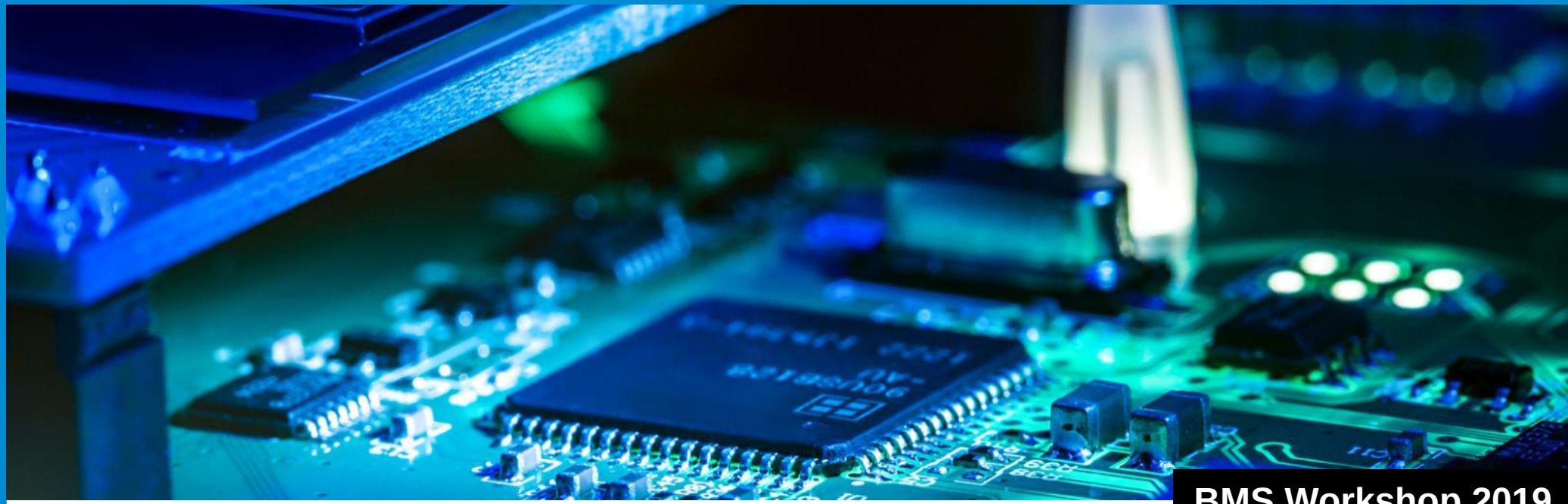

BMS Workshop 2019

Advanced Functional Safety in Battery Management Systems based on Advanced BMS Solutions

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Mirko Vogelmann
Product Sales Manager Power
Gerrit-Jan Van Os
Field Application Engineer

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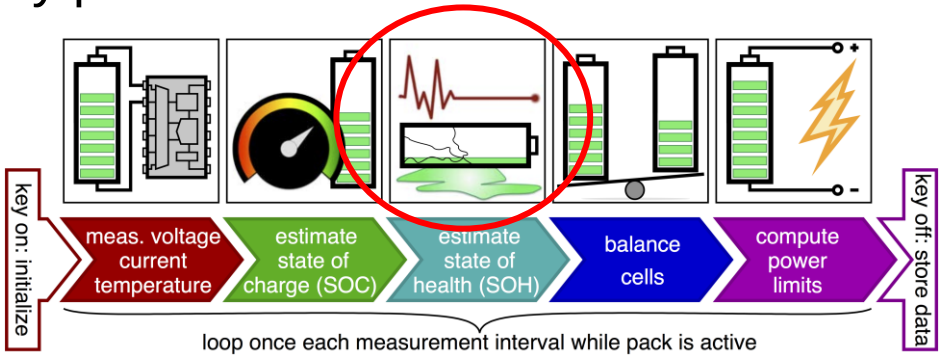
Content

- Motivation – EV Battery Management
- Thermal Runaway
- Thermal Model Behavior and Thermal Management
- New Advanced Diagnostics Features
- System Structure and Implementation
- Results and Conclusion

Challenges

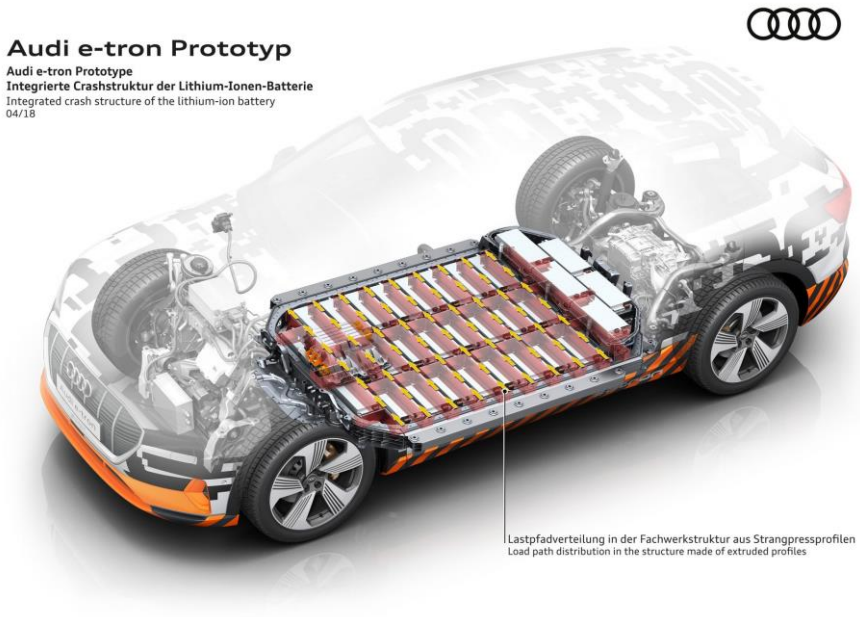
Functions of a battery management system

- Battery models and simulation of battery packs
- Battery state estimation
- Battery health estimation
- Cell balancing
- Voltage-based power limit estimation
- Aging mechanisms and degradation models
- Optimized controls for power estimation

