Embedding electrochemical impedance spectroscopy in smart battery management systems using multicore technology

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Agenda

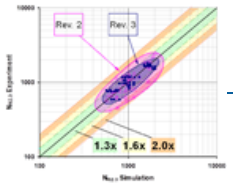
- INCOBAT project in a nutshell
- Deployment of safe and secure multicore-based computing platforms
- Embedding EIS in automotive control units
- Thermo-mechanical stress investigations
- Outlook: demonstrator vehicle integration

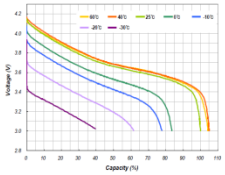
INCOBAT project in a nutshell

*IN*novative *CO*st efficient management system for next generation high voltage *BAT*teries

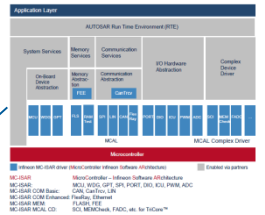
INCOBAT – key facts

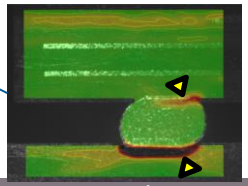
- **Project Name:** INCOBAT - INnovative COst efficient management system for next generation high voltage BATteries
- **Funding:** European research project ICT STREP (FP7)
- **Project Duration:** 39 months
- **Duration:** Oct. 2013 – Dec. 2016
- **Budget:** 5.8M€





Participant organization name	Country	Status
AVL List GmbH	AT	LE
Ideas&Motion	IT	SME
Fraunhofer Institute ENAS (Chemnitz)	DE	RE
Infineon Technologies Austria AG	AT	LE
Infineon Technologies AG	DE	LE
Impact Clean Power Technology S.A.	PL	SME
Kemet Electronics Italia SRL	IT	LE
Chemnitzer Werkstoffmechanik GmbH	DE	SME





INCOBAT – abstract

The aim of INCOBAT is to provide **innovative and cost efficient battery management systems for next generation HV-batteries**. To that end, INCOBAT will propose a **platform concept** in order to achieve cost reduction, reduced complexity, increased reliability as well as flexibility and higher energy efficiency.

The main outcomes of the project will be:

- Very tight control of the cell function leading to **an increase of the driving range** of the FEV for current chemistry and by enabling the use of new cell chemistries such as LiS or even Li-air
- **Radical cost reduction** of battery management system
- Development of **modular concepts for system architecture and partitioning, safety, security, reliability** as well as **verification and validation**, thus enabling efficient integration into different vehicle platforms.
- INCOBAT is in the position to provide a 100% European value chain for the development of next generation HV battery management systems.

INCOBAT – innovation topics

Customer needs and integration aspect

1 Mission profiles

12 Car demonstrator / vehicle validation

Ensure ***validity of the technology*** for integration in vehicle platform

Transversal innovation: consistent concept and specification

2 Model-based systems engineering

3 System architecture – efficient partitioning of the functionalities

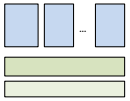
4 Integration of multiples functionalities (such as charging and billing)

Provides more ***consistent system definition*** and enables ***global optimization*** (instead of local)

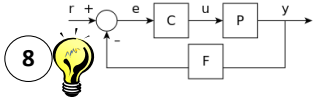
Technology innovation: E/E control system

5 TriCore AURIX platform for additional computing resources

6 Smart and integrated module management unit



7 Modular SW platform



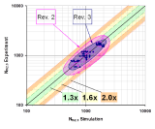
8 Improved BMS control algorithms

Provides innovation for the E/E control system based on ***multicore*** technology and ***smart sensors***

