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Smart Components for the Software-Defined Vehicle of the Future

HiPE
High Performance Power Electronics Integrations

Advanced Chassis Actuators with 400V GaN Power Electronics

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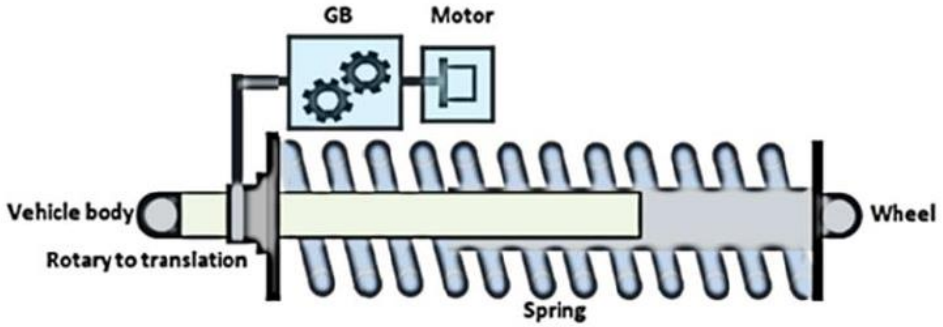
This Work

- This work is proposing an **electro-mechanical levelling system** based on WBG power electronic.
- The system is currently under development in the framework of the HiPE project. This presentation aims to motivate the choice of the technology and to show some preliminary simulation results
- Motivations:
  - A levelling device can enhance **EV's range** of autonomy by optimizing the height to appropriate driving situation
  - Electro-mechanical systems are novel and show the advantages to be **compact, less complex and cheaper** compared to hydraulic, pneumatic (air springs) or hydro-pneumatic systems (accumulators)
  - HV devices avoid voltage conversion
  - **GaN inverter improve efficiency**

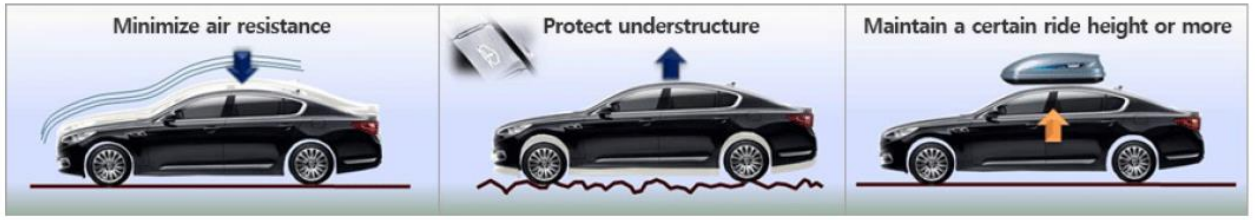
Concept

- Mechanical sub-system
  - The system consist of an actuator placed at each corner of the car
  - It is acting like a variable spacer, mounted between the top mount and the upper spring seat of the shock absorber
  - It is made of an electric motor, gear boxes and rotary to linear translation mechanism
  - The motor drive read the position and regulate the height according to the driver request, via a torque/current to the motor to provide force to lift the car



Concept

- Mission profile
  - The typical usage of the system will be:
    - On the **rear axle** to compensate for trunk loading, to improve comfort, maintain ground clearance and to ensure efficient passive cooling of the battery
    - On the **front axle** to adjust clearance for speed bumps and driveways;
    - On **both axle**: to lower the vehicle on highways and reduce drag coefficient and increase the range of autonomy.
  - HV system cannot be located in the wheel arches for safety reasons. The electronics will mostly operate in an environment exposed to moderate temperature (max 70°C) but without air flow to dissipate the heat. This motivate further the need for a highly efficient power electronics to reduce the heat dissipated by the system
  - The changes will be manually selected by the user with a maximum of few time per minute. The duty cycle is therefore not very intense for the power stage



