COSIVU

compact, smart and reliable drive unit for fully electric vehicles

AMAA 2014

COSIVU - Compact, Smart and Reliable Drive Unit for Commercial Electric Vehicles

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AMAA ADVANCED MICROSYSTEMS FOR AUTOMOTIVE APPLICATIONS

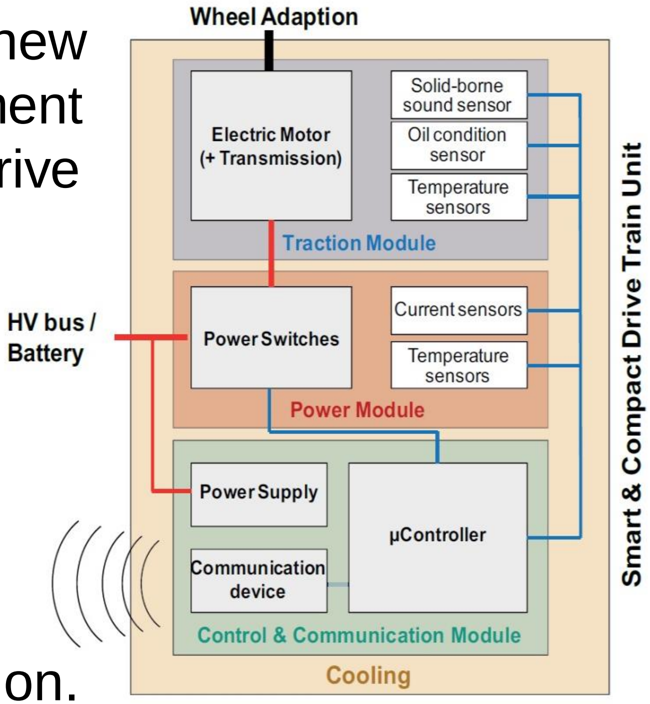
SEVENTH FRAMEWORK PROGRAMME

Outline

- Introduction
- COSIVU System Architecture
- Inverter Packaging Concept
- Power Module Cooling Concept – ^{2}COOL
- Conclusions

Introduction

- The EU-funded FP7 project COSIVU aims at a new system architecture for drive-trains by development of a smart, compact and durable single-wheel drive unit with:
  - integrated electric motor,
  - compact transmission,
  - full silicon carbide (SiC) power electronics,
  - and an advanced ultra-compact cooling solution.
- Project Started 2012-10-01, and ends 2015-09-30