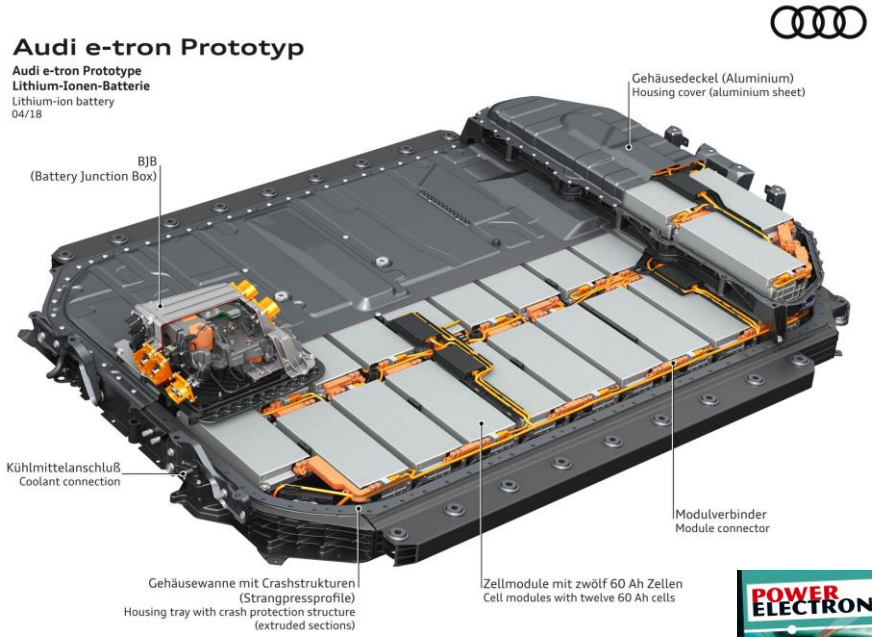


Source Figure UCCS University of Colorada Colorado Springs

Integrated Crash Structure of the Li-Ion Battery



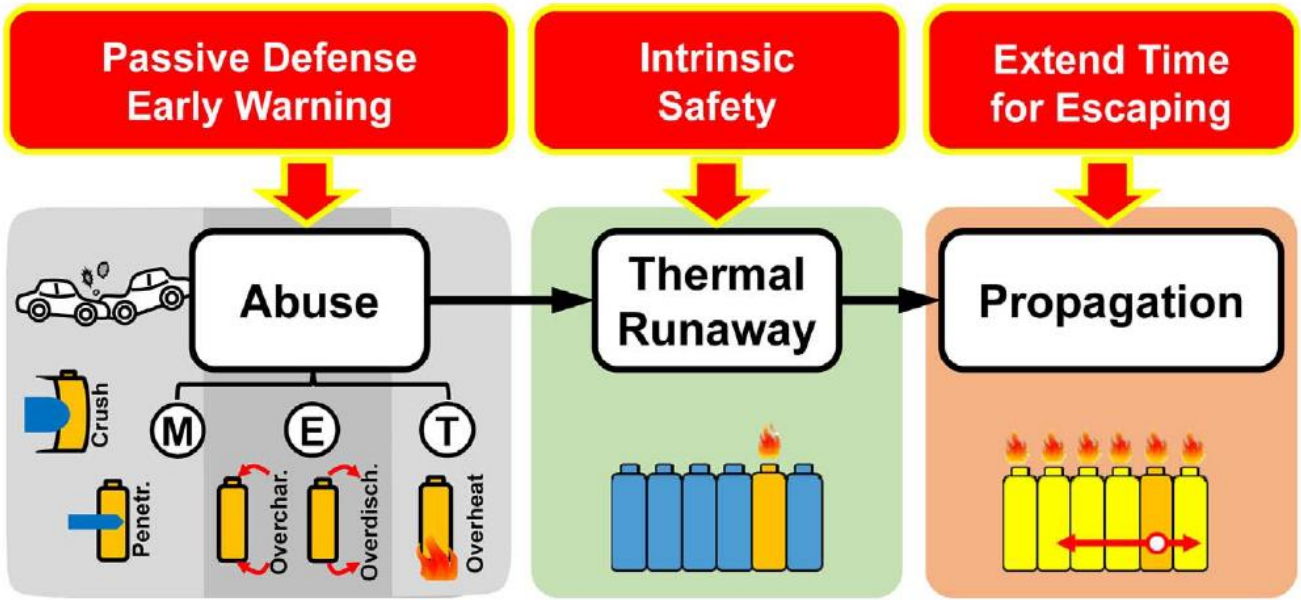
Battery System Structure



Source: Audi Media Center, Automobil Produktion

Thermal Runaway

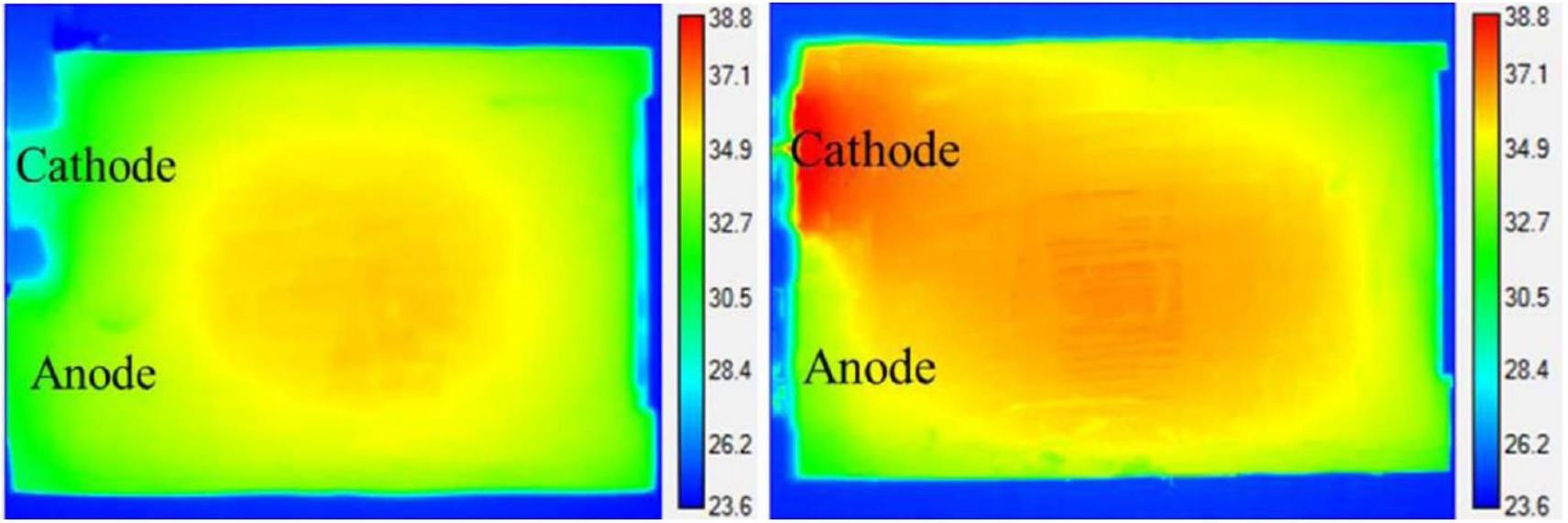
The three-level strategy of reducing the hazard caused by thermal runaway.