Concept

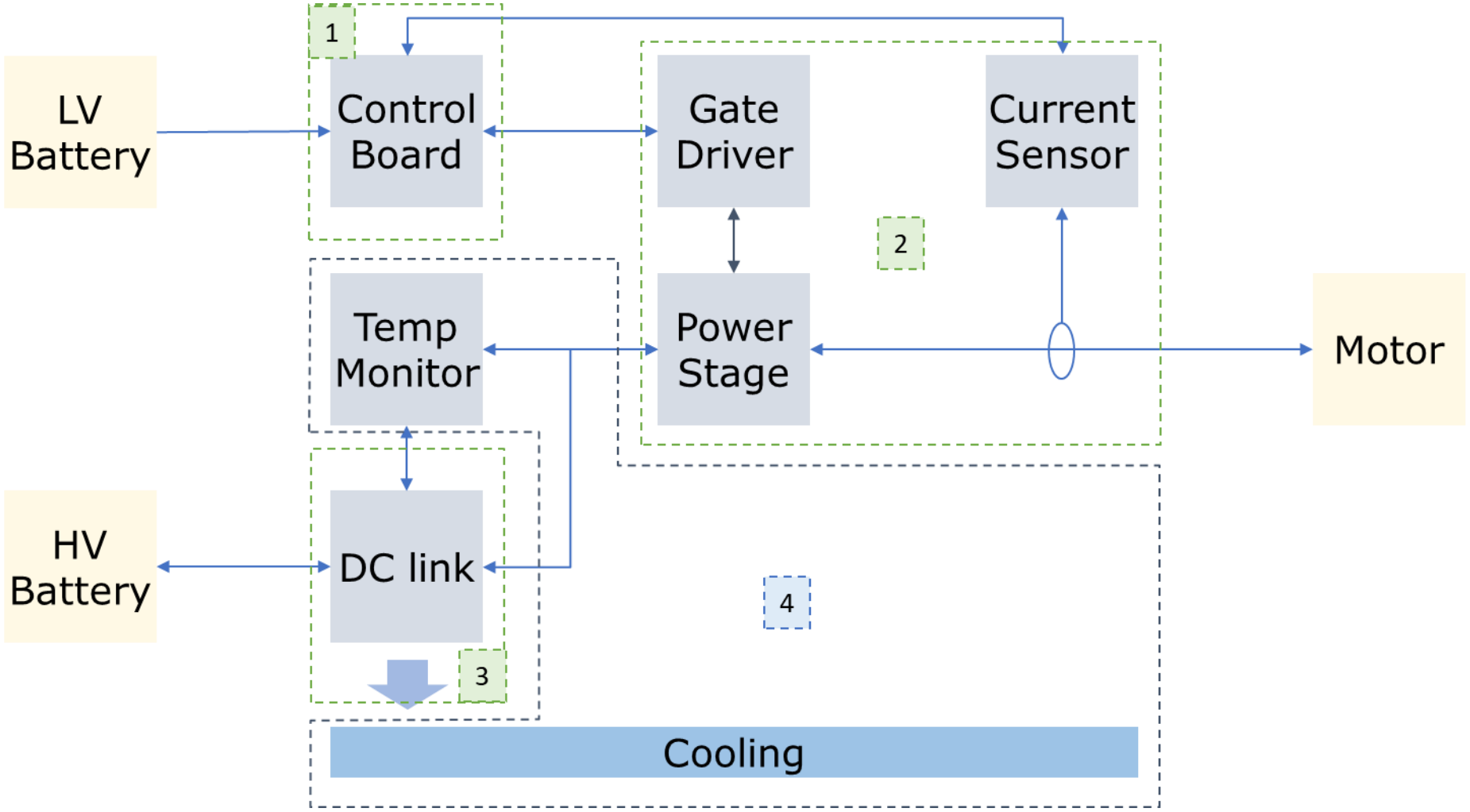
- Motor drive
  - Structured in a **modular** way to be easily adapted to different applications
  - Composed of three separate blocks
    - The Control Board
    - The Gate-Driver Board
    - The Power Stage

- Two different power stages for comparison
  - Silicon based
  - GaN based

- Based on automotive-grade microcontroller
- Integrating safety functionalities (native ASIL-B)
- External communication interfaces
- Sensor conditioning

