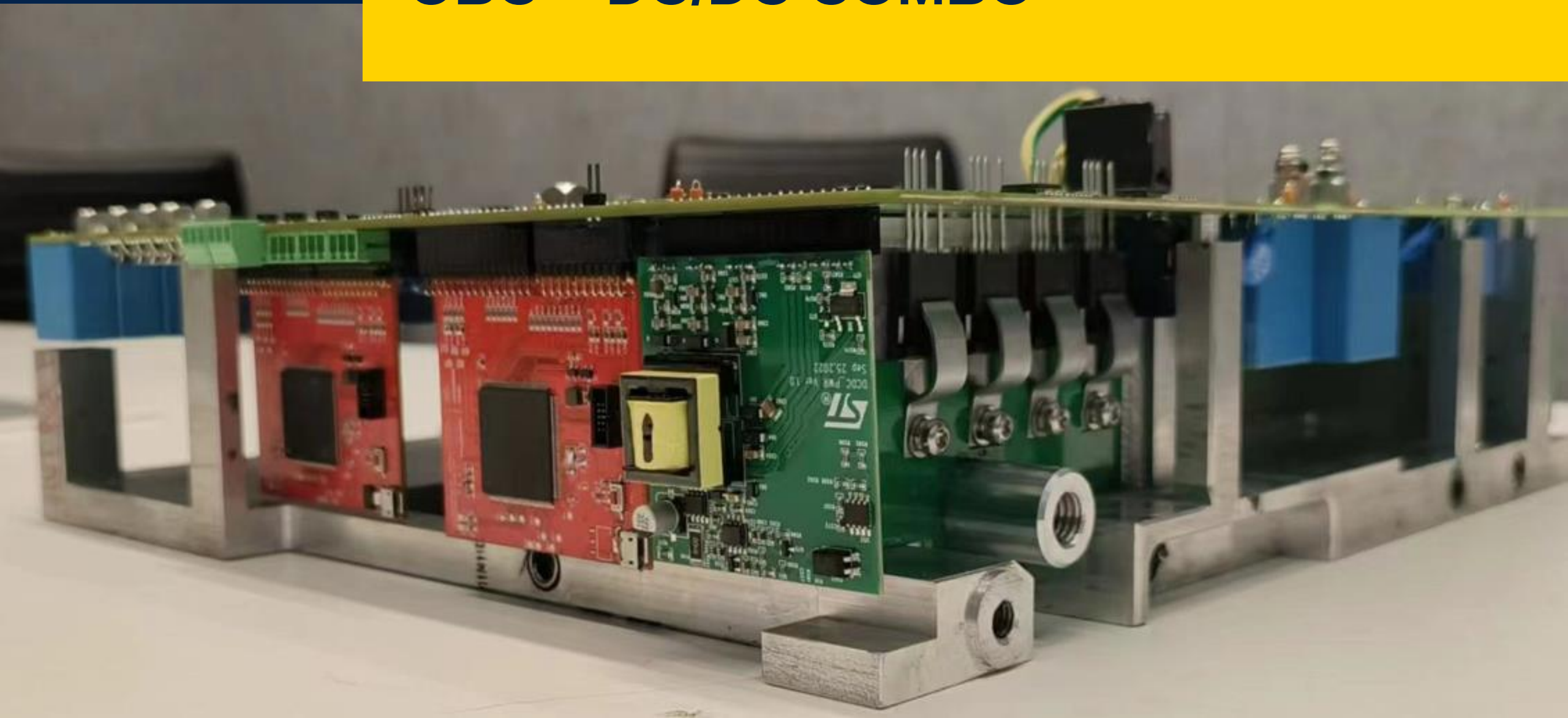
OBC + DC/DC COMBO



ST's Technologies for OBC and DC/DC

IGBTs

650V «HB» series for fast switching

- Automotive qualified 650V IGBT in SMD package, 30A and 80A rated
- Suitable for PFC operations
- H2PAK package for increased creepage distances
- ACEPACK SMIT available in half-bridge configurations

HV MOSFETs

Non exhaustive examples

Complete and wide product portfolio for low-power high efficiency solutions

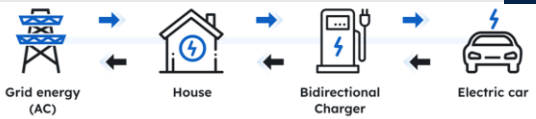
- Wide package options: from small SMD to bigger TH
- Boost and half-bridge topologies available in ACEPACK SMIT
- Wide BV to cover several application requirements
- Dedicated MOSFET series for a specific function
- HV MOSFET based on Multi-Drain technology

