



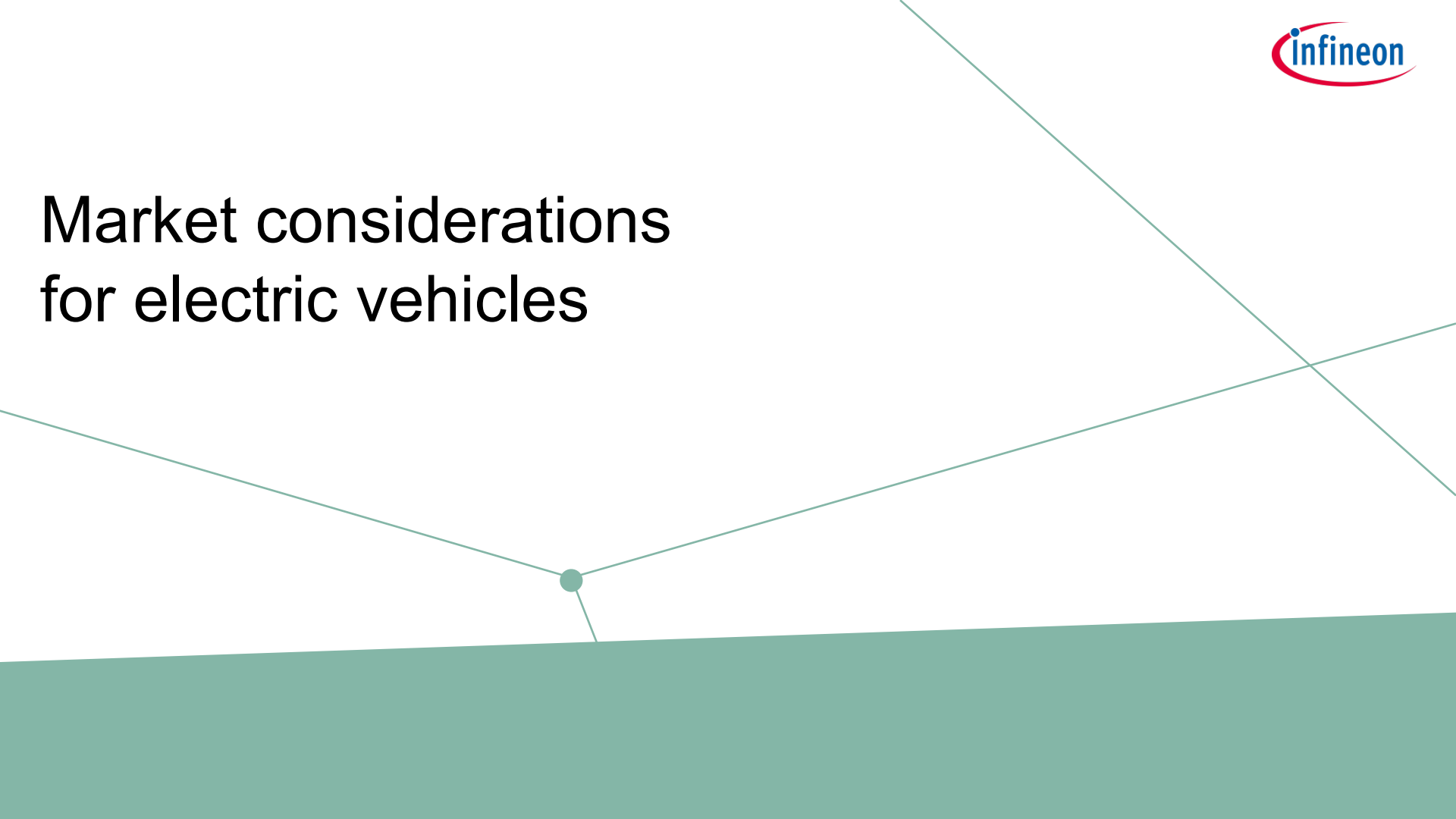
We are the link
between the real and
the digital world.