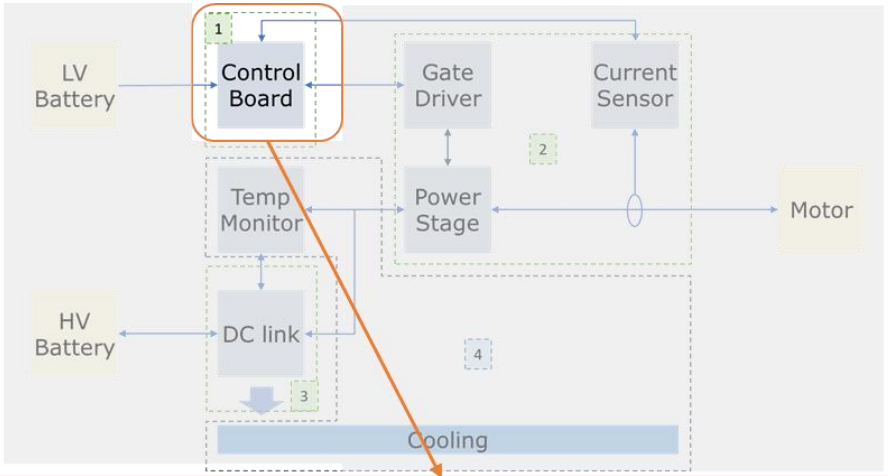
- Signal adaptation between uC and power stage
- High-voltage insulation

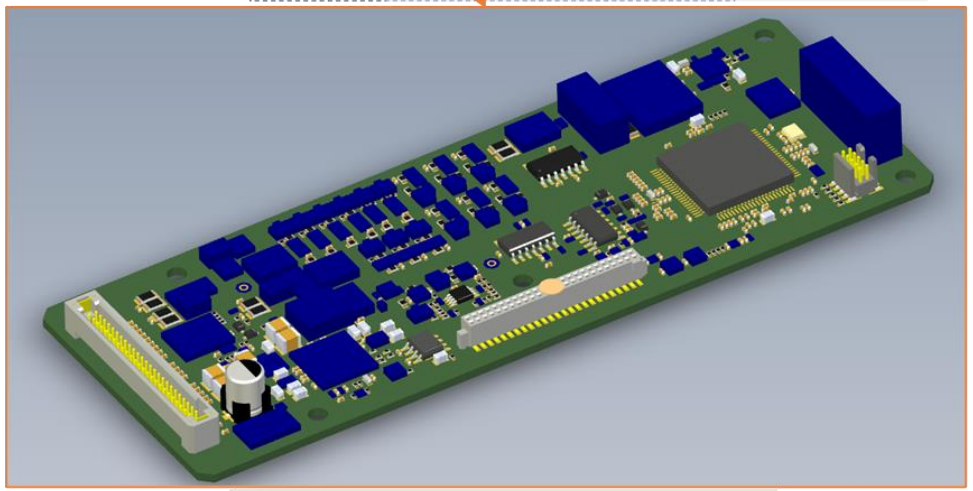
HV Inverter Architecture



1. Control Board

- Digital subsystem
  - Under development
  - Based on NXP's S32K3 microcontrollers (ARM core for automotive application)
  - Flexible I/Os for easing the **reuse** of the control platform
- PCB
  - Schematic entry: Completed
  - Layout: Completed
- Schedule
  - First prototypes available for internal testing: August 2024
  - Board testing: Completed successfully