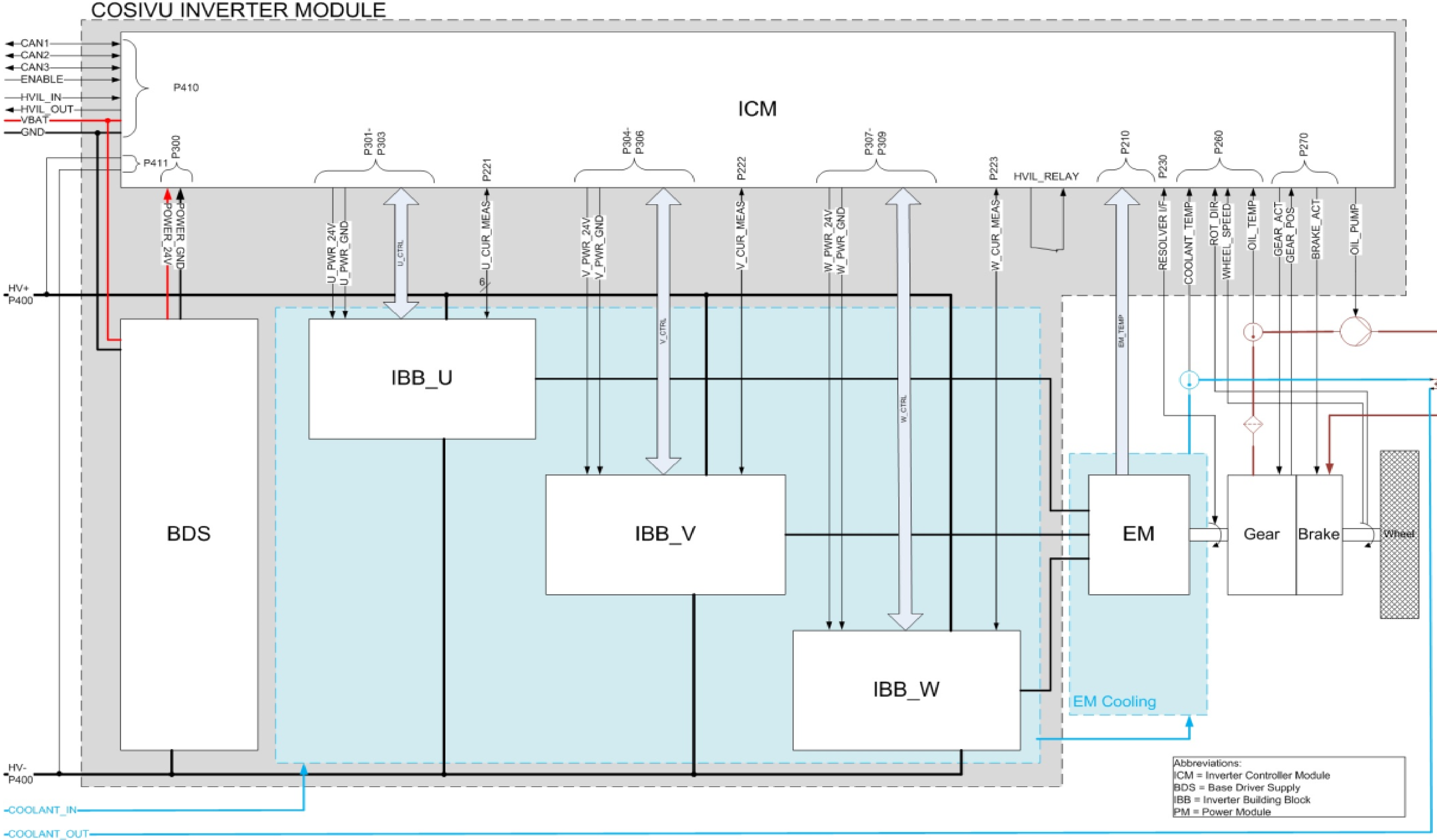
Project partners and their main roles

swerea IVF	Project coordination. Novel heat removal solutions – technology and material development,
VOLVO	Definition of Requirements, providing of In-Wheel motor, functional testing of developed demonstrator
TranSiC / FAIRCHILD SEMICONDUCTOR®	1200 V SiC bipolar junction transistors and SiC-based Power modules
HELLA	Health monitoring (solid-borne sound sensor, oil condition sensor), µController programming
SENSiTEC	Current sensors (anisotropic magnetoresistive - AMR effect)
elaphe	Overall system integration & optimization (design, prototyping, testing), transfer of COSIVU architecture to an alternative direct drive electric motor version for other vehicle platforms
NANOTEST Berliner Nanotest und Design GmbH	Material characterization (for FE-Simulations), thermal characterization, failure analyses
Fraunhofer	<u>ENAS</u>: Electrical & thermo-mechanical reliability assessment, in co-operation with Chemnitz University (e.g. power cycling) <u>IISB</u>: Power module system integration, development of gate driver stage
TECHNISCHE UNIVERSITÄT CHEMNITZ	Functional & health monitoring based on thermal impedance spectroscopy and current sensing

COSIVU System Architecture

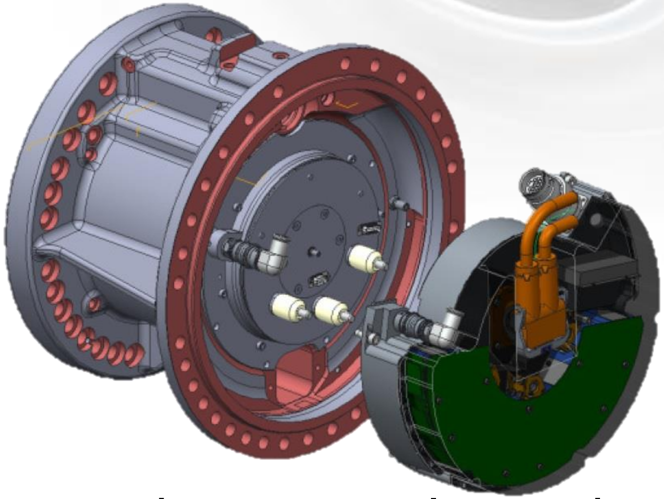
- The picture on the next slide shows the overall COSIVU system architecture consisting of the
  - ICM (Inverter Controller Module),
  - BDS (Base Driver Supply),
  - IBBs (Inverter Building Blocks).
- For clarity the EM (Electrical machine), Gear and brake together with auxiliary systems (water cooling and oil cooling) is showed in order to give the complete system overview.