SiC MOSFETs

Non exhaustive examples

Enaber of bi-direction

Bidirectional
V2G/V2H



- **SiC MOSFET is key enabler for bi-directional usage V2X**
- **Different BV available: from 650V to 1700V**
- **Best efficiency solution**
- **Ideal to reach high power density**

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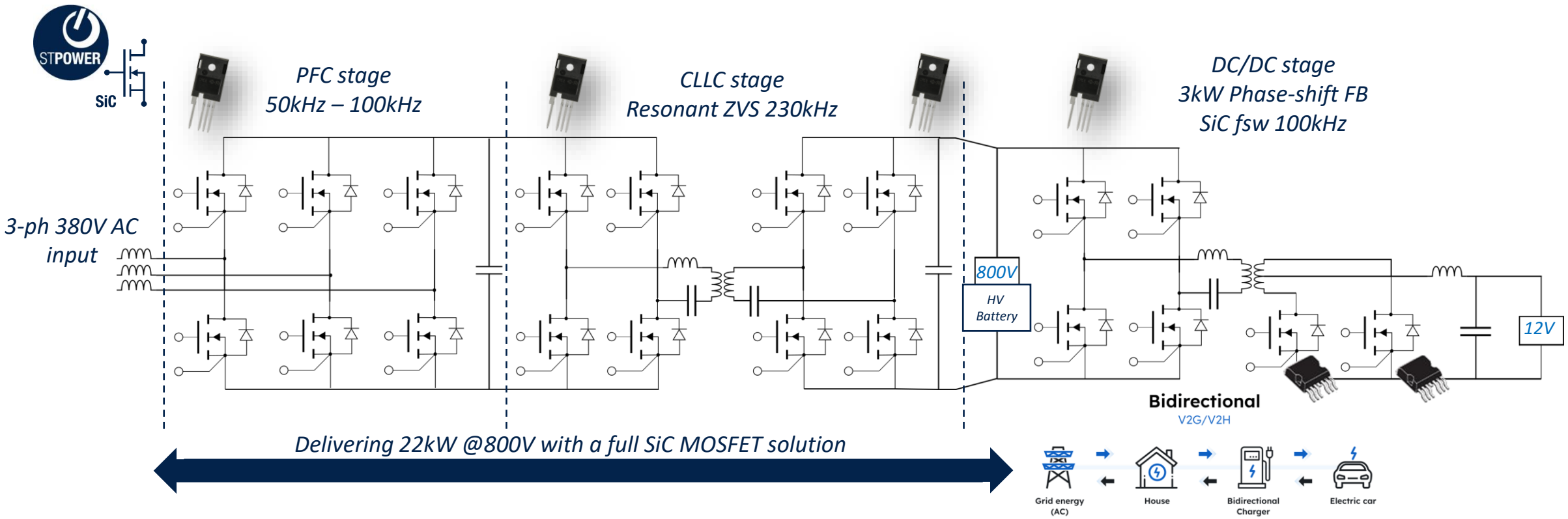
OBC+DCDC Combo Topology and Control Structure