Transversal innovation: improving system maturity

9 Definition and integration of safety and security concepts

10 Design and validation plan including reliability consideration



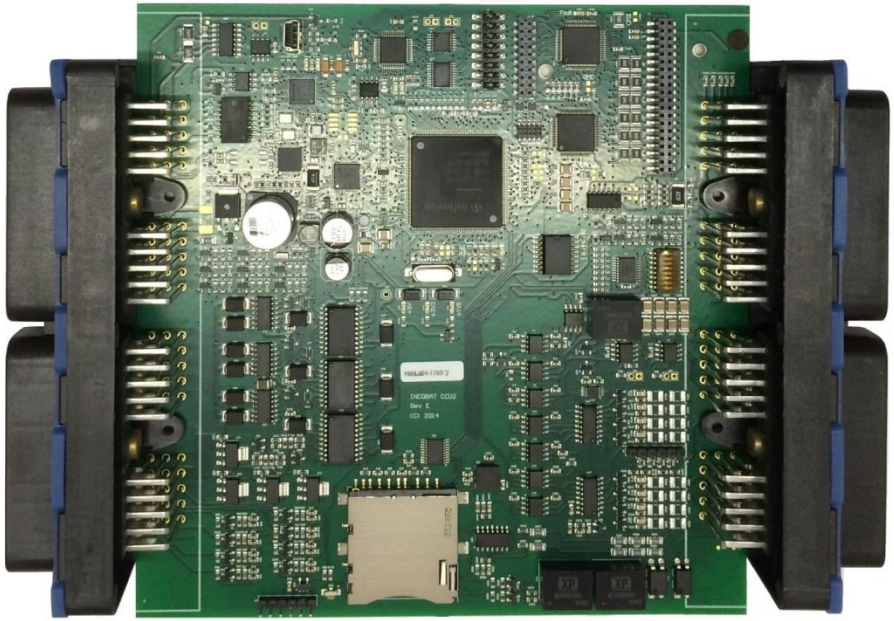
11 Reliability and robustness assessment

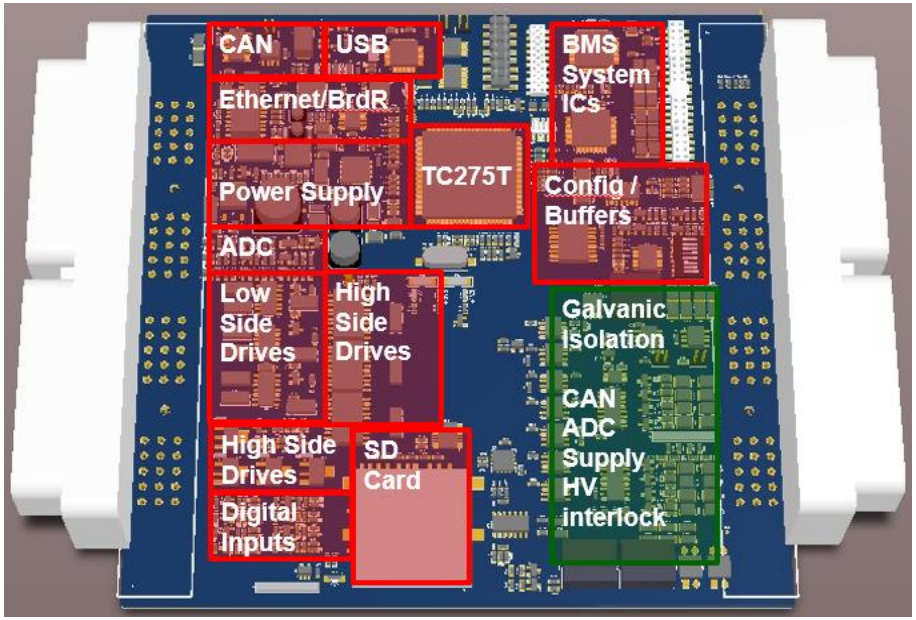
Ensure the ***maturity and readiness for industrialization*** of the proposed technology