Make battery systems safer and more secure

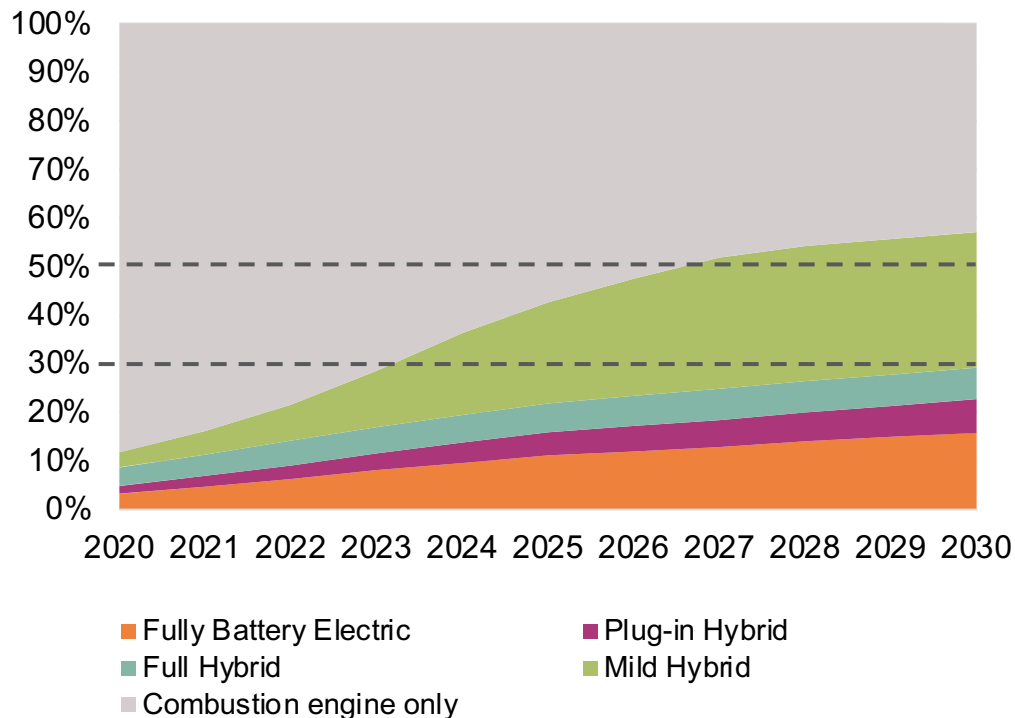
Infiniteon's virtual show 2020



Market considerations for electric vehicles



Global market penetration by powertrain type



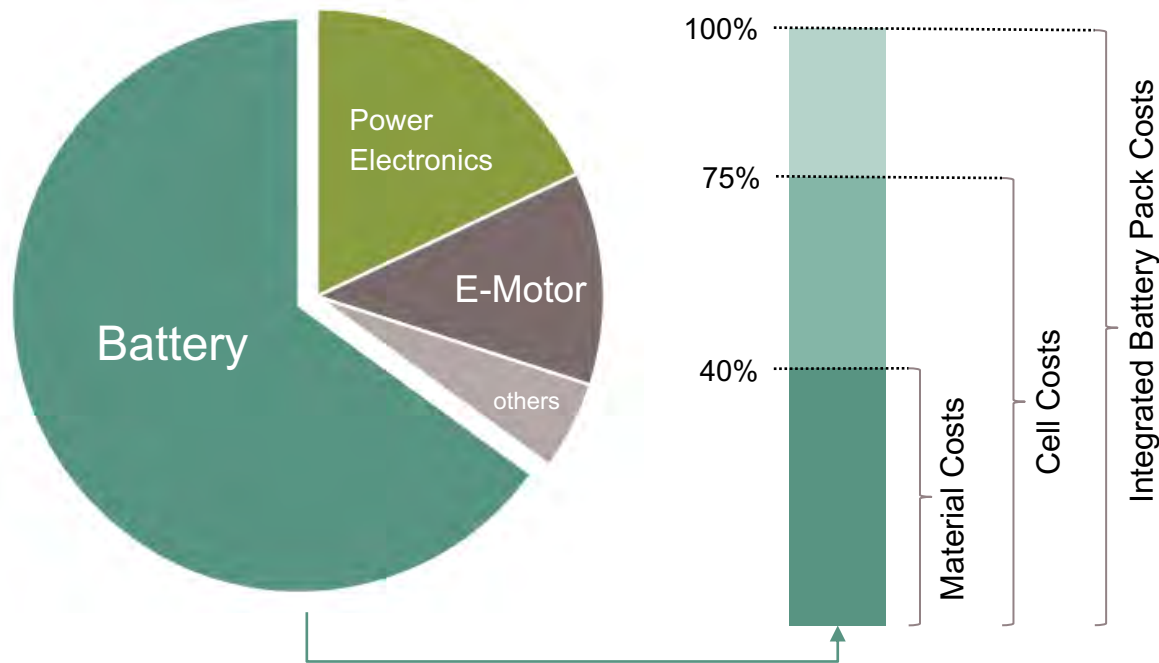
- › Growth drivers for electro-mobility are
 - Increasingly strict CO₂ regulations
 - Incentives as part of industry politics
 - Decreasing Diesel share
 - Increasing SUV share