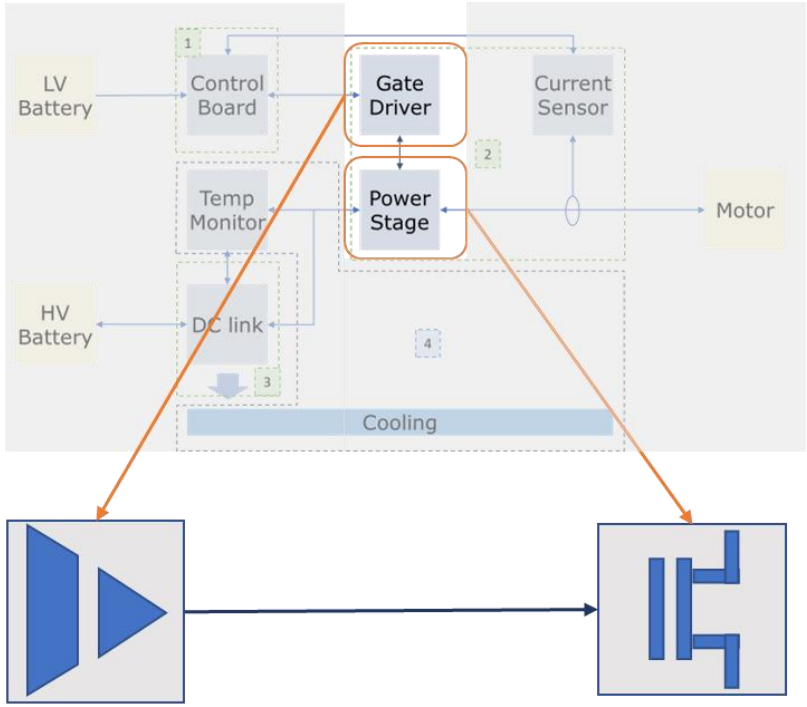




3D of the board in production

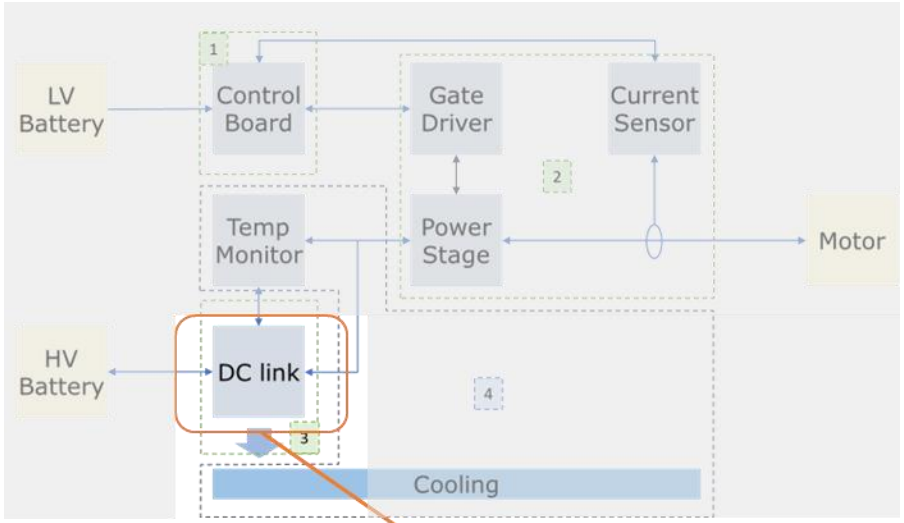
2. Power Stage + Gate Driver

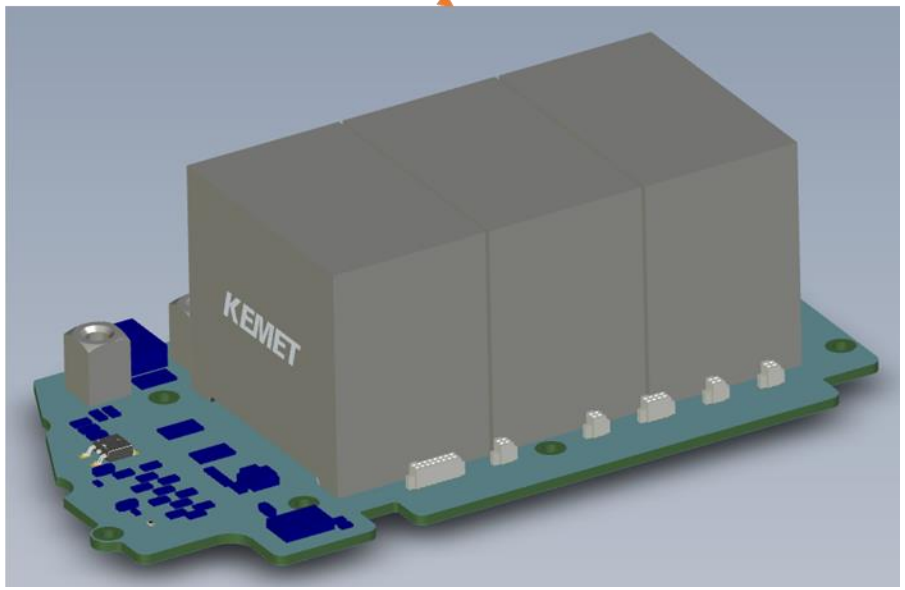
- Design
  - Simulation: completed
  - Architectural design: completed
  - Component Selection: completed
- PCB
  - Gate Driver
    - Schematic entry: Completed
    - Layout: Completed
  - Power Stage
    - Schematic entry: Completed
    - Layout: To be finalised
- Schedule
  - First prototypes (Gate Driver): Received, to be tested