Deployment of safe and secure multicore-based computing platforms

Targeting mature demonstration of
the technology based on open source solutions

INCOBAT iBMS-CCU Prototype

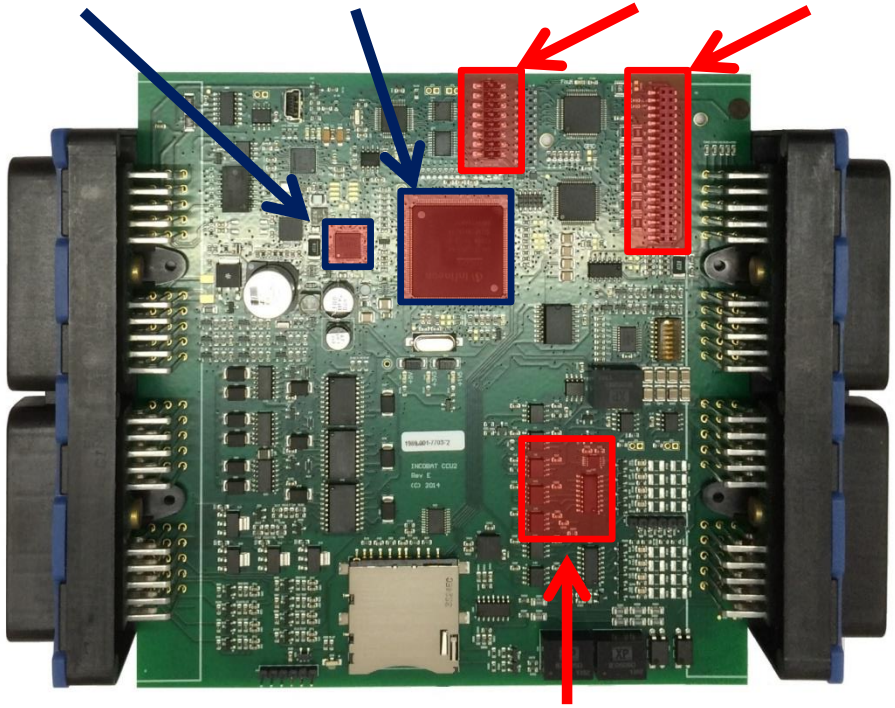




- ***Lowest cost*** BMS system solution by fully integrating all main BMS functions into one ECU
- ***Close-to-production platform*** supporting the exploitation of advanced BMS approaches
- ***Reduced system installation space***, high level of integration and of functional density
- **Comprehensive hardware safety measures** by Infineon AURIX™ and Safety Power Supply ASIC

INCOBAT iBMS-CCU Prototype Safety and EIS

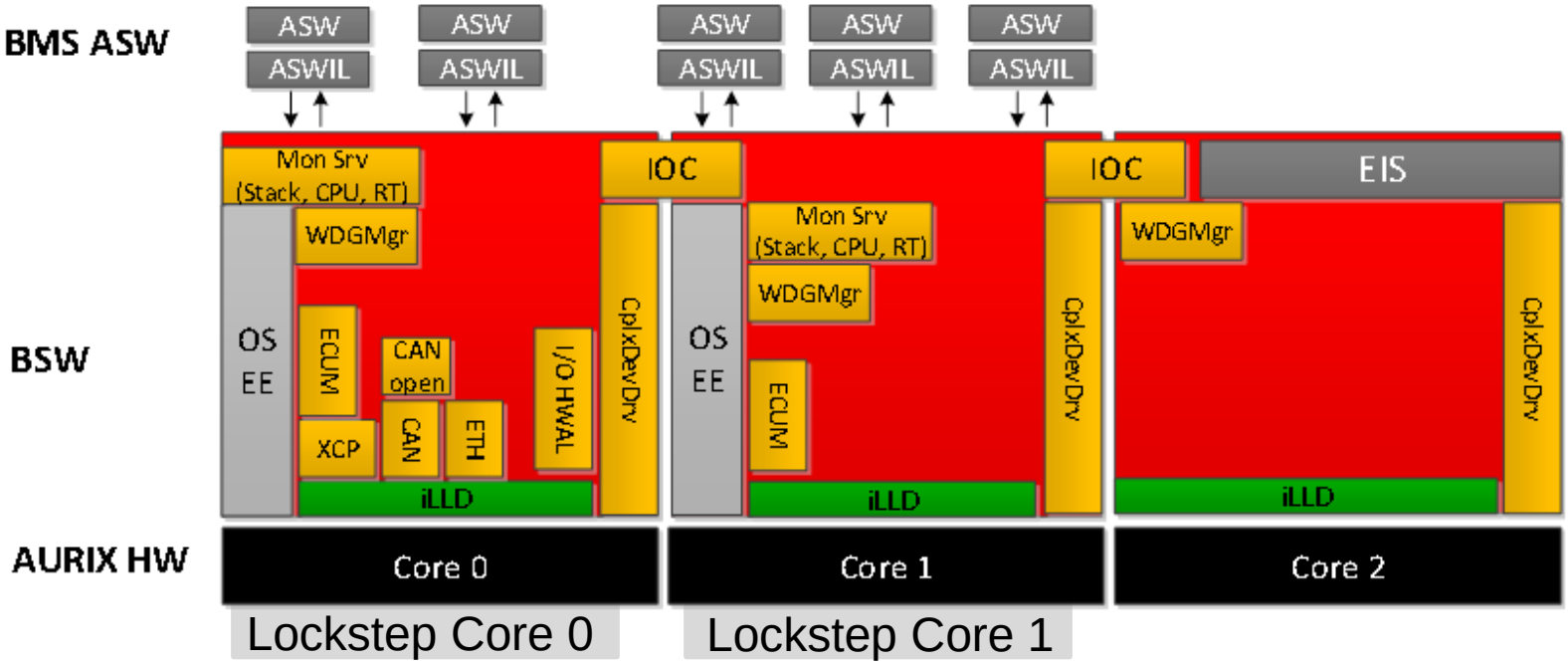
Safety Power Supply ASIC AURIX TC275 Connectors for EIS Expansion Board