Source: [1] Thermal runaway mechanism of lithium ion battery for electric vehicles: A review; Xuning Fenga,b, Minggao Ouyanga,□, Xiang Liua, Languang Lua, Yong Xiaa, Xiangming Hea,b a State Key Laboratory of Automotive Safety and Energy, Tsinghua University, Beijing 100084, China b Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing, 100084, China; http://dx.doi.org/10.1016/j.ensm.2017.05.013

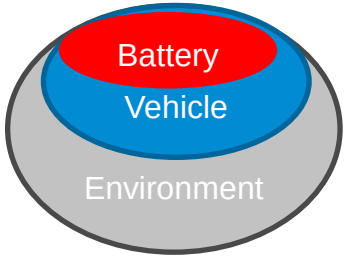
Contour of temperature distribution in a pouch cell @ 3C:

Infrared thermal images of cell at the end of a 3C discharge with a cooled cathode (left) and with no cooling on the cathode (right).



Source: [1] Journal of The Electrochemical Society, 161 (14) A2168-A2174 (2014); Thermal Effect of Cooling the Cathode Grid Tabs of a Lithium-Ion Pouch Cell; Stephen J. Bazinski and XiaWang; Department of Mechanical Engineering, Oakland University, Rochester, Michigan 48309, USA

Advanced Battery Monitoring, Analysis and Diagnostics



- State of Charge - SoC Analysis
- State-of Health - SoH Analysis
- Remaining Useful Life - RuL
- Non-invasive Temperature Measurement

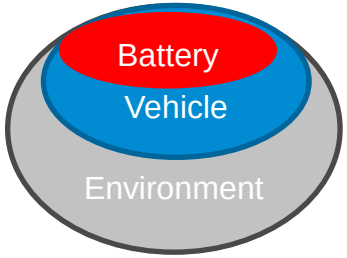
Why Electro Impedance Spectroscopy (EIS) is so important ?

- Range Forecast and Prediction
- Maintenance Alert
- Power Control Limitation
- Increased System Integrity
- Thermal Management
- Increase Functional Safety

Bosch: EBS

Source: TU-Chemnitz – Professorship Sensor and Measurement Technology – Olfa Kanoun

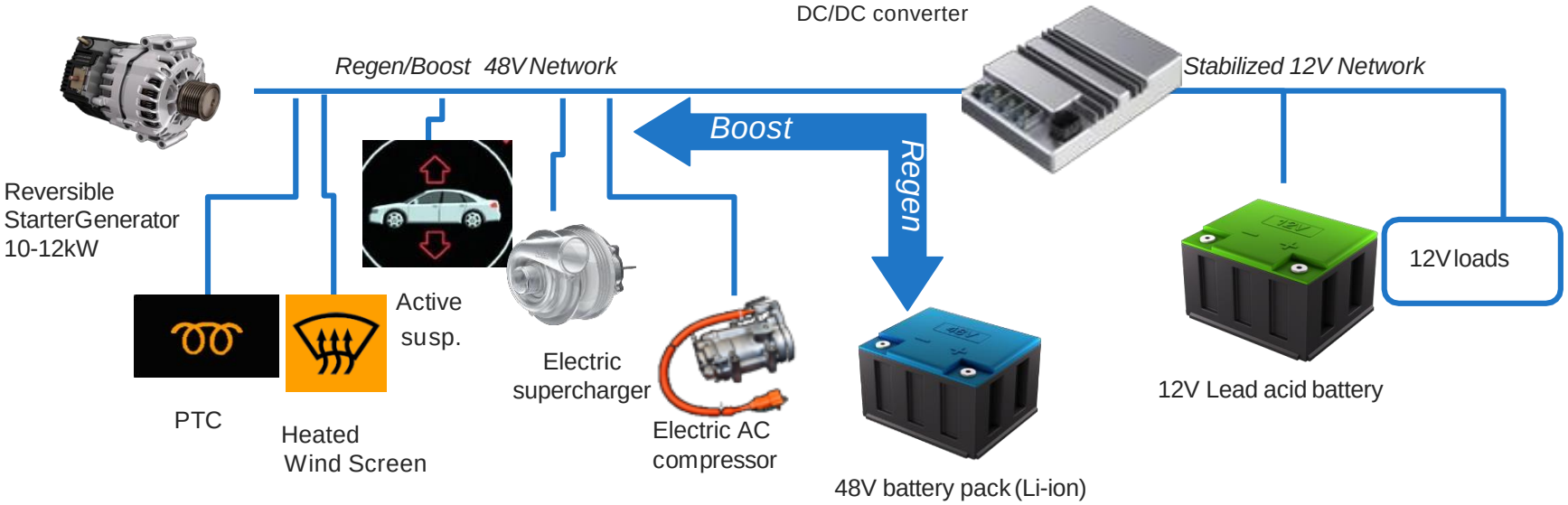
Advanced Battery Monitoring, Analysis and Diagnostics



- Vehicle to grid, Smart Grid
- Pay-by-Use or Leasing Business Model
- Second (extended) life
- Qualification of the battery
- Battery Life Prediction without Big Data
- 80% Capacity Analysis
- Analysis Counterfeit Cells
- Use of new or different Cell Chemistry
- Various Cell Manufacturers (Korea, China, Europe, America)

Source: TU-Chemnitz – Professorship Sensor and Measurement Technology – Olfa Kanoun