  - First prototypes (Gate Driver): End of 202



3. DC-Link

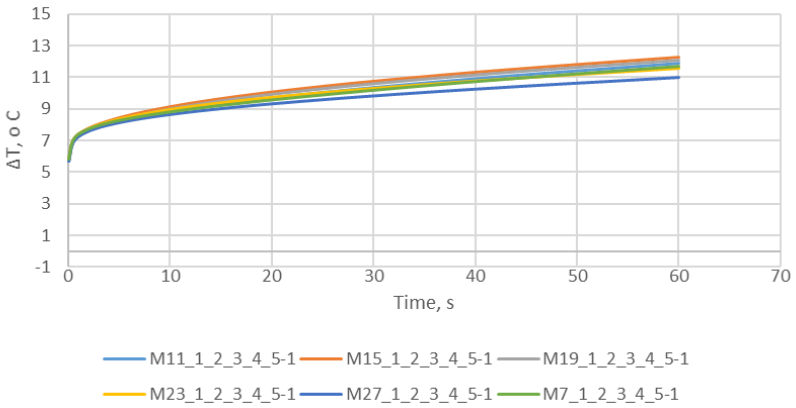
- Capacitor sizing has been done according to electrical and thermal constraints
- A hybrid architecture, based on film and ceramic devices, has been studied to conjugate
  - low impedance at high frequency
  - high current capability
  - a reasonable cost
- Schedule
  - Device selection: Completed
  - First prototypes: September 2024 (assembled on the power stage)
  - Testing: Ongoing