- › Within this decade the majority of new cars sold has a fully or partially electrified drivetrain (incl. 48 V MHEV)

- › By the end of this decade roughly 30% of new cars will include a high voltage battery

Based on or includes content supplied by IHS Markit, Automotive Group, "Light Vehicle Powertrain and Alternative Propulsion Forecast Database", February 2020. Information is not an endorsement of Infineon Technologies AG. Any reliance on these results is at the third party's own risk.

Cost decomposition for powertrain of electric vehicles



- › 70-80% of overall powertrain costs in EV are caused by power electronics and battery
- › 75% of the battery costs originate from the battery cells (housing, materials for electrodes and electrolytes, protection features)
- › 25% are spent on system integration, electronics and software

(Source: P.Lamp [BMW] in "Lithium-Ion Batteries: Basics and Applications", p.389, Springer, 2018)

The automotive landscape for electric vehicles is facing disruptive change

20+ traditional OEMs

Past



Today

Additional 40+ new startups

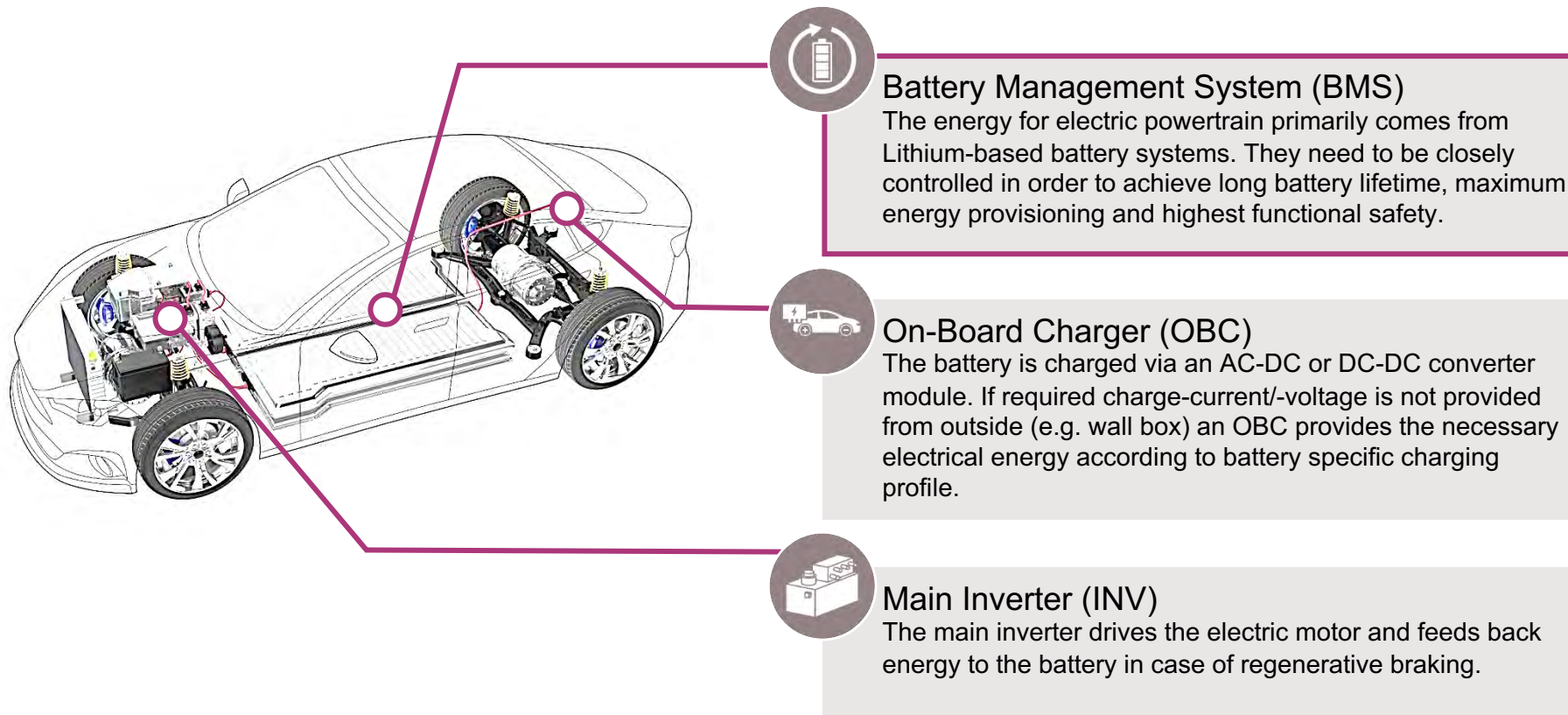


- › Huge amount of new players are penetrating a market which was formerly facing solid structure
- › Startups are developing own functional components or integrating off-the-shelf components for electrical powertrain of their vehicles
- › Differentiation based on driving experience, range, advanced mobility functionalities, quality and cost