COSIVU System Architecture



COSIVU System Architecture

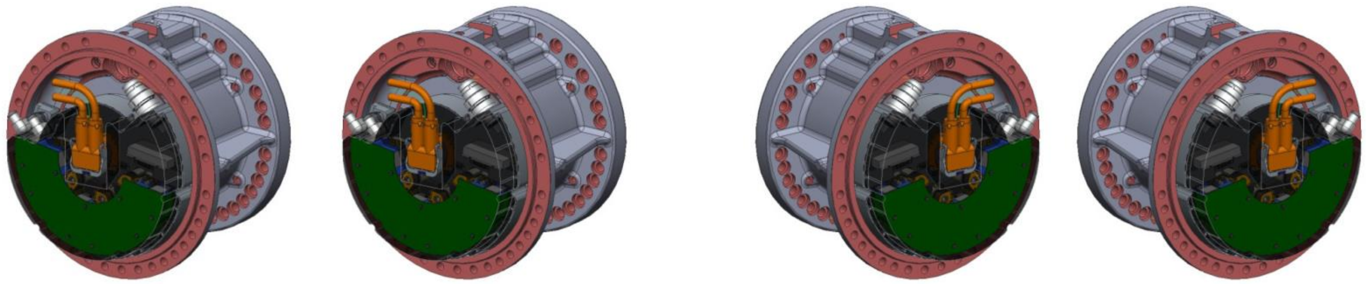
- The strategy for the system architecture was to create a decentralized modular design that was
  - compact,
  - easy to repair,
  - and cost effective.



- This resulted in a compact inverter unit integrating power electronics and control electronics.
- For ease of service and repair the whole unit is a fully pluggable solution including all electric and leakage-free fluid connections.

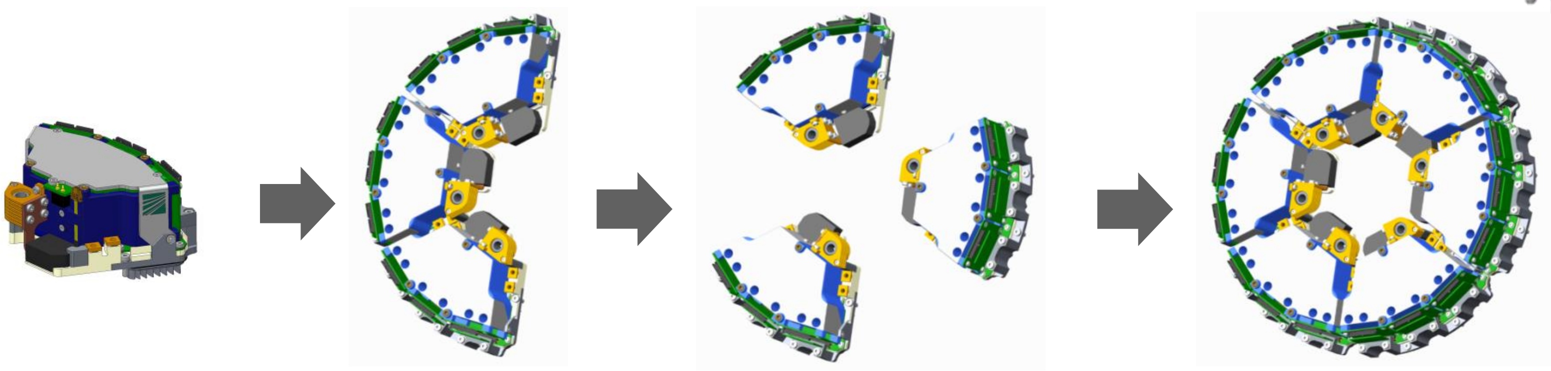
COSIVU System Architecture

- On a 4WD vehicle there will be four COSIVU systems, one in each wheel, all systems are identical allowing less different parts and higher volumes and thus lower production and storage cost.
- Each COSIVU system can be controlled independently via a CAN bus by a master ECU that uses complex drive schemes such as torque vectoring, at local level each COSIVU system will control the electric machine with a local and fast control loop for highest performance and accuracy.