STGAP

Gate Drivers: STGAP2SIC

Stellar E1
Core1: PFC Core2: CLLC

Stellar

Stellar E1
Lock step core: DC/DC

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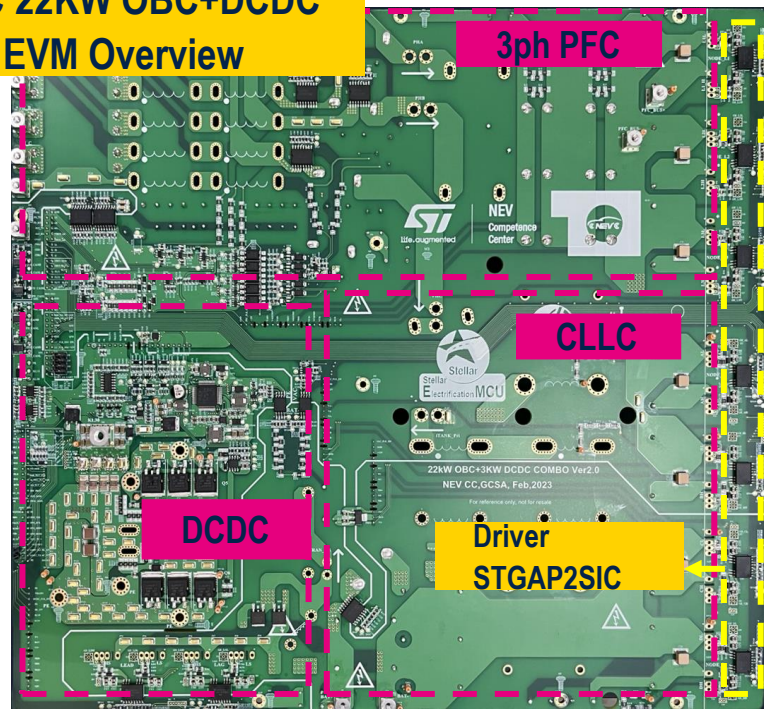
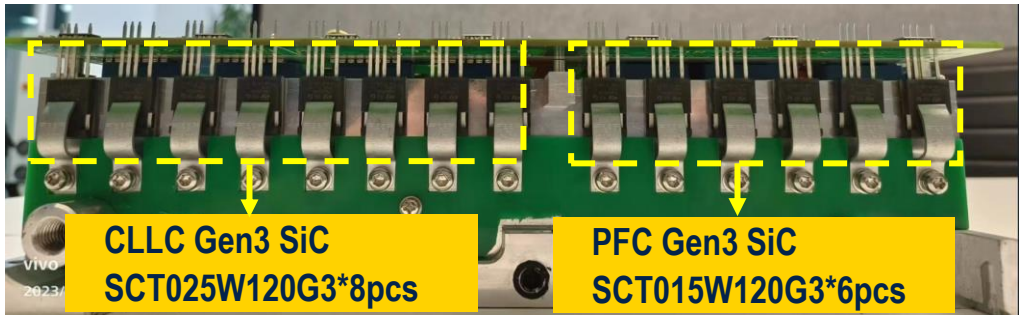
800V & SiC Contribute Higher Power Density

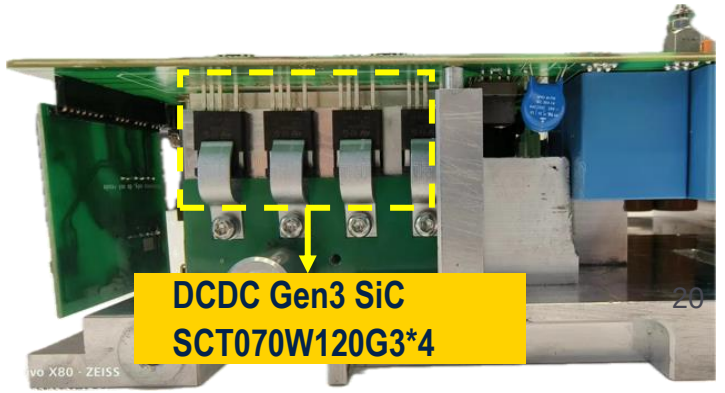
800V + Gen3 SiC 22kW OBC, power density @ 2.45kW/L

Solution supplier	ECU Size	Power & weight
ST NEV CC	**2.45kW/L(**363mm*330mm*85mm **)**	22kW OBC+3KW DCDC, 15kG
Global mainstream OBC player	**2.38kW/L**	6.6kW OBC+2.5kW DCDC, 5kG

NEV CC 22KW OBC+DCDC Combo EVM Overview







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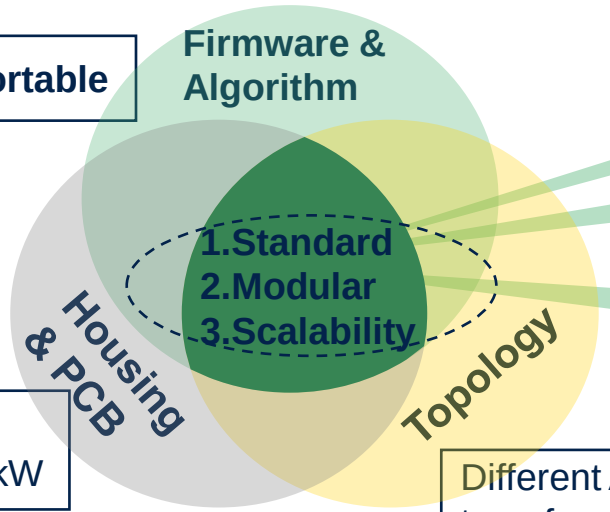
More Than 22kW with ST OBC Platform Reusable to Different OBC Power