ADCs for EIS signal capturing

- EIS hardware was put to an expansion board for risk mitigation

INCOBAT SW architecture



SW association to cores according to safety considerations:

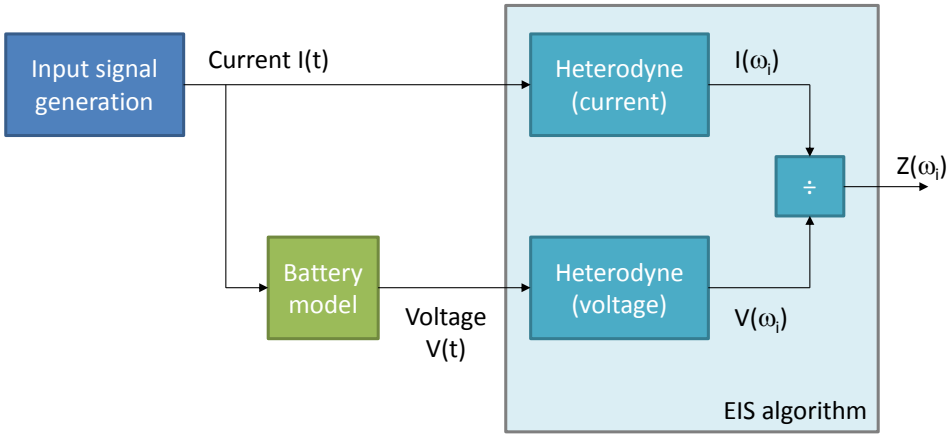
- Core 0: safety (monitoring functions) and I/O management
- Core 1: battery state estimation algorithms
- Core 2: Electro-chemical Impedance Spectroscopy (EIS) algorithm