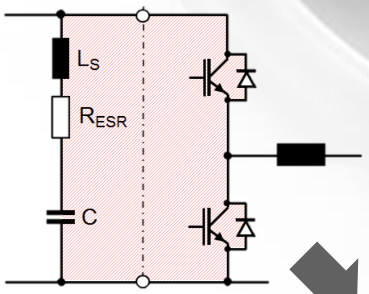
Inverter Packaging Concept

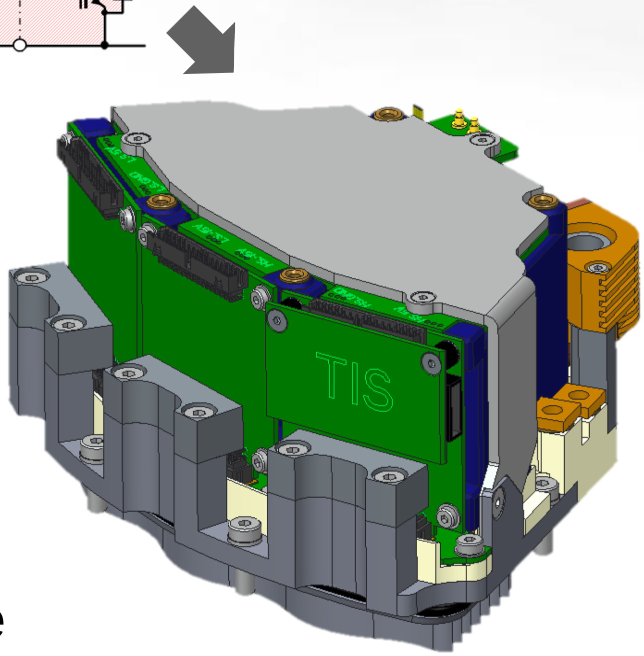
- Modular Inverter Powerstage with “Inverter Building Blocks” (IBB)
- Easy servicing due to reduced spare parts and new mechatronic interfaces
- Possible adaption to different design-spaces using identical system architecture