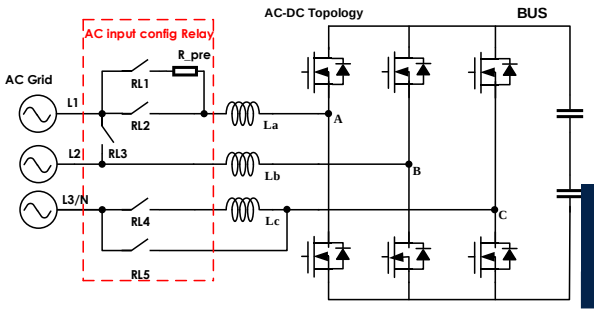
1. Platform **compatible** to **global AC grid** infrastructure, **1/3ph AC**, **6.6/11/22kW OBC power**
2. One **system platform** to validate **different SiC PN.** tailer for **different OBC power**

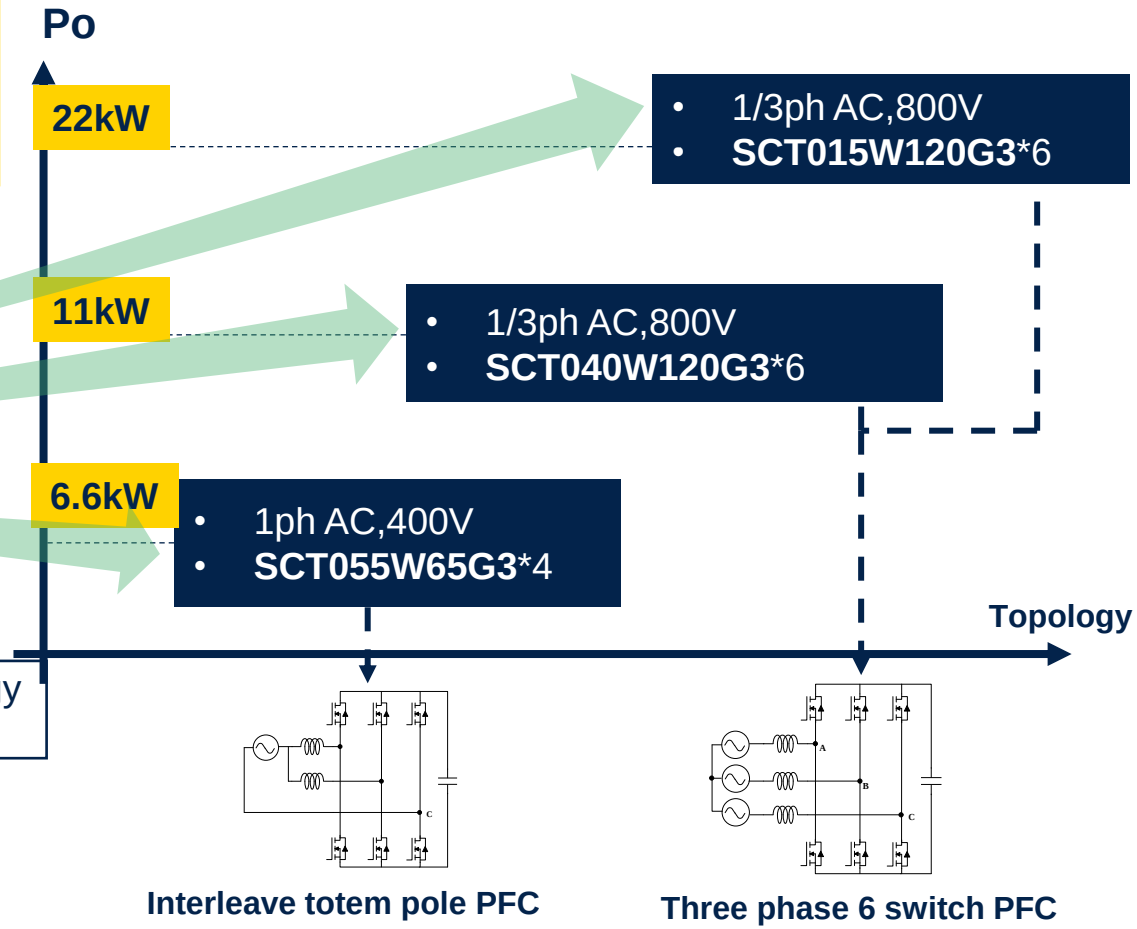
Modular firmware & portable



Max support **22kW/800V**, capable **down** to 11kW/6.6kW

Different AC grid & topology transformation





Topology Transformation

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SiC MOSFET Portfolio for OBC and DC/DC application