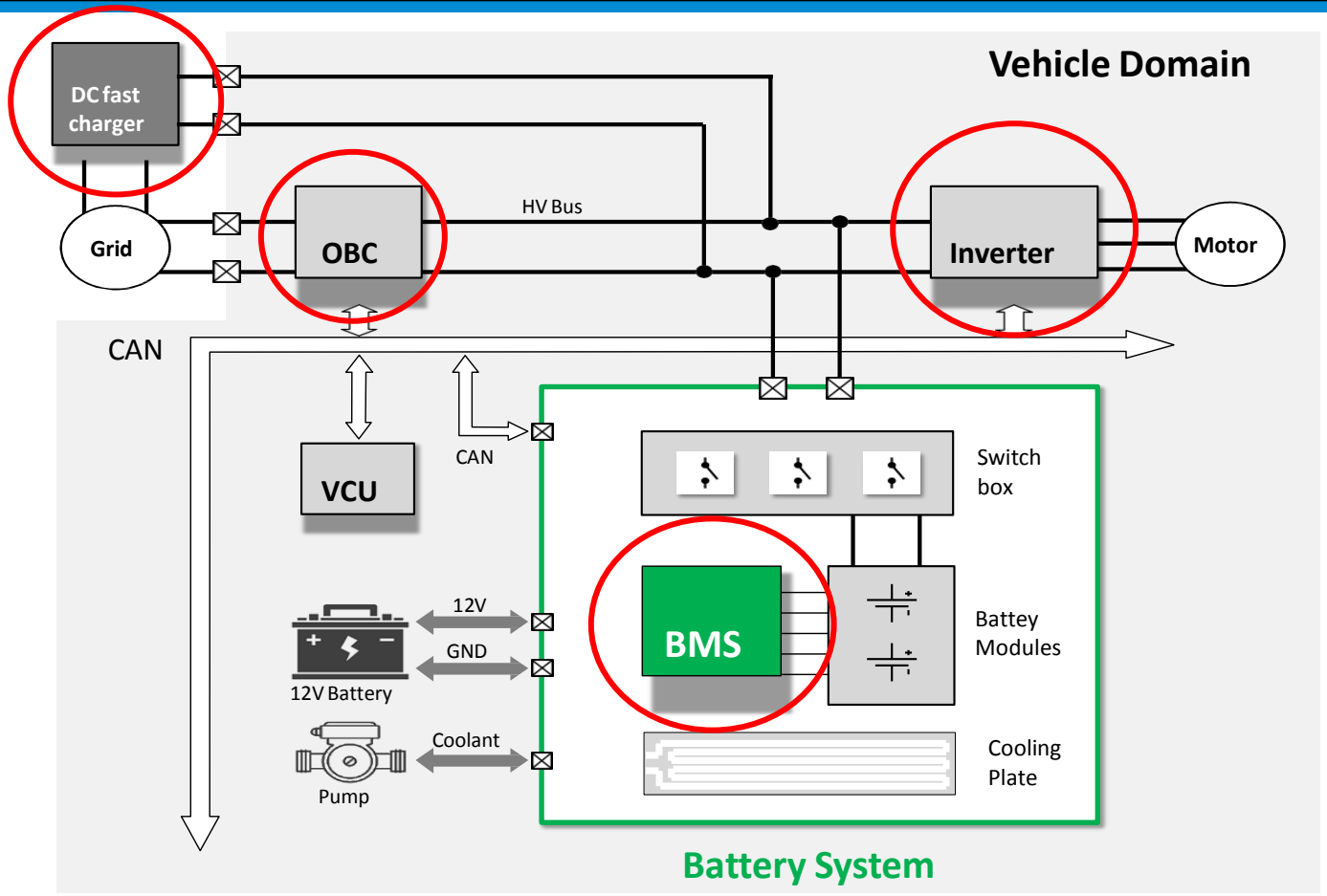
High Peak Current at 48V Loads



12V to + 48V Extended Board net

Source: Dr. Ing O. COPPIN - Valeo Powertrain Systems – France, From 12+12V to 48V:a new road map for hybridization, Engine Expo 2016 – Stuttgart June 2016

Introduction – Simplified xEV Powertrain

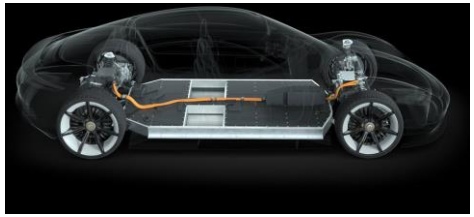


Measure, analyze and characterize a battery without knowing anything about the life of the battery before !!!!

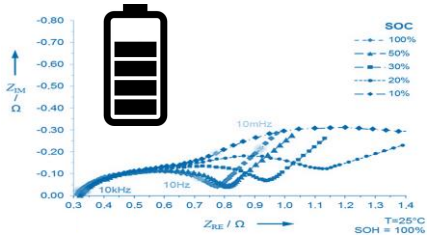
High Voltage Battery System based on Stack Structure

Challenges

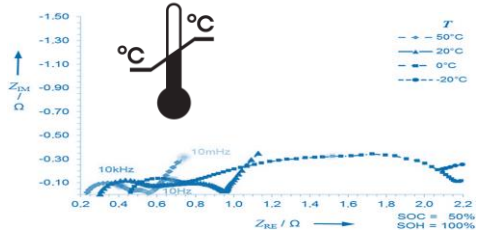
- Monitoring and analyzing on cell level and / or stack level
- High voltage power net up to 800V
- Fast charging mode based on higher voltages
- Temperature Measurement and Analysis
- Thermal management during charge and discharge cycles , Pressure Measurement
- Load current limitations without limiting the driving performance
- Real time battery analyzing procedure during traffic light stop
- Battery analyzing based on functional safety without big data or cloud connectivity



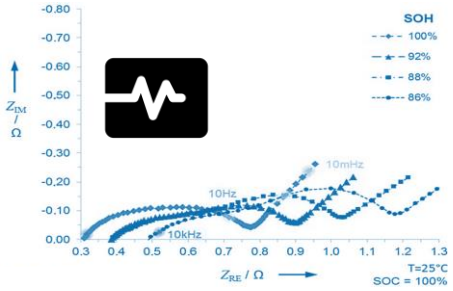
SoC Analysis and Monitoring



Temperature Analysis and Monitoring



SoH Analysis and Monitoring



Why Electro Impedance Spectroscopy (EIS) is so important in BMS?

Source : Photo Porsche AG

Battery Diagnostics via Impedance Measurement

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- Electrochemical dynamic response
  - Response is related to ion-current/diffusion rate in the cell

  => Slower response for weaker batteries
- Characterization
  - LF dubbed diffusion
  - MF charge transfer
  - HF migration

=> Batteries with faded capacity suffer from low charge transfer and slow active Li-ion diffusion.