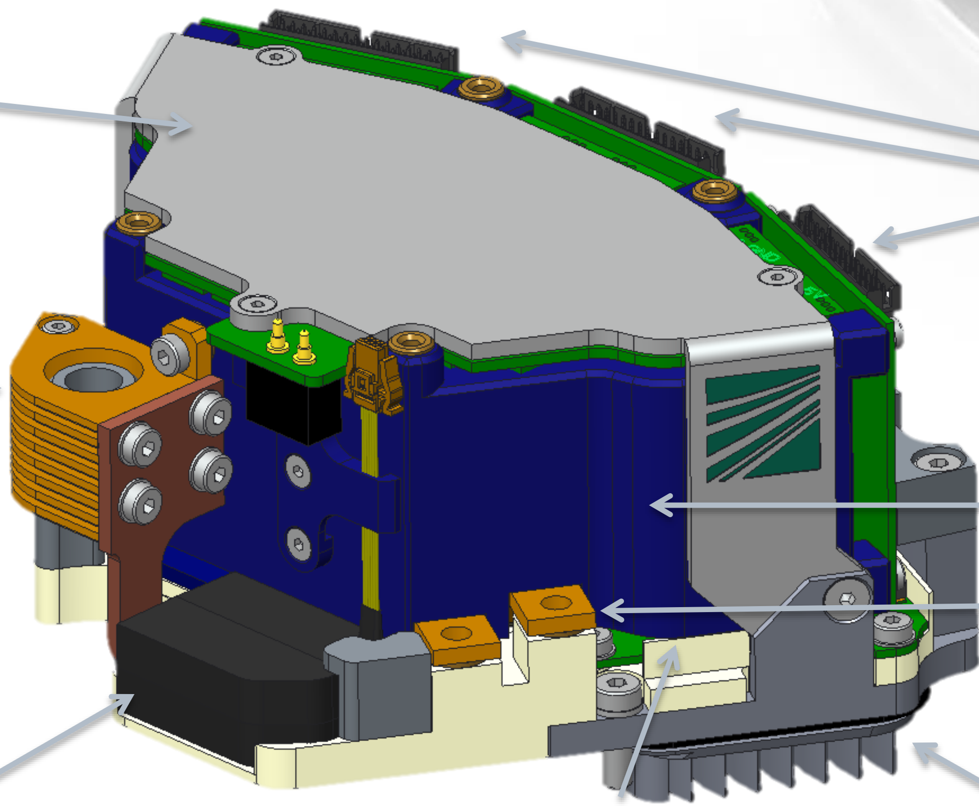
Inverter Building Block

- Complete half-bridge to drive one phase leg of the electric machine
- Mechanically self-supporting structure
- Reduced cable harness – direct board-to-board connection between drivers & Inverter Controller Module
- Piggy-back-board solution for extended driver functionalities e.g. Thermal Impedance Spectroscopy (TIS)
- Complete pre-assembling and testing possible