Breakdown Voltage

650V / 750V	900V	1200V	1700V	2200V

Series

G3	G3	G3	G1	VHV

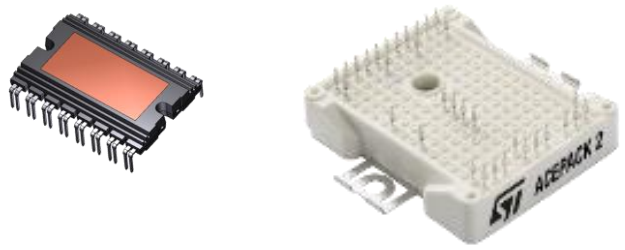
On-state resistance

14-16-17-18-27-40-55-60 mOhm	12 Ohm	15-16-20-25-40-70 mOhm	1 Ohm- 65 mOhm	31mOhm

Packages

SMD approach, most compact

THD: HiP-247 200°C qualified



Power module: complex topologies inside

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STGAP2SICSAC, STGAP2SICSANC

Galvanic isolated, AUTOMOTIVE qualified single channel gate driver for SiC in SO-8N and SO-8W package

Compactness

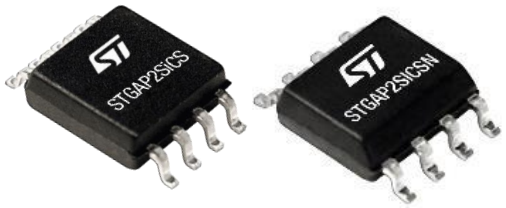
- On-chip galvanic isolation
- **SO8N Isolation V_{PEAK} 4.8 kV**
- **SO8W Isolation V_{PEAK} 6 kV**
- **Compact SO-8N and Robust SO-8W package**

Robustness

- **Specific part with optimized UVLO for SiC**
- **Watchdog**
- **Transient immunity ± 100 V/ns in all temperature range**
- **Automotive Grade qualification**

Features

- High voltage rail up to 1700V (SO-8N), 1200 (SO-8W)
- Up to 26 V supply voltage
- 4A sink / source driver current capability
- **Miller Clamp function**
- **Optimized Propagation delay 45 ns**
- Stand-by function
- Thermal shut down function
- Interlocking function
- 3.3 to 5 V TTL/ CMOS inputs with hysteresis

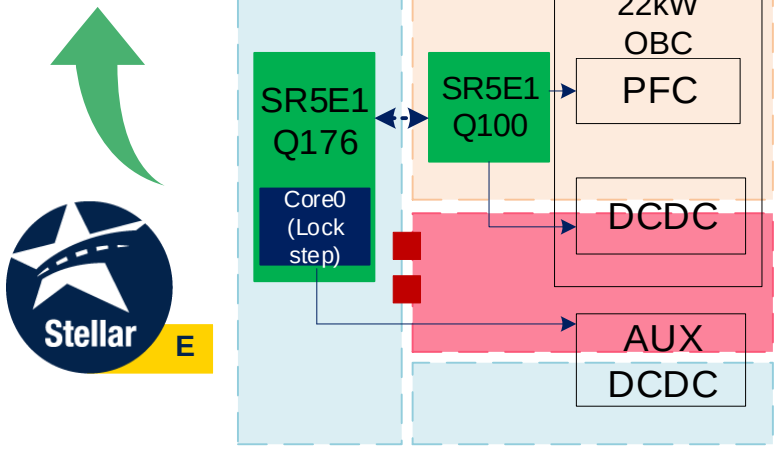


AECQ100
AUTOMOTIVE GRADE qualified

Key applications

- On Board Chargers
- Motor control
- Switch-mode power supplies
- Factory automation
- Industrial drives and fans
- DC-DC converters
- EV Chargers

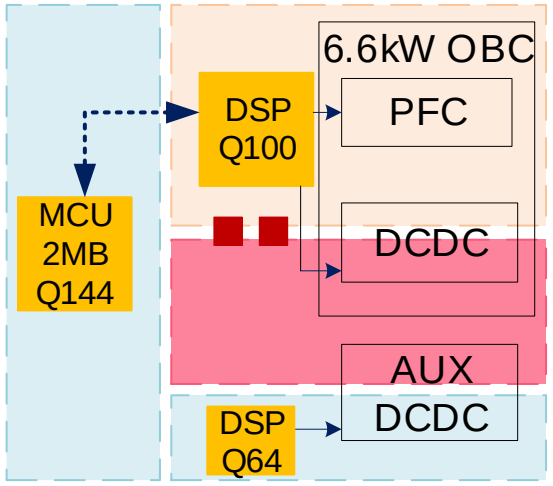
Innovative MCU structure with Stellar E: One MCU for power control + Safety&Communication