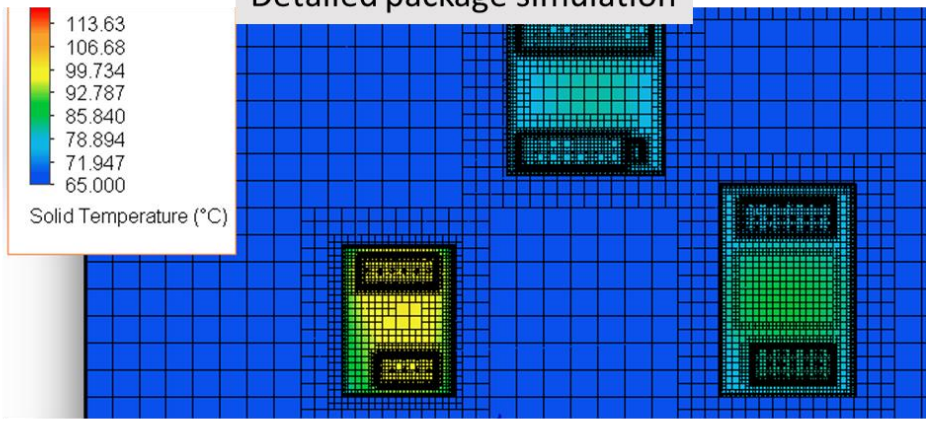


4. Cooling System

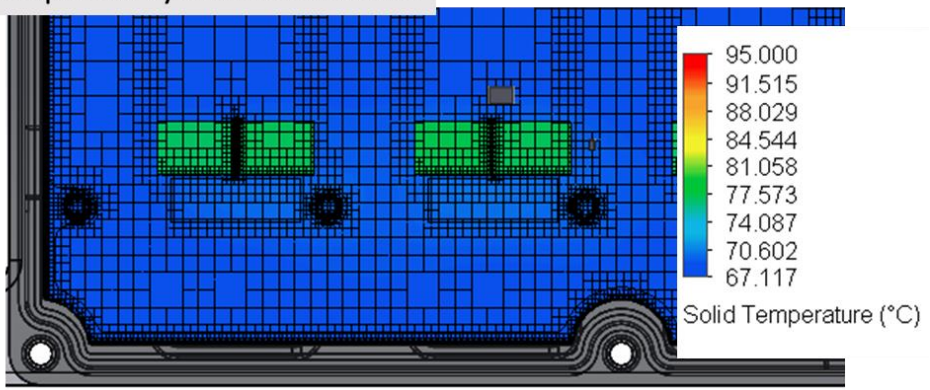
- Only air-cooling will be available for this application
- Transient simulation to emulate the usage
- Cooling properties studied in WP6
- Scheduling:
  - Simulation activity: Completed
  - Mechanical design: Completed
  - Final report: Part of D6.2