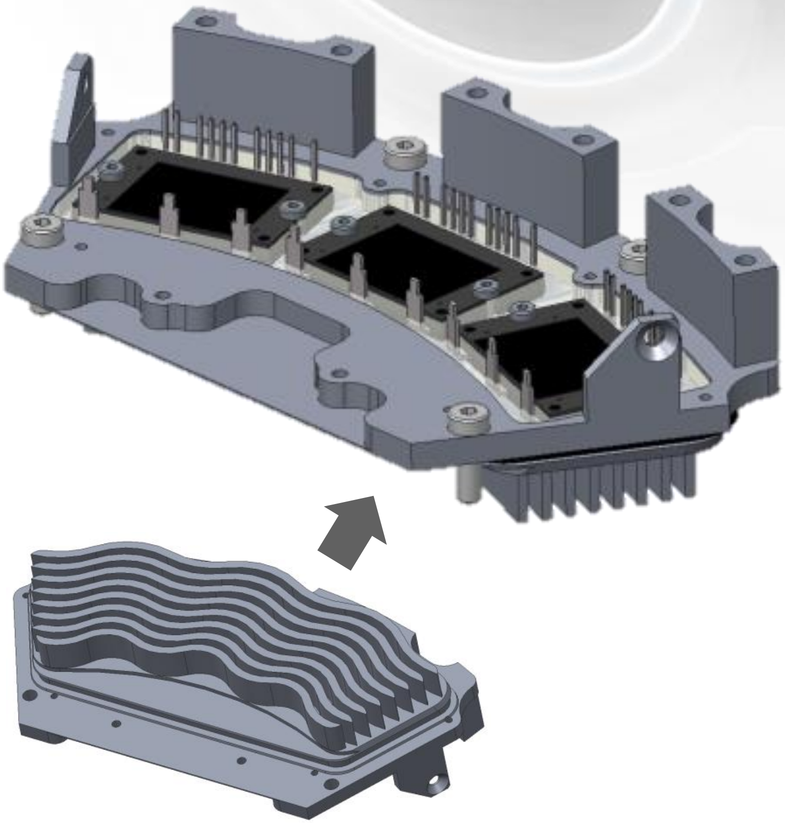


Inverter Building Block



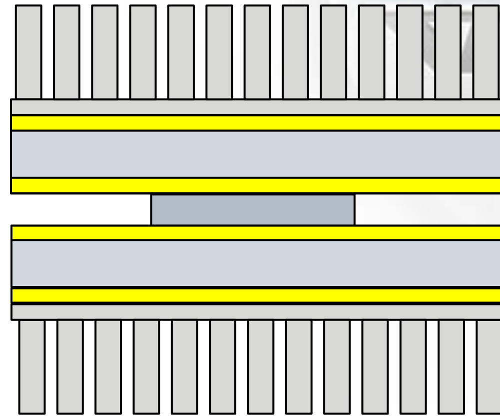
Single sided cooling IBB version

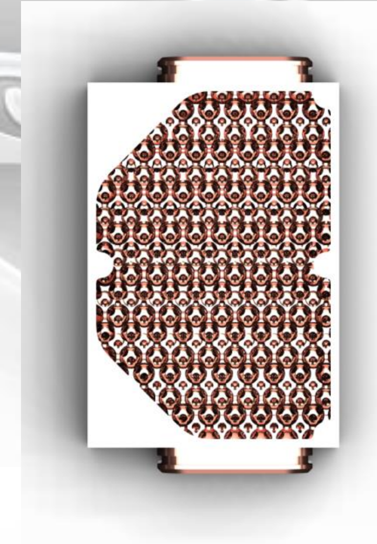
- Three paralleled SiC Power Modules
  - Max. 300 A_{RMS} phase current
  - Modular approach from the power modules over the IBB to the pluggable inverter
- Direct cooled IBB baseplate
  - Low thermal resistance from chip to fluid
  - High mechanical stability
  - FEM-optimized waves structure

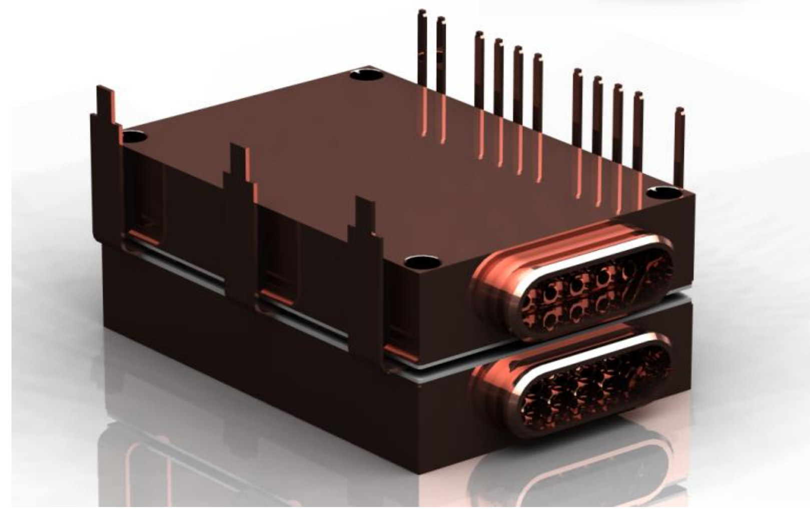


Power Module Cooling Concept
^{2}COOL

- Smaller devices → Improved current density and thermal conductivity → **SiC based power devices**
- Lower thermal resistance → increased current carrying capability/chip area → **double sided cooling**
- **Removal of wire bonds** significantly reduces switching cell inductance → high speed switching → lower switching losses.