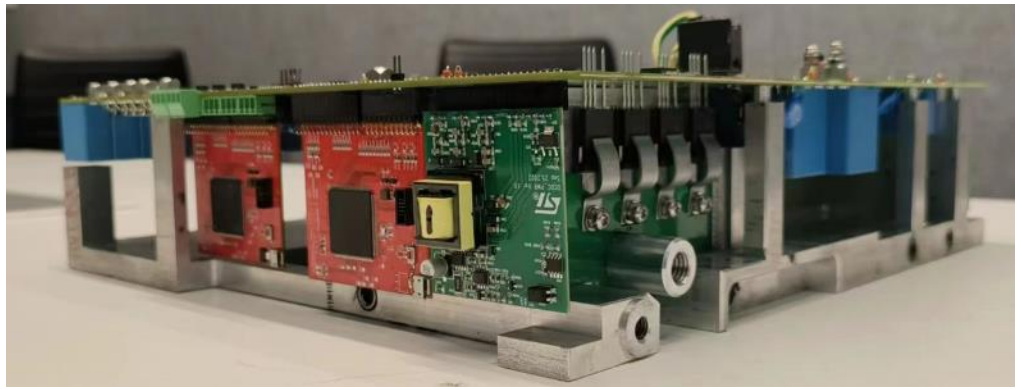


- **High Voltage side Stellar E1** to control OBC (PFC & CLLC)
  - Fast control loop latency & dedicated peripheral optimized for SiC/GaN
    - 300MHz core, HRTIM, DAC, comparator, 2.5Msps ADC
  - FuSa ASIL-B, dual core config

- **Low Voltage side Stellar E1** to control AUX DCDC+ system safety/communication
  - Peak current mode control, best for power loop control
  - FuSa ASIL-D, OTA, AUTOSAR fully support

State of Art:
2 DSP+1MCU





Develop by NEV competence center China

AC GND domain
HV GND domain
LV GND domain
Isolated amplifier
Digital isolator
Stellar-E MCU
Competitor MCU