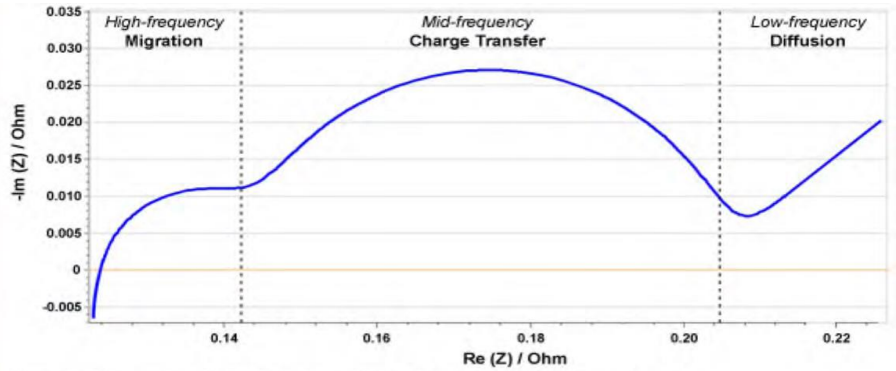


Figure 3: The Nyquist plot is divided into high, mid and low frequency sections.
The mid-frequency semi-circle represents battery characteristics best. Larger batteries require lower frequencies.

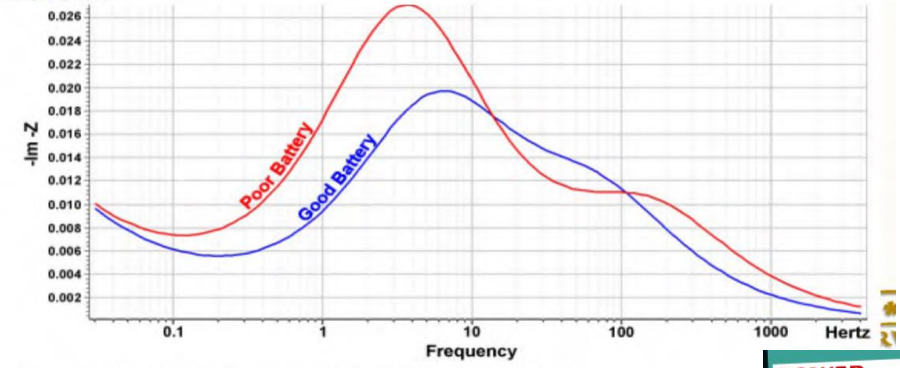
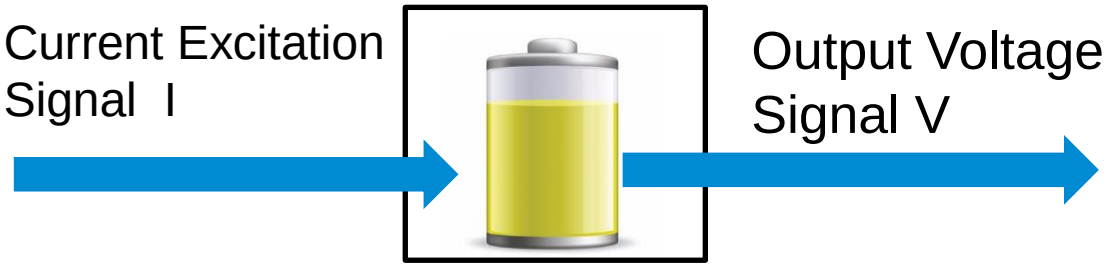


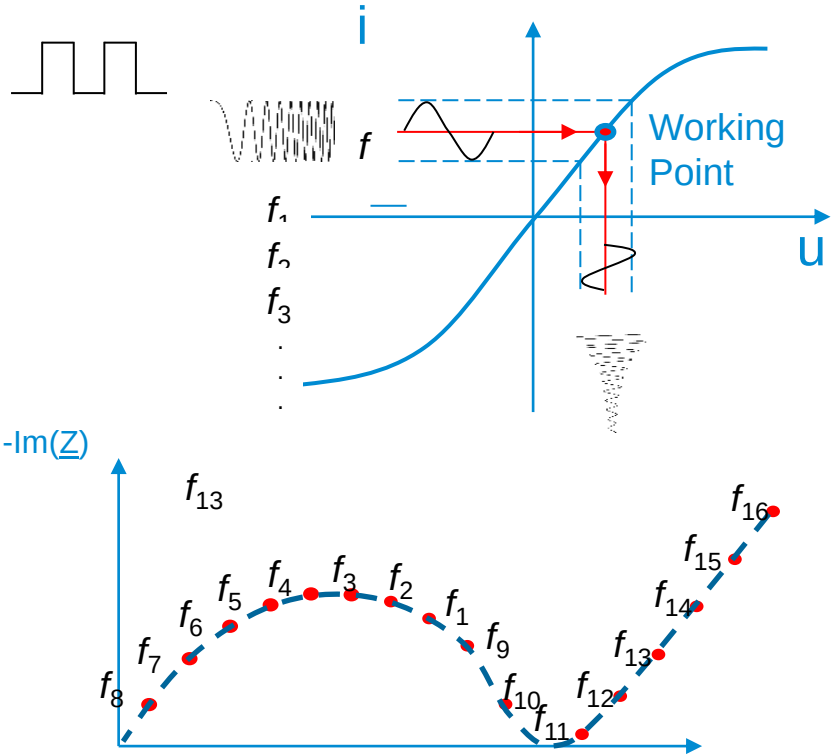
Figure 2: Frequency scan of good and weak mobile phone batteries.
Impedance variances are most visible below 10Hz. The horizontal scale is logarithmic to c
frequency range.

Source : http://batteryuniversity.com/learn/article/testing_lithium_based_batteries

Impedance Spectroscopy - Method



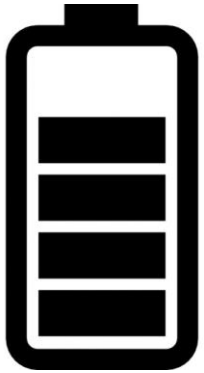
$$\underline{Z}(\omega) = |\underline{Z}(\omega)| \cdot e^{j\varphi(\omega)}$$

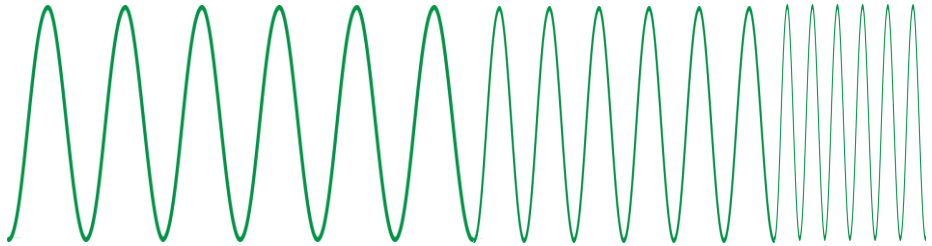


- Experimental **efficiency and non-invasiveness**
- More **information** than only by resistive, capacitive or inductive measurement
- Possibility to **separate effects** dominating in different frequency ranges