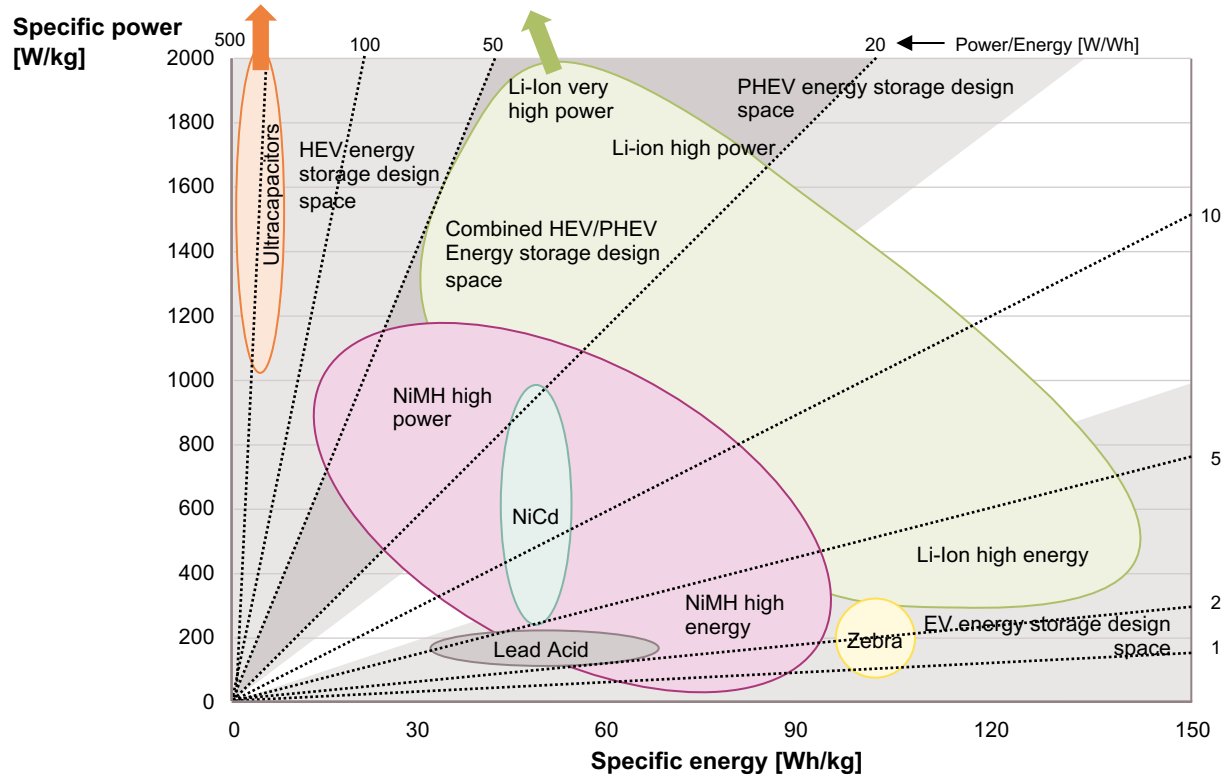
Right products make
the batteries work



Main powertrain related building blocks of a battery electric vehicle



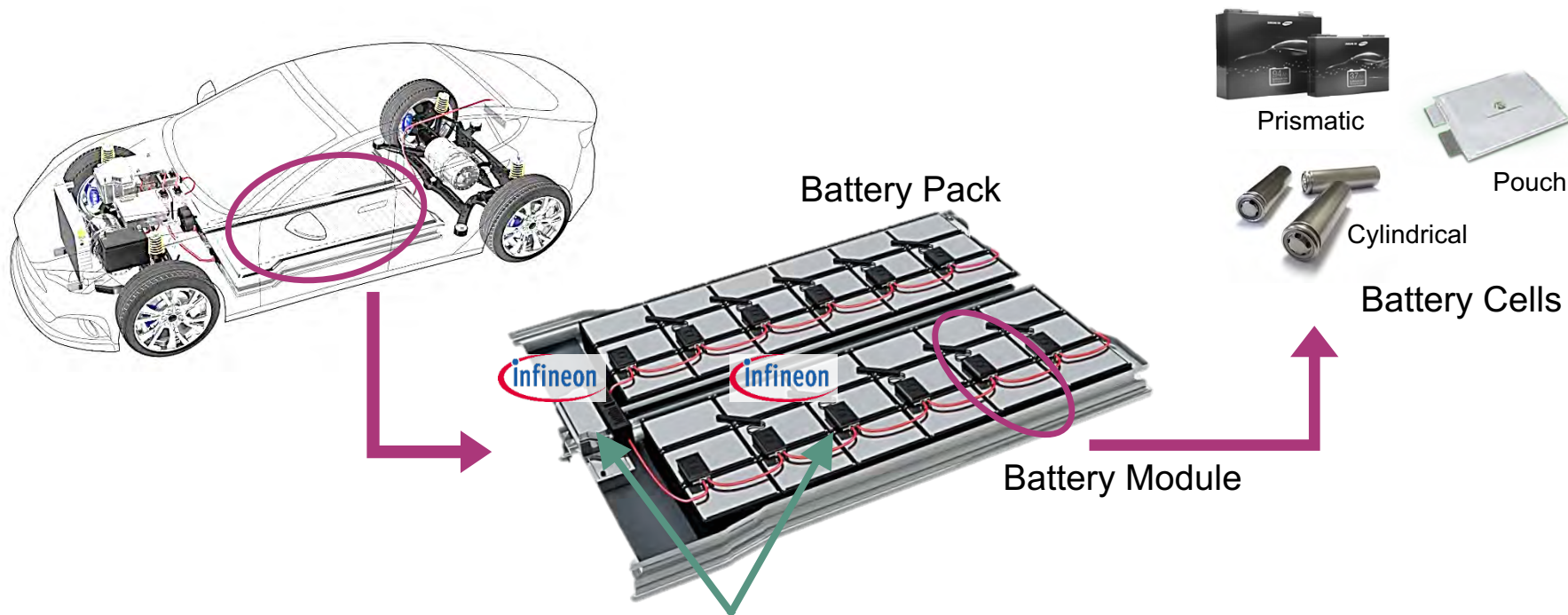
The battery technology challenge: Compromise between high storage capacity and short transfer times of energy



- › Energy storage capacity important for range maximization w/o recharging ("specific energy")
- › Short energy transfer times determine the battery's ability to support fast charging, recuperation, and peak energy provision for e.g. acceleration ("specific power")
- › Li-Ion is the predominant cell technology with differentiating cathode chemistries and cell topologies