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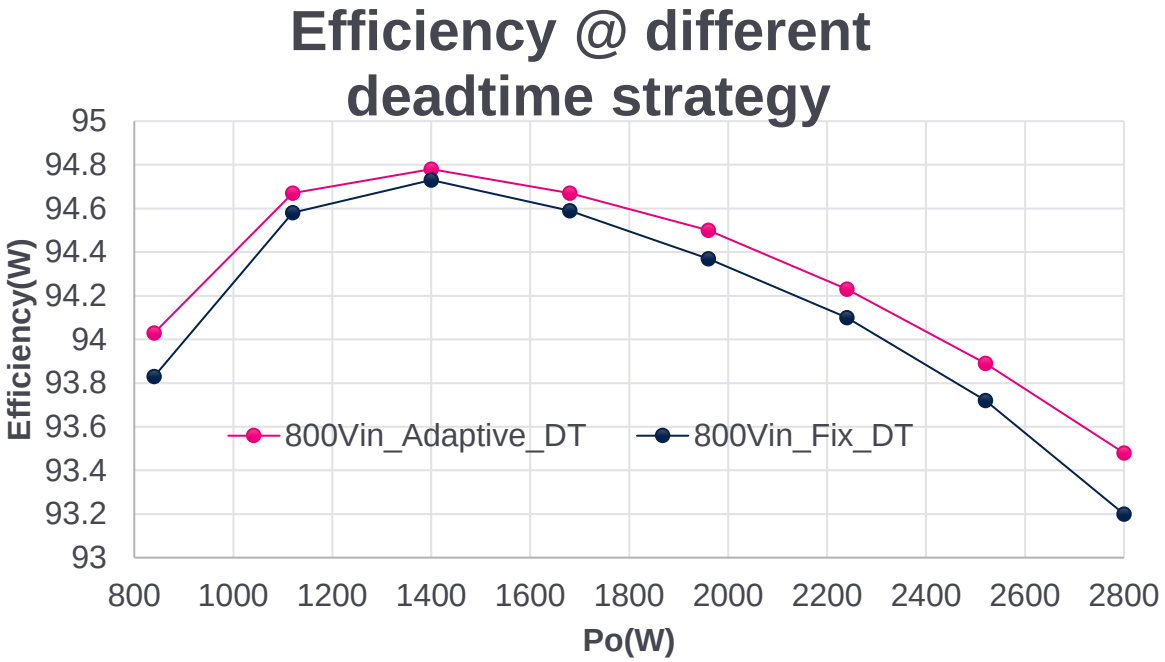
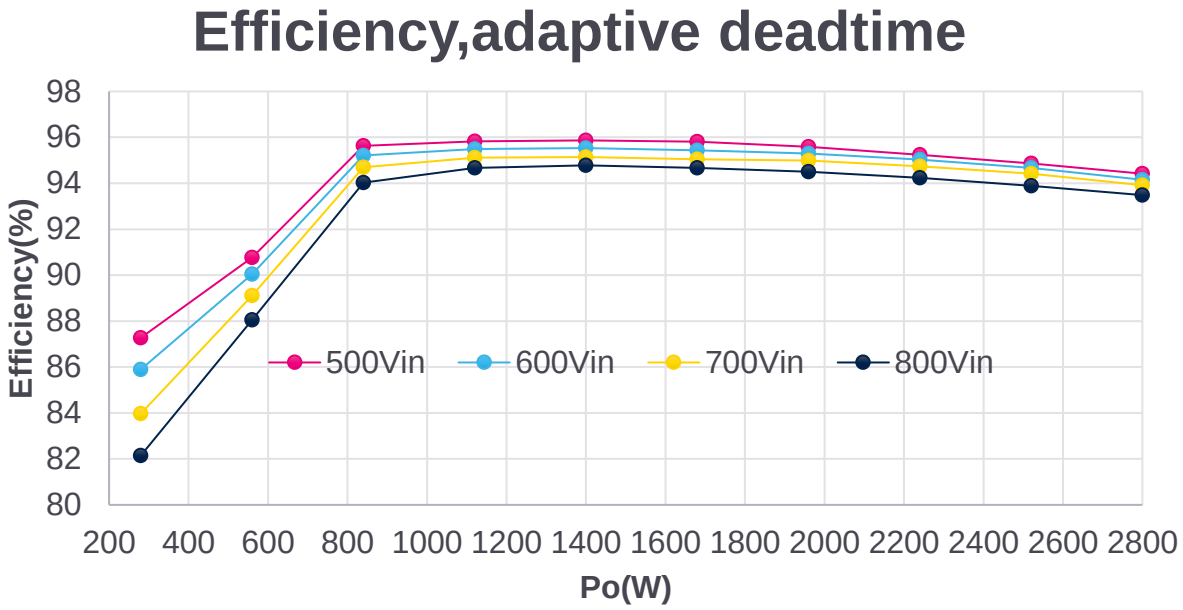
DCDC efficiency optimize by adaptive deadtime @ Stellar-E high resolution timer-156ps

- **Precise dead-time** control **optimize efficiency,0.46%** increase @ 800V
- **Peak efficiency 95.89%** with **Gen3 SiC MOSFET**





- **Adaptive dead-time:270ns-60ns**
- **Fixed dead-time:150ns**
- Bias power loss included, safety MOSFET loss excluded
- Water cooling,25℃ water,burn-in 10min to measuring