Typical Parameters for an EIS data analysis

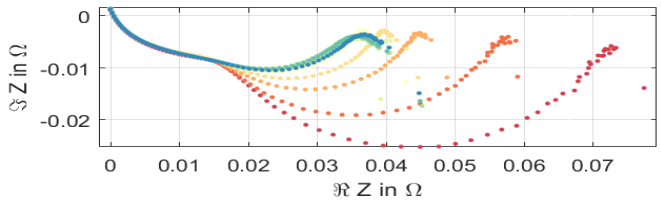
- State-of-Charge SOC from 0% to 100% in 10% steps
- Temperature Range from -20°C to +60°C in 5 Kelvin steps
- Frequency Range Analysis 10mHz to 1kHz on defined points of interest

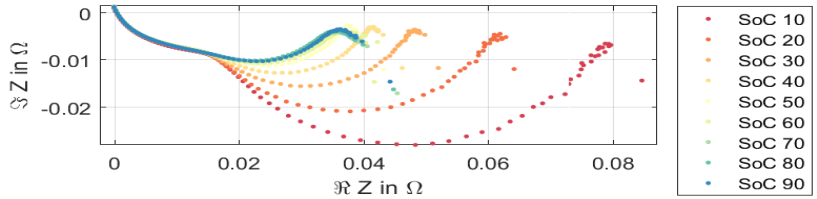


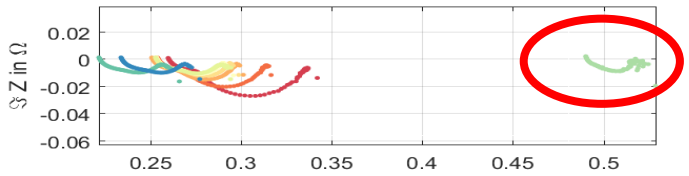


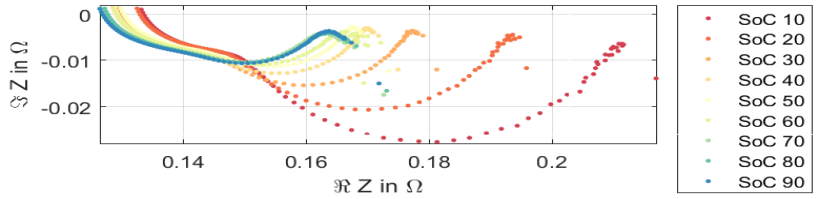
Application Example: Intelligent BMS

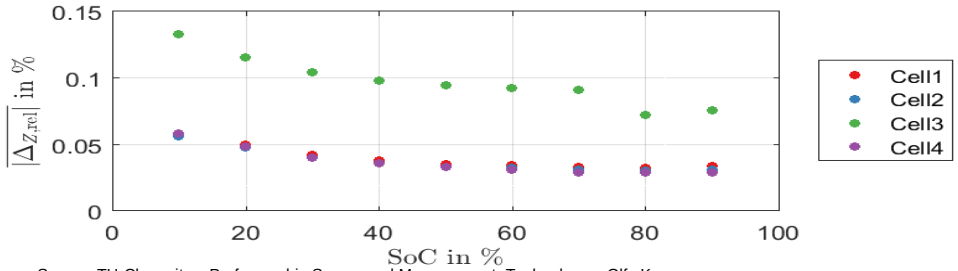
→ Impedance Spectra @ different SOC (10-90%) of 4 equivalent cells







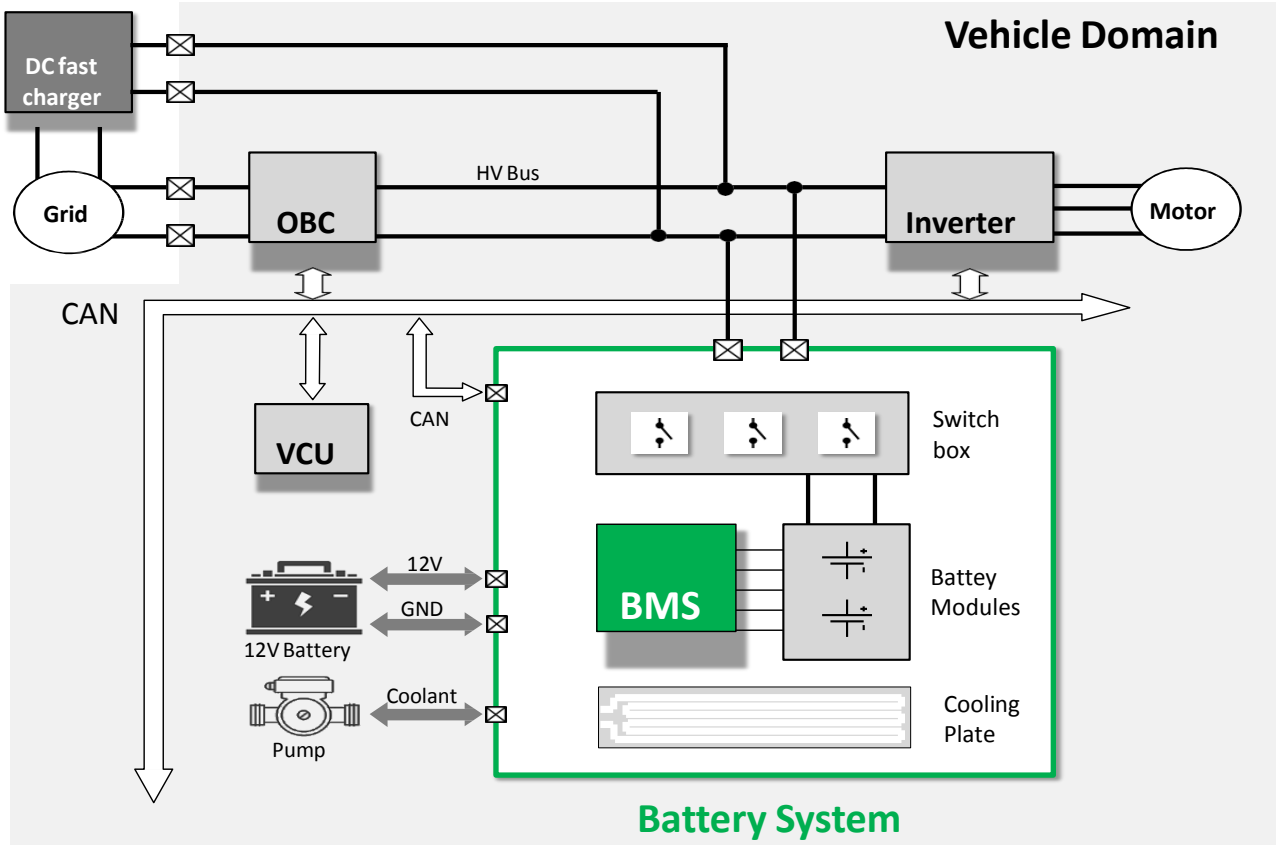




Source: TU-Chemnitz – Professorship Sensor and Measurement Technology – Olfa Kanoun