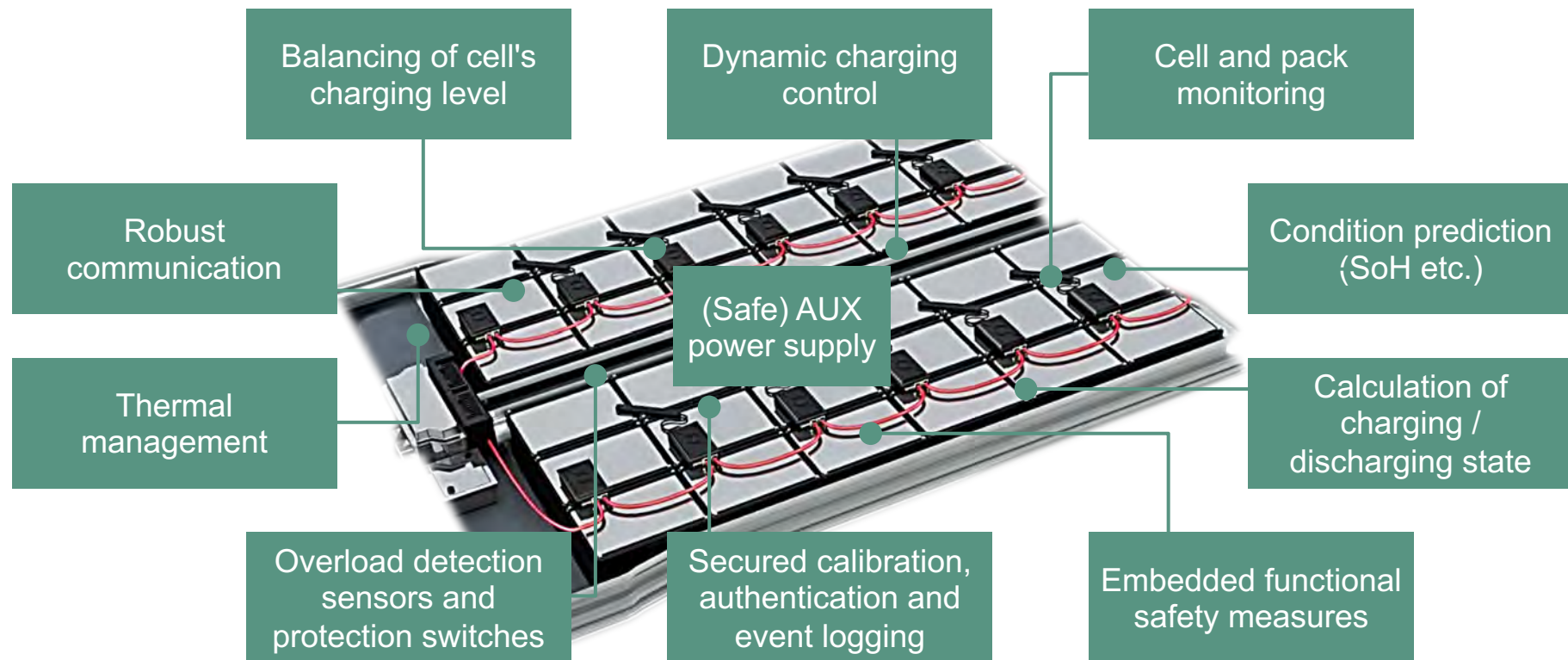
Source: exida.com, Infineon Safety Presentation – BMS, A.Griessing et al., 9-JUN-2019

Structure of an electrical vehicle's battery



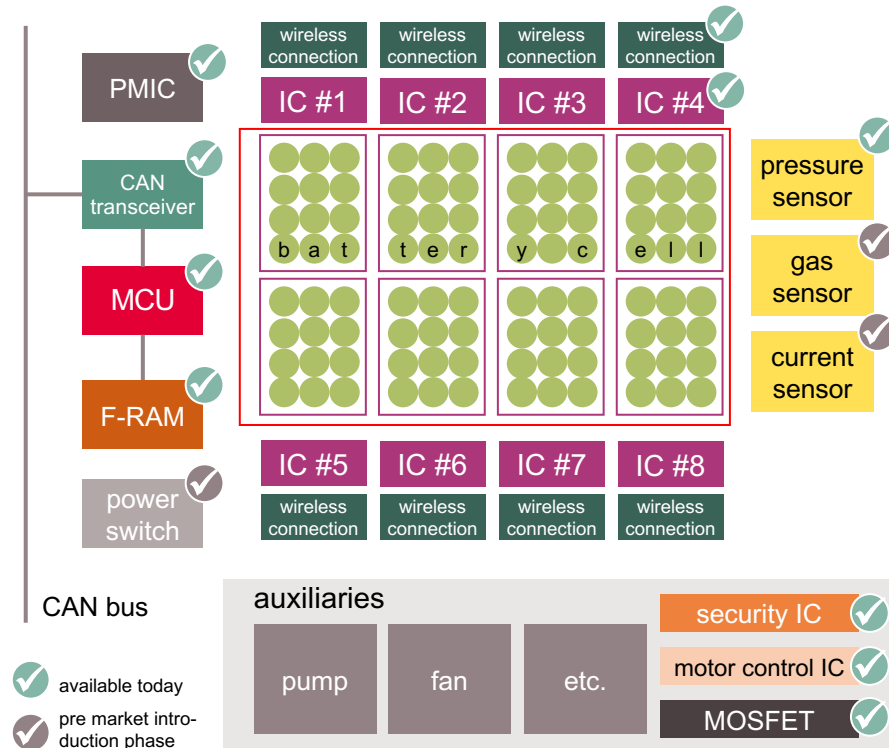
Battery management functions covered by Infineon product portfolio

Infiniteon's existing product portfolio perfectly fits for these BMS functions



BMS is a good example for Infineon's system solution competence

Infineon offers basically all components of a complete battery management system (BMS)