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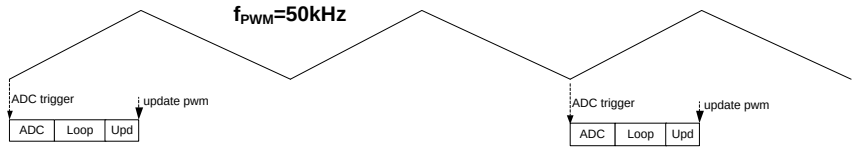
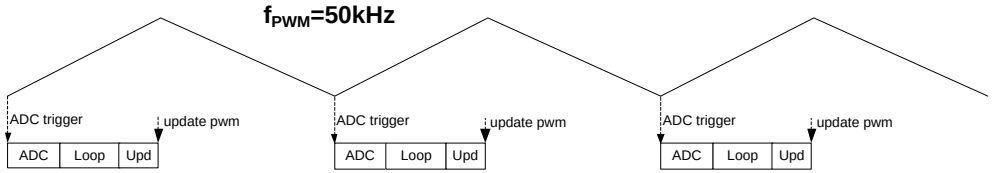
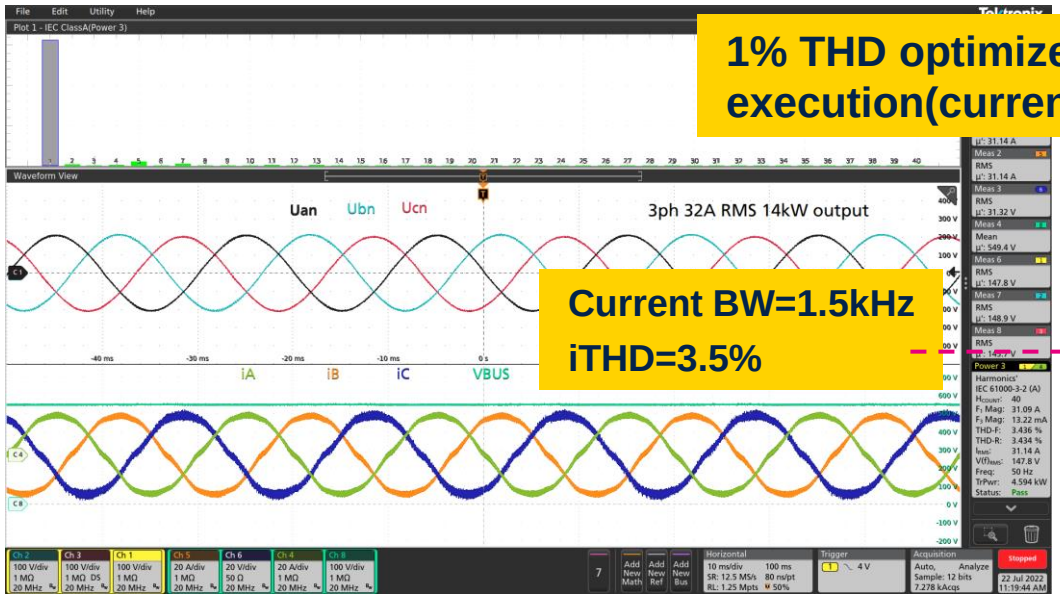
iTHD optimized with MCU cycle by cycle(CBC) control loop updating

Control loop updating every two PWM cycle



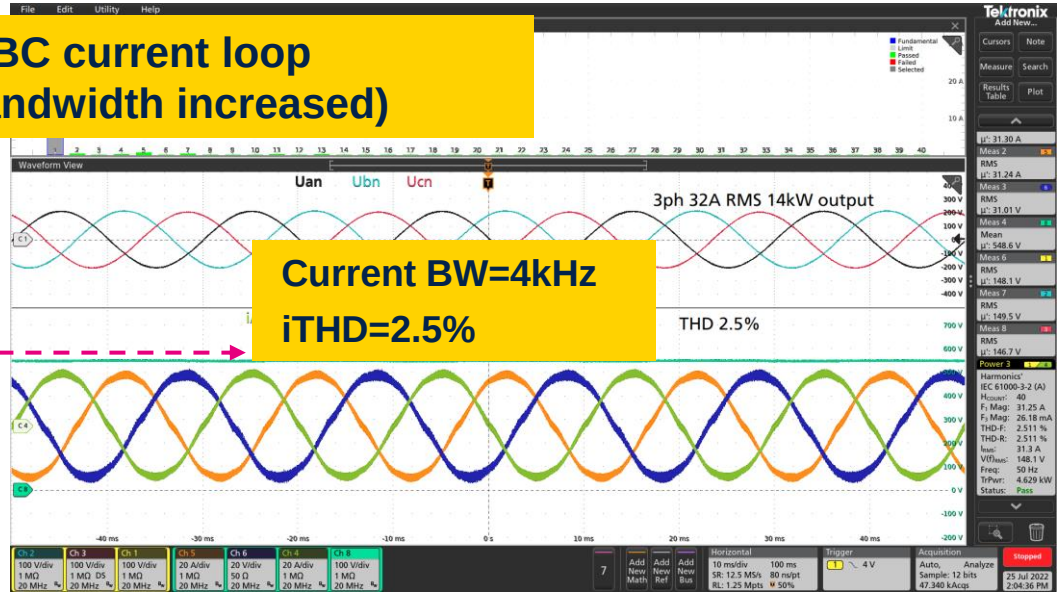
Control loop updating every PWM cycle





1% THD optimized with CBC current loop execution(current loop bandwidth increased)

Current BW=1.5kHz
iTHD=3.5%



Current BW=4kHz
iTHD=2.5%

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50 System AE

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Customization service

2019
- Electrification Solution roadmap
- 1st Solution Release
- 1st Solution DIN

2020
- Digitalization Solution Roadmap
- 1st DWIN

2021
- New EEA Architecture
- Implement in Real Car
- 4TH CIIE Event

2023
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- SOA
- Autonomous

* SDV = Software Defined Vehicle

* SOA = Service Oriented Application

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