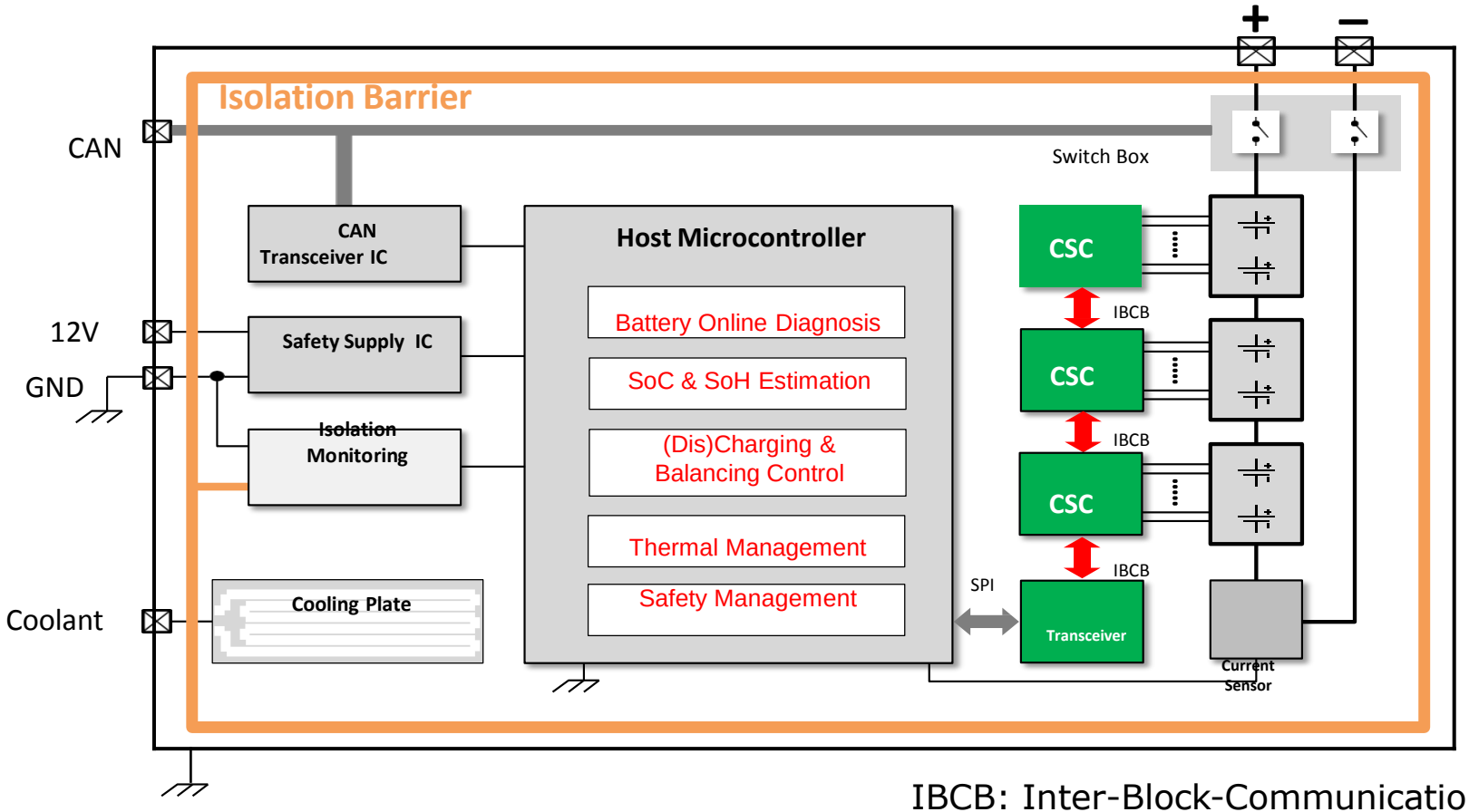
→ Incorrect cells are detectable by impedance spectroscopy

Introduction – xEV Powertrain



› Only parts of the entire xEV Powertrain

Battery System



IBCB: Inter-Block-Communication-Bus
CSC: Cell Supervisory Chip

Our BMS Chipset Solution

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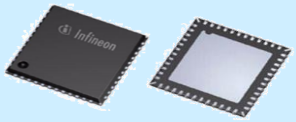
TLF35584
Safety power supply