Embedding EIS in automotive control units

Targeting more comprehensive battery state evaluation

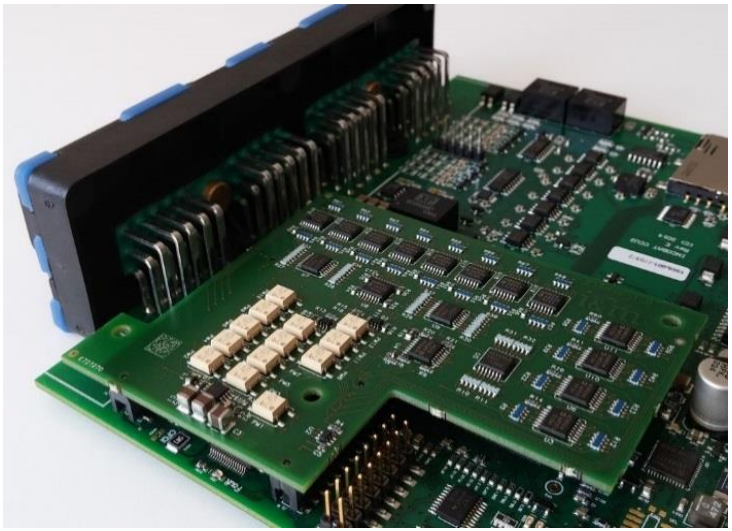
EIS algorithm

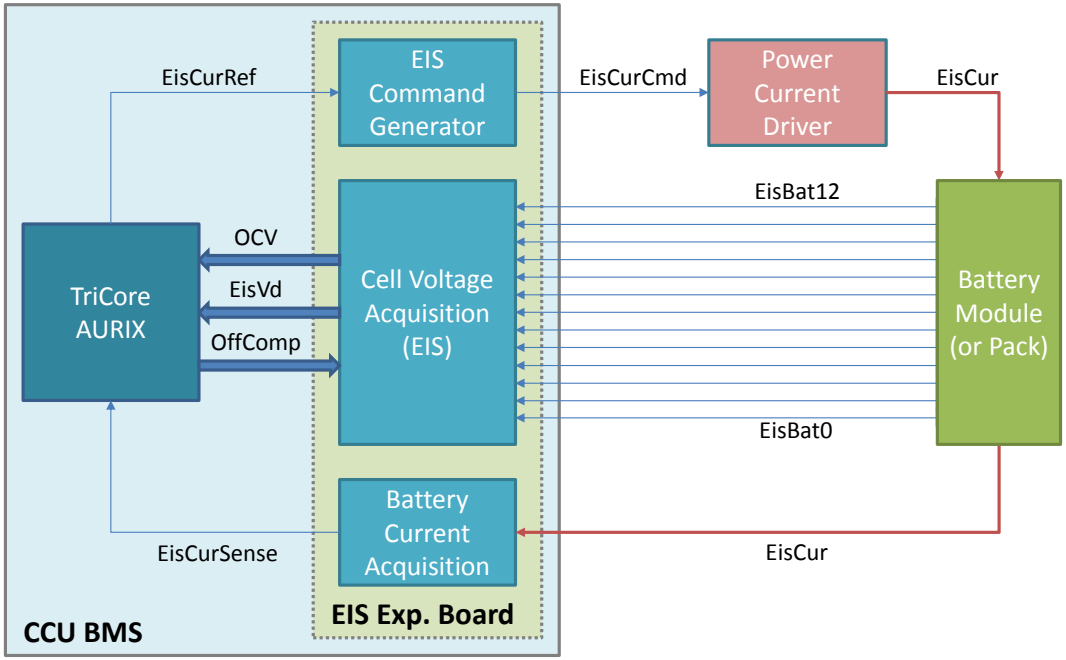
- ***Downscaling*** of existing EIS technology to fit on automotive embedded computing platform, using simple calculations that can be performed on real time
- Approach based on **heterodyne** and coherent demodulation to reduce amount of data to process while still having a good coverage over the frequencies
- The development of EIS algorithm in INCOBAT has been supported through dedicated development of HW and SW solutions



EIS: HW development

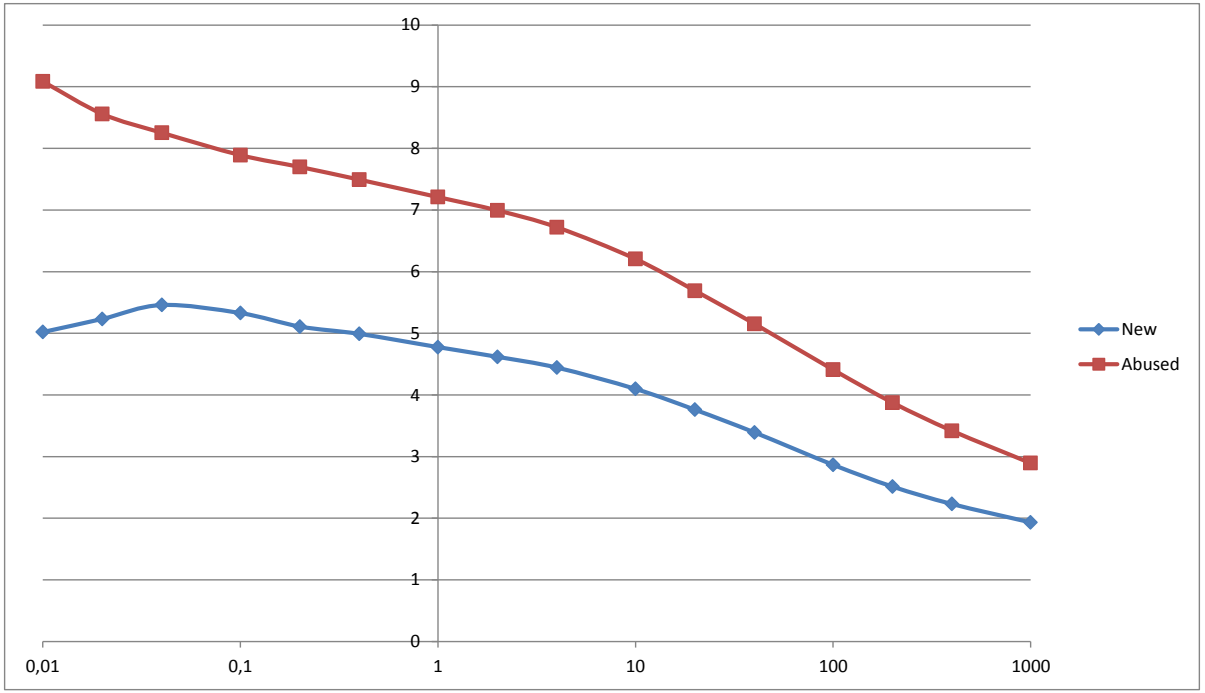
- EIS currently available as discrete solution (prototyping platform); integration in standard smart sensors already evaluated