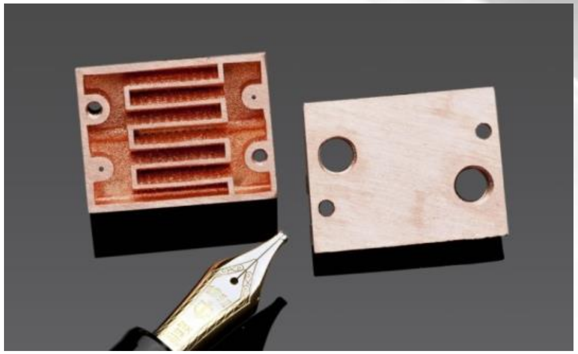


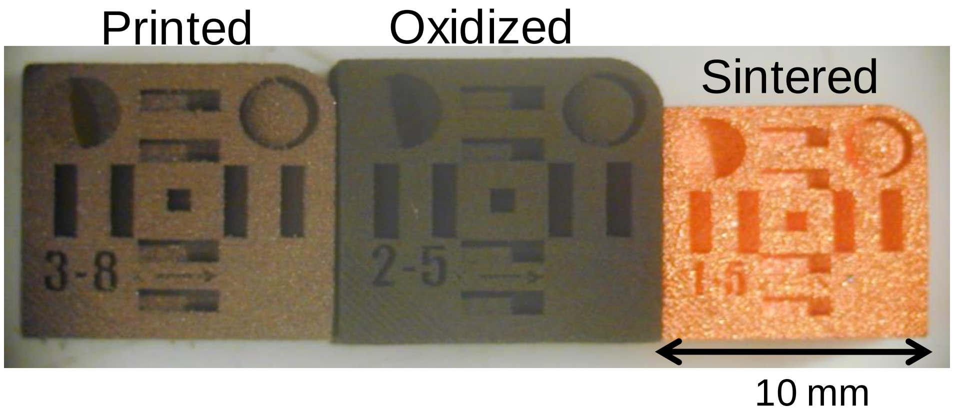




3D Manufactured Heat Exchangers

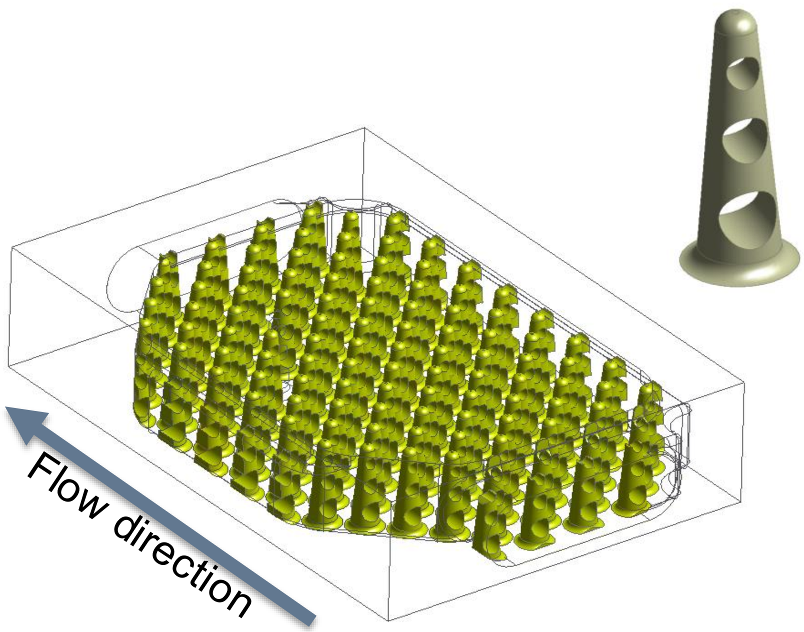
- Heat exchanger design based on novel 3D printing technology
- Process developed in FP7 project MORGaN.
- Thermal conductivity < bulk material.
- Large freedom in available geometries and an opportunity to try different new cooling concepts.
- No added material interfaces.



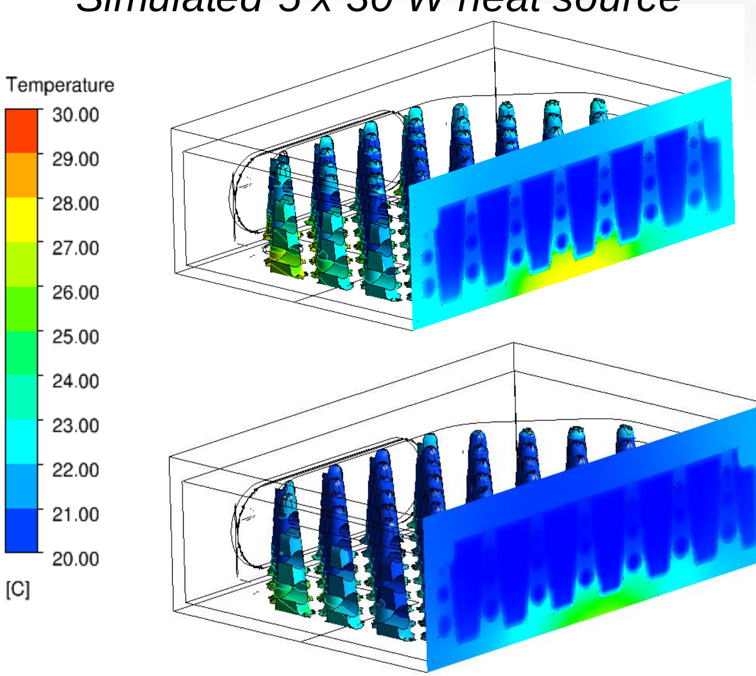


Modified Pin Fin Cooling Structure

- Staggered pins.
- Decreasing pin diameter towards cooler side resembling cone shape (improved conduction heat transfer from hot side).
- 3 holes/pin enabling better pin cooling and improved pressure drop.