- 8x..12x multi-channel battery monitoring and balancing system ICs covering cell charge balancing, cell voltage and temperature measurement
- 8x..12x wireless control ICs
- 1x..2x Power management IC (PMIC), optional w/ functional safety
- 1x..2x CAN transceivers for robust communication between cells and battery main controller
- 1x..2x MCU with scalable processing performance, connectivity and embedded hardware security, optional w/ functional safety
- 1x F-RAM for data logging and mission profile recording
- 1x..5x high-voltage power MOSFET replacing traditional relay
- 1x..8x low-power pressure sensors
- 1x..8x gas sensor (H₂ or HCO₃)
- 1x..2x current sensor; type depending on cell topology
- 1x..3x trusted security solutions to support battery authentication, functional safety and IP protection
- 1x..2x embedded motor control ICs for various motor types
- 1x..12x standard power MOSFETs

Σ total system BOM for BMS

Differentiating feature overview for cell monitoring and balancing IC "TLE 9012-AQU"



Voltage Measurement

Synchronicity

12x Delta-Sigma ADCs ensure that voltage of all cells is measured **synchronously**

Accuracy

Stress sensor and active temp. comp. guarantee **over lifetime** $\pm 5.8\text{mV}$ measurement accuracy

Filtering

Noise elimination on measured signals without influencing system cost

Diagnosis

Block voltage reference measurement for HW error detection



Temperature Measurement

Automatic Triggers

Measurement w/o external triggers minimizes load on microcontroller and COM-links

Adaptive NTC currents

Selective compensation by device maximizes measurement accuracy over full range



Communication

Robust COM-links

Differential signaling and end-to-end 8-bit CRC protected data for **full integrity** on UART frames

Ring Mode topology

Supports ring topology to ensure **fail safe operation** in case single slave/wire is failing



Cell Balancing

Balancing diagnosis

Overcurrent, undercurrent and open load diagnosis available

Time targets

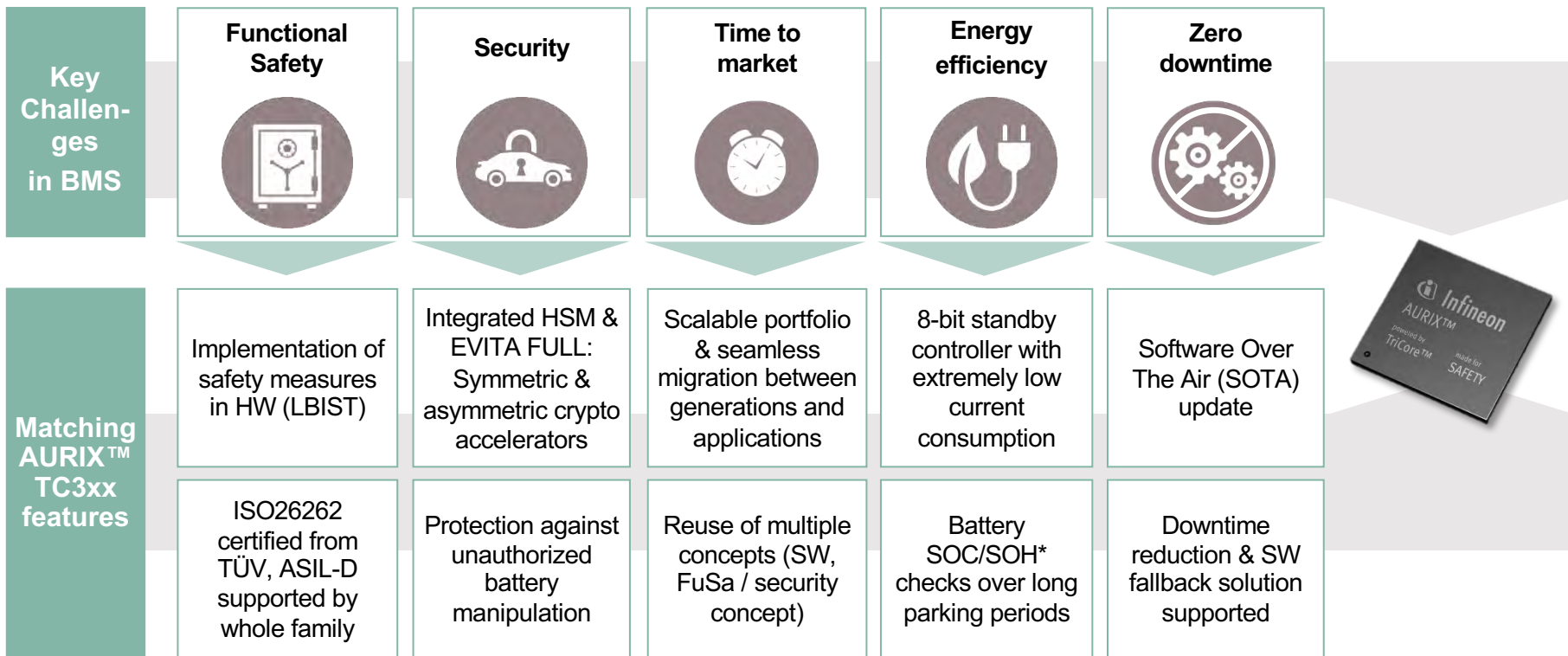
Microcontroller **independent cell balancing** within programmable time budgets (up to 32 hours)