EIS: tests over different scenarios

- Several tests were performed, using cells with different ageing and SoC conditions
  - For instance, the picture shows a new cell, and an abused, inflated cell
  - Most of the variations were noticed on the cell resistance (module), that changes significantly between one cell and the other

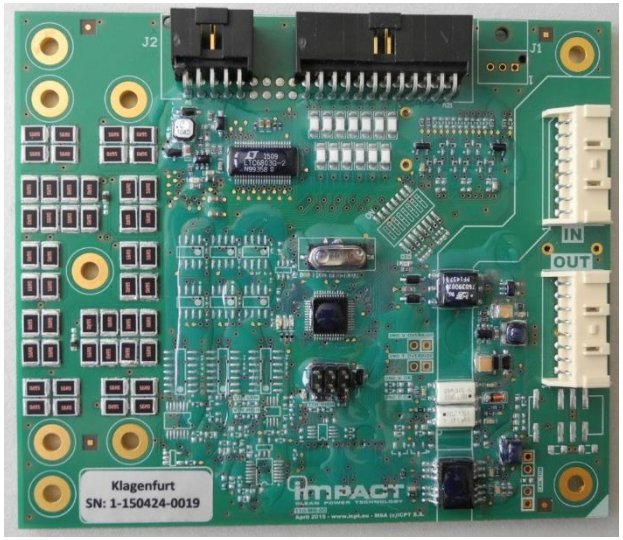


Thermo-mechanical stress investigations

Targeting more comprehensive reliability assessment of the electronic platform

Key points of the reliability assessment during the design phase are:

- Ensuring ***functionality of the modules during lifetime*** due to the definition of design rules at the beginning of the development phase
- ***Environmental tests*** by considering different load cases (temperature, vibration and humidity)
- Lifetime tests to ensure the electrical functionality during the module life time



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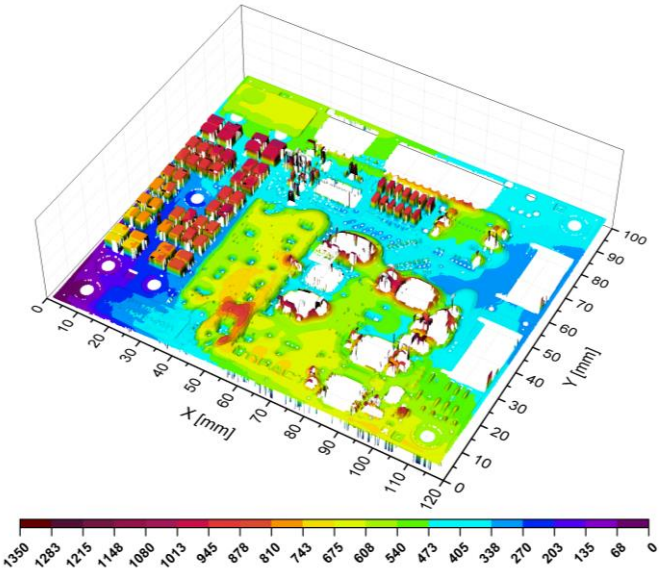
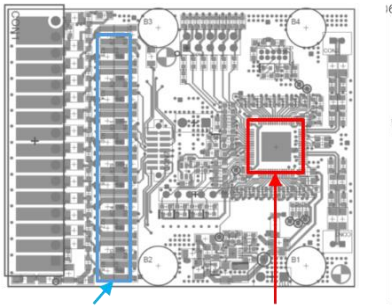