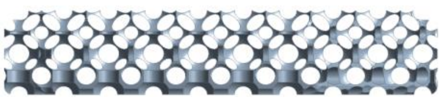
Simulated 5 x 30 W heat source



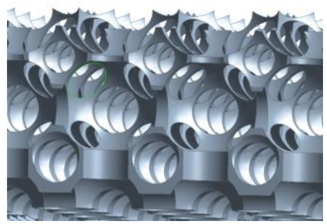
Graded Sponge Cooling Structure

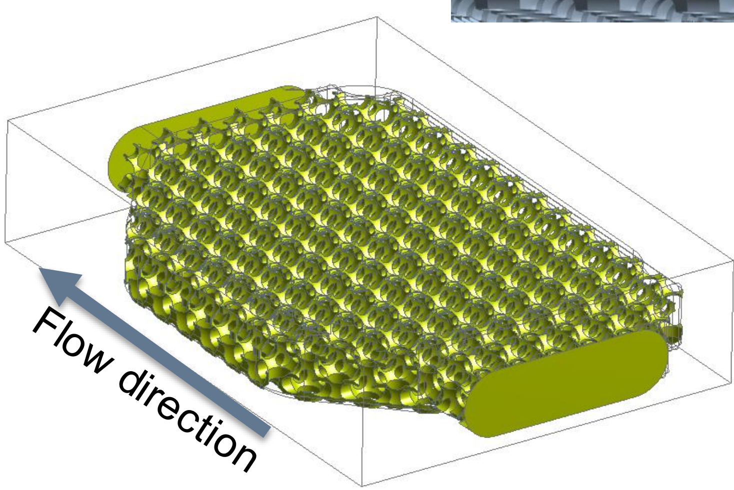
- Sponge structure to maximize interface surfaces.
- Sponge has increased wall thickness towards hot side of chassis.
- Improved conduction heat transfer into cooler fluid domain.
- Thinner walls improve pressure drop.

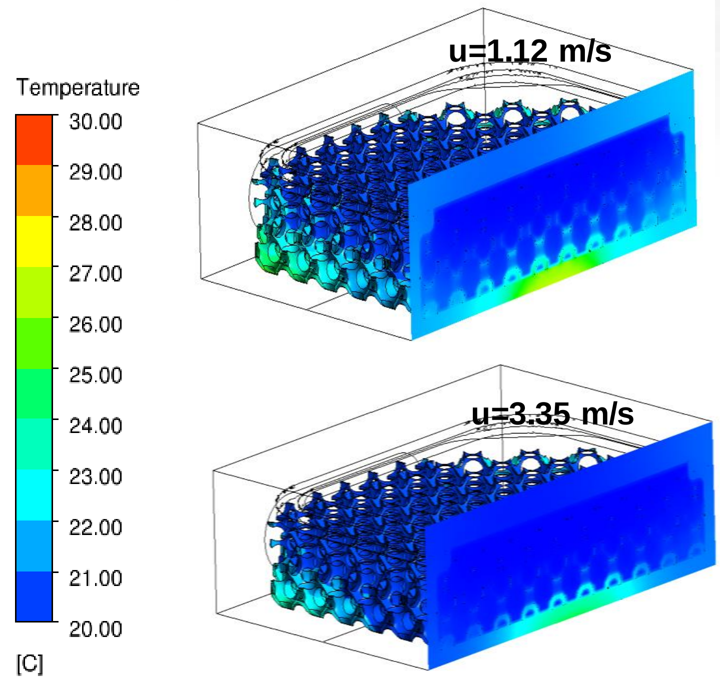
Simulated 5 x 30 W heat source



Sponge structure viewed from inlet







Design of cooler verified in stainless steel

Complex design verified using established process conditions

Next step – realisation in copper

Conclusions

- We have presented a Compact, Smart and Reliable Drive Unit for Commercial Electric Vehicles within the frame of the currently running project COSIVU.
- Furthermore the strategy for the system architecture was outlined and the Inverter Packaging Concept with its high integration level combined with high modularization was described in detail.
- Finally, a new package cooling concept, which integrates the cooling system with the substrate, was discussed and simulations on different cooling structures was presented.

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Thank you!

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