Detailed package simulation

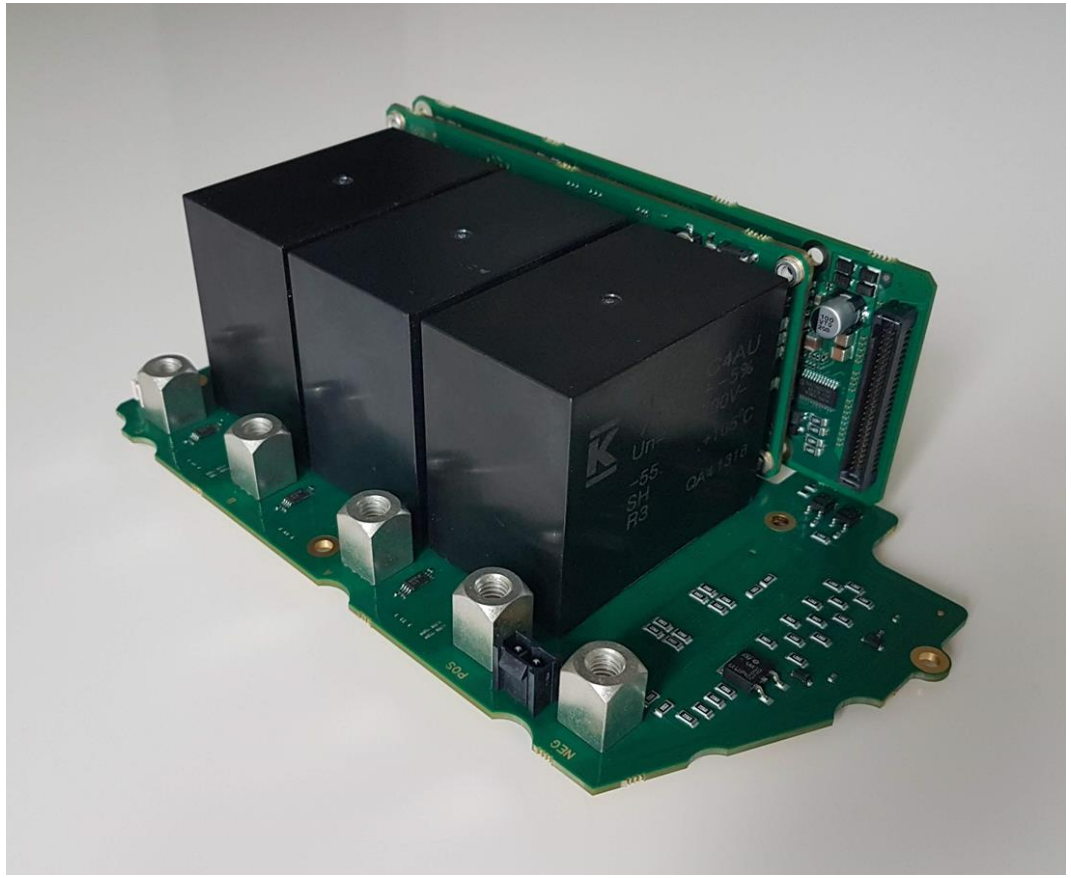


Simplified system simulation



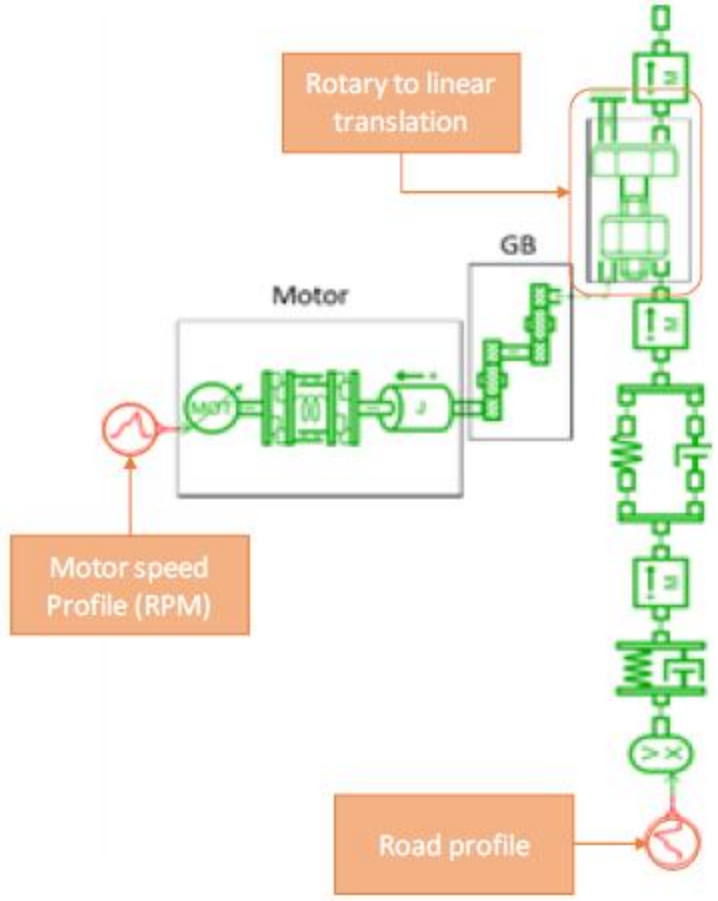
First Prototype

- The first prototype has been (partially) realised (the final power stage is still on the way).
- It will go in the testing phase very soon to check if expected performance have been achieved.
- Expected performances:
  - Operating Voltage: 350 – 450 V
  - Switching frequency: 20k Hz
  - Output current (rms, cont.): 50 A
  - Output current (rms, peak): 150 A