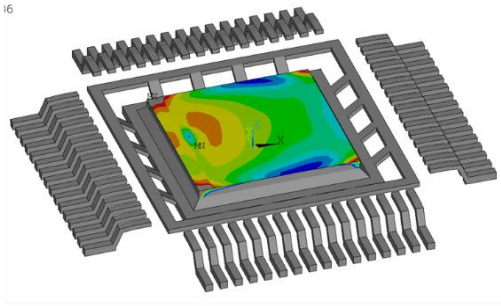
Ensuring functionality of the modules during development phase

- Within INCOBAT, the ***temperature behavior of overall BMS satellite board*** was physically tested in order to assess the dependences on:
  - location of the balancing resistors,
  - balancing power losses,
  - number of cells,
  - and intrinsic power losses of the measurement chip.

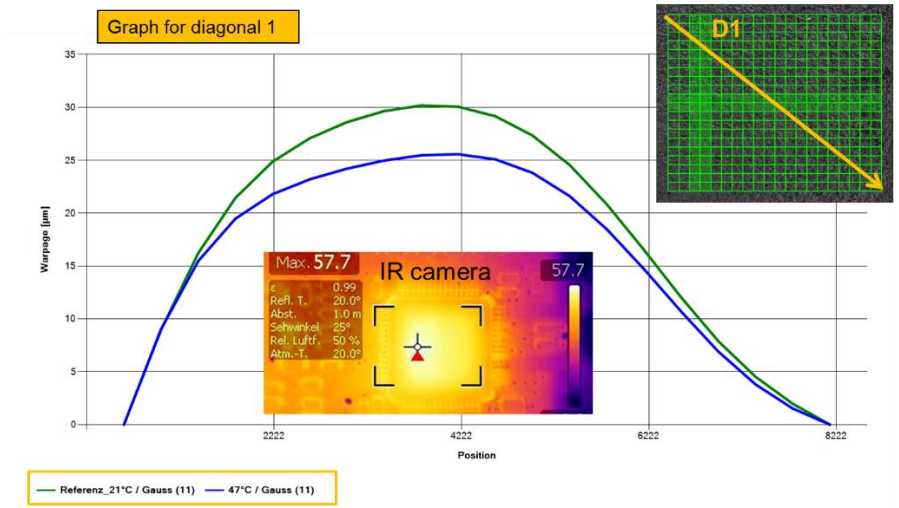
→ With this information the ***thermo-mechanical stress within the package*** of the measurement chip (which has influence on measurement accuracy) was investigated and optimized

Thermal-mechanical behavior of the measurement chip (BMS satellite board) during operation:





Experimental verification of numerical simulation:

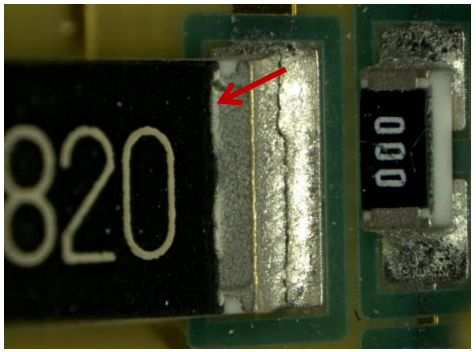


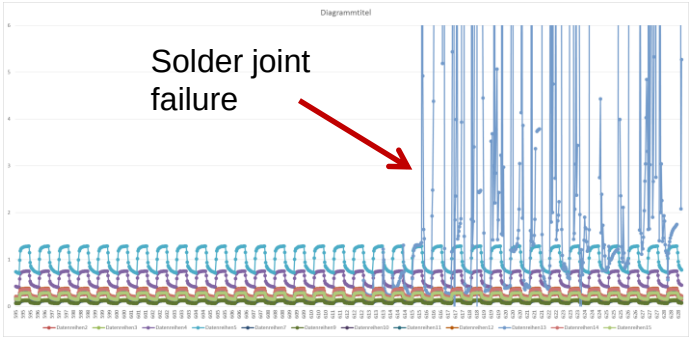
Environmental and lifetime testing

- ***Environmental and accelerated lifetime testing*** is an essential part of the technological qualification process
- The goal is to check and validate the functionality over lifetime by considering all relevant external (and internal) load conditions
- Within INCOBAT, new test schemes for ***combined reliability tests*** are investigated → Goal: Triggering of more realistic failure mechanisms and reducing testing time
- As test vehicles, dedicated test boards with various daisy-chain structures for in-situ monitoring (e.g. of solder joints) as well as INCOBAT BMS electronic boards are used