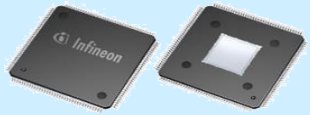
Safety Supply Chip

Battery

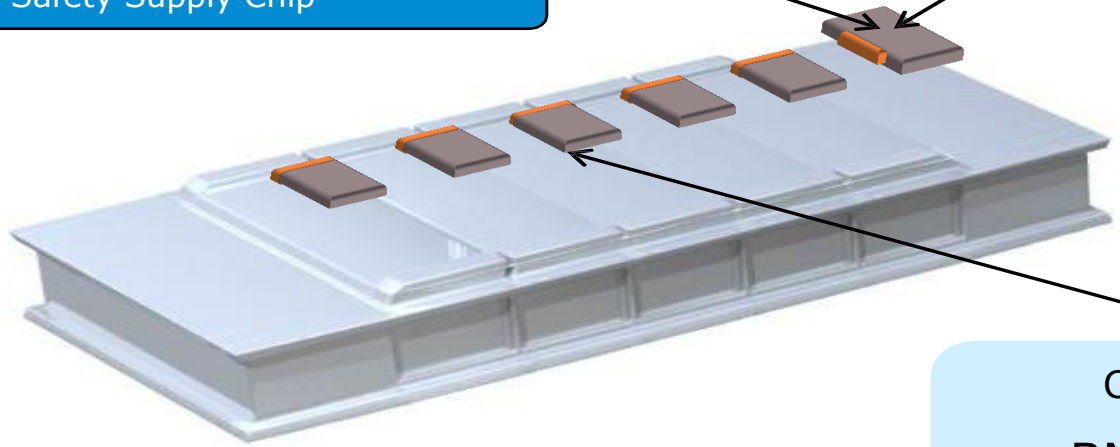
eMobility

Host Controller

Aurix™



Main Microcontroller

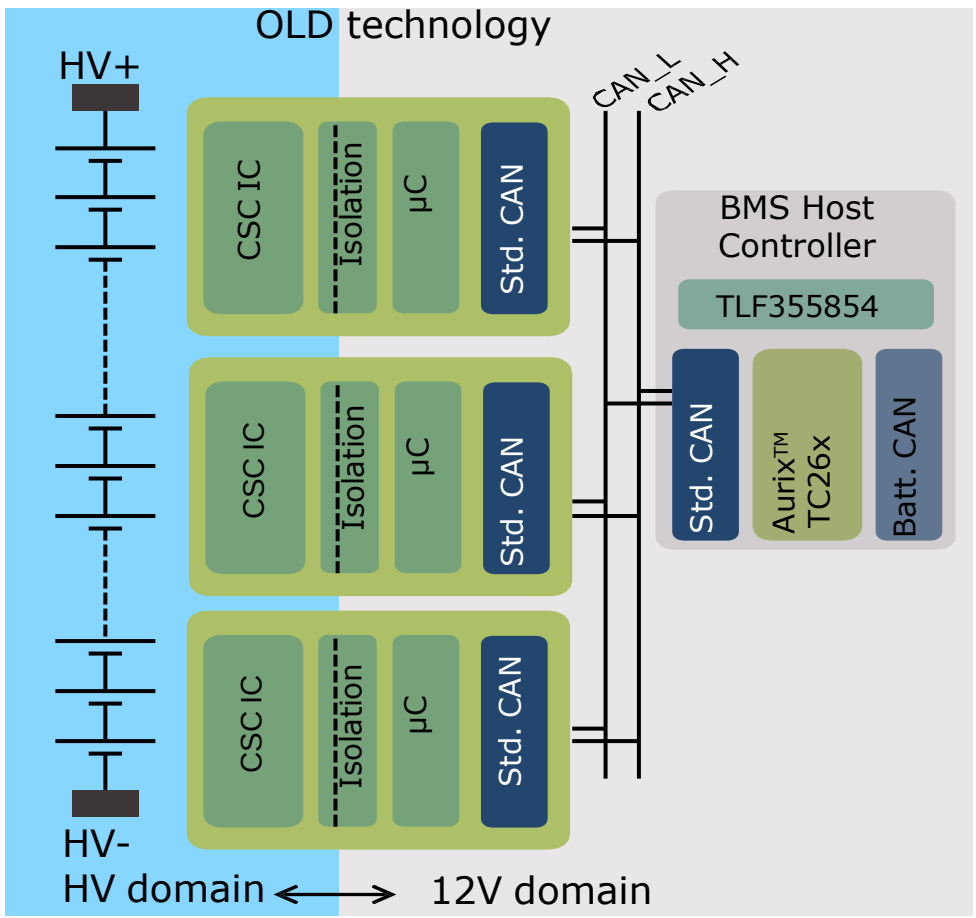


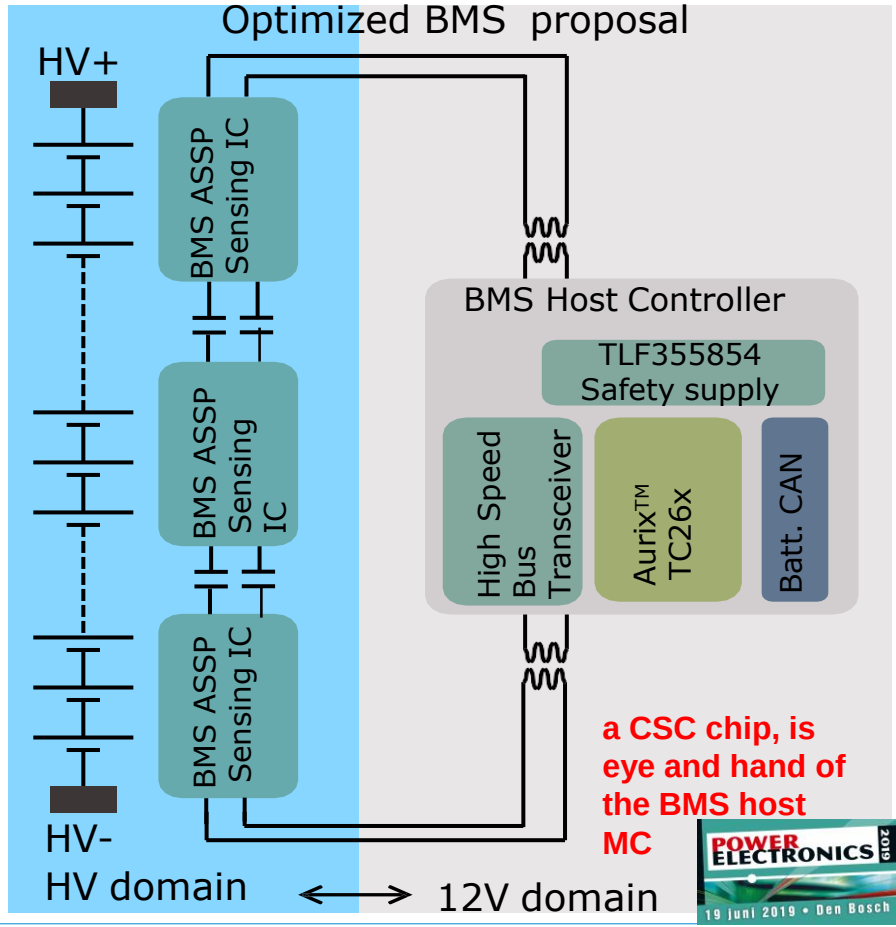
CSC Controller

BMS ASSP
12ch Sensing IC

Sensing IC

System Architecture





Conclusion

- Characterization, modeling and parameter extraction for different cell types, cell chemistries and battery systems
- Intelligent battery management systems (BMS)
- Advanced signal processing for impedance measurement
- Implementation of laboratory stages or embedded µC based systems for
  - Comprehensive laboratory investigations
  - Online observations with less resources

Potentials:

- Monitoring of formation process (cell production)
- Cell qualification for stack construction
- Accurate knowledge about SOC, SOF and SOH
  - Considerable reduction of cell weight
  - Higher efficiency
- Modeling for state estimation
- Measurement of inner cell temperature

Significant Improvement of Functional Safety

Thank you very much for your attention

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