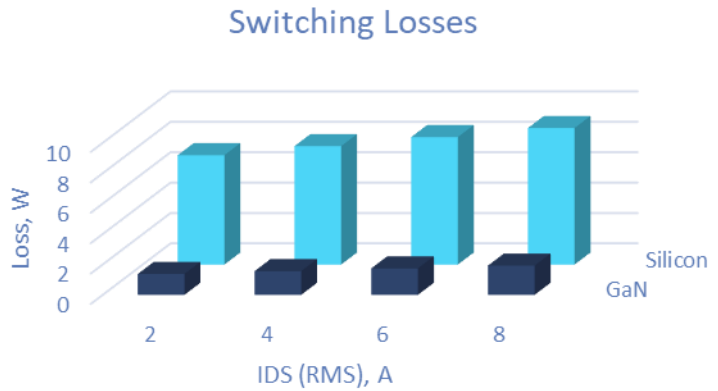
Simulations

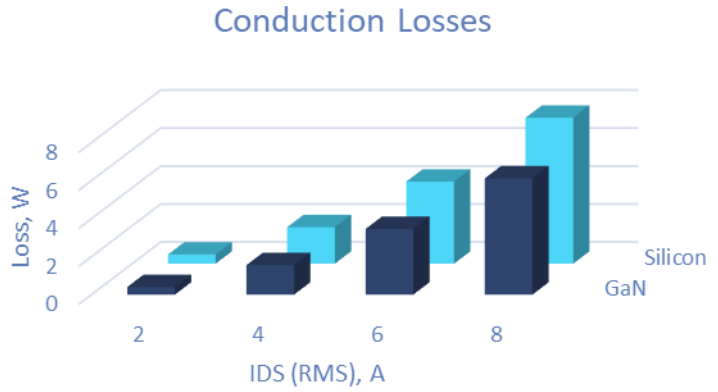
- Electro-mechanical device
  - The full model is developed with Amesim software
  - The motor, gear box and rotary to linear translation mechanism are connected to a quarter car
  - The system is sized to lift a typical **light SUV at 10 mm/s** in each direction
  - **INPUTS**: the user profile is translated to a motor speed profile (in RPM) and is working under a certain road profile
  - **OUTPUTS**: related torque and power request



Simulations

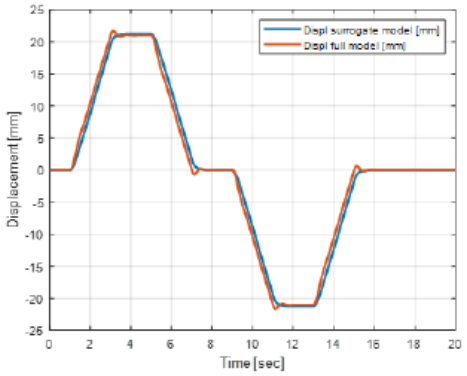
- Electronics
  - Two different power stages, one silicon-based, one GaN-based
  - To compare these implementation an accurate thermal model is needed
  - Losses
    - Conduction losses have been extracted from datasheet parameters
    - Switching losses have been extracted from SPICE models
  - Both power stages have been described inside the SimPLE modelling environment and simulated to estimate power losses and junction temperature
  - The net result is shown in the graph aside: up to 85% reduction in the switching losses and up to 20% reduction in conduction losses



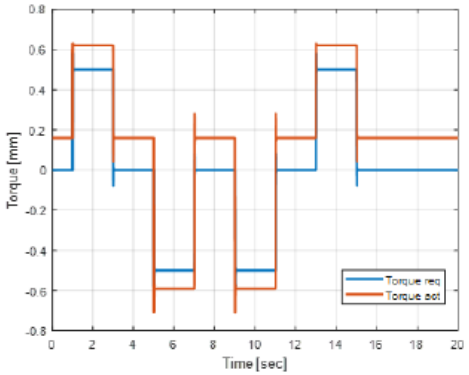


Simulations

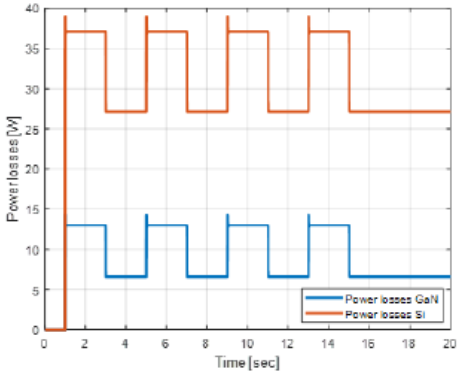
- Results
  - Examples of system-level simulation showing:
    - The displacement request profile (a)
    - The torque delivered (b)
    - The power loss of the motor drive (c)
  - Good agreement between the full models and the combined surrogate model
  - It shows the potential of h**igh-level simulation model to evaluate complex behavior** and estimating functional details of subparts



(a)



(b)



(c)

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Thank you!

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