Test bench for accelerated lifetime tests:

Example of failed solder joint:





Outlook: demonstrator vehicle integration

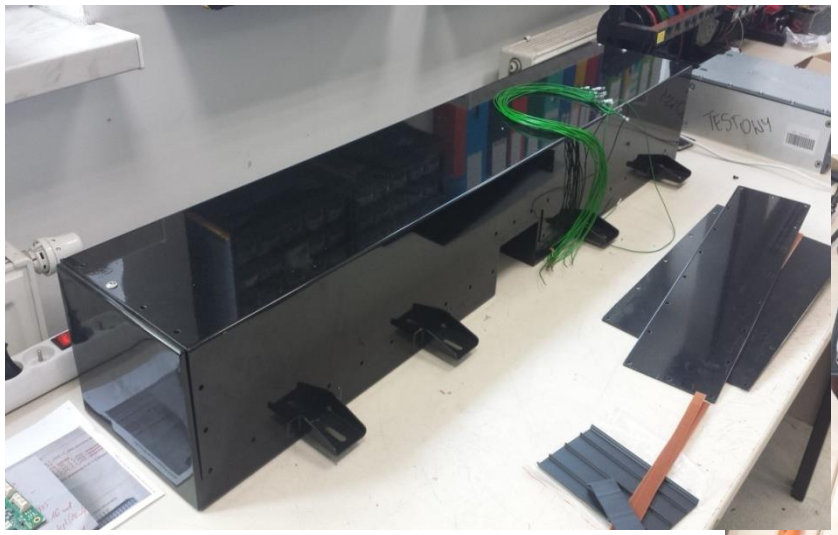
Illustrating the maturity and use-ability
of the INCOBAT technologies

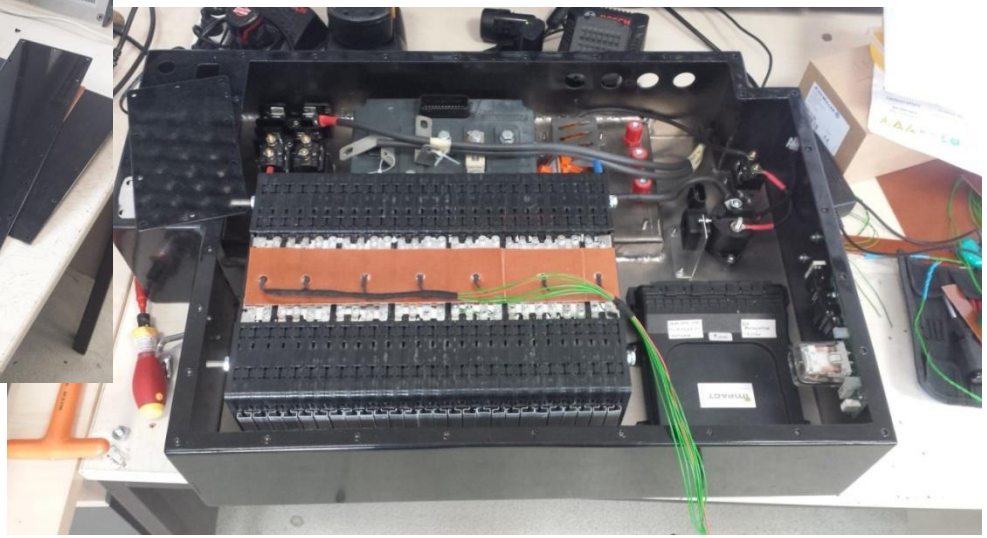
Integration into battery modules

- Battery modules has been purchased and reassembled into fitting electric blocks. Connections had to be redesigned to meet 6s4p (12s4p) requirements. Original modules were 12s2p configured.

Integration into battery packs

Two battery packs at front and rear of the vehicle





Vehicle demonstrator

Basis vehicle: Renault Twingo 2004 , modified as eVehicle running with battery pack

Conclusion

- INCOBAT project delivering solutions for ***improving E/E control systems*** for HV batteries based on multicore CPU (AURIX™)
- ***Flexible and cost-optimized*** development and test environment proposed
- ***EIS as innovative control strategy*** for more accurate estimation of the battery state