Scalable currents

Internal switches for $<150\text{mA}$ or control for external switches beyond; external resistors for optimized power consumption

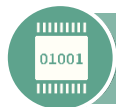


AURIX™ TC3xx microcontrollers solve algorithmic and control challenges for Battery Management Systems (BMS)



* SOH: State-of-Health
SOC: State-of-Charge

BMS functionality beyond basic cell control to improve battery lifetime and to enable new business models



Parameter and Event Logging

Purpose

Capture (safety) critical battery parameters like U/I/T/... or/and status info like SOC, SOH, DOD to track mission profiles for predictive algorithms / new business models or flight-recorder-like identification of root-cause for failures and catastrophic events

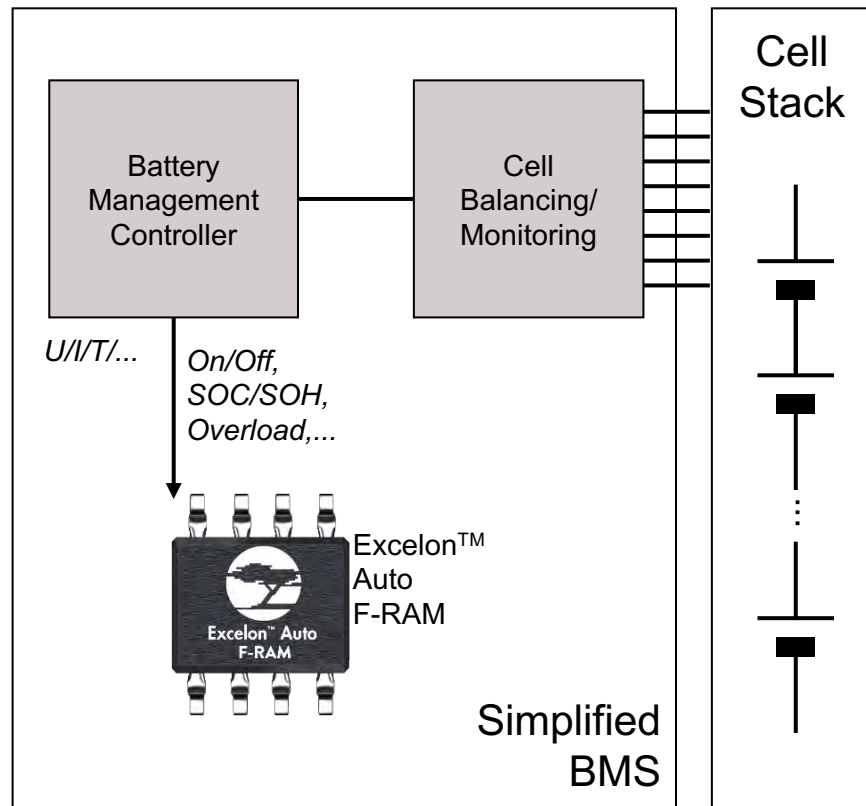
Challenge

Instant recording of real-time data in a continuous fashion and **retaining on power-loss**, even if battery is switched-off in uncontrolled fashion

Lowest power consumption and no software/firmware overhead
Write-cycle endurance to log data for 20 years

Solution

Execlon™ F-RAM with **0ms write latency**, 0.1uA hibernate / 0.6mA write current, 100 years data retention, endurance of 10^{14} cycles, AEC-Q100 qualified memory component



Highlevel Infineon portfolio overview for improved BMS solutions

Battery function

Examples

Cell pack monitoring and balancing

Multi-channel battery monitoring and balancing system ICs covering functions such as accurate **cell voltage** and **temperature measurement**, **cell charge balancing**, or robust daisy-chained **communication** across cell clusters

e.g. TLE9012-AQU



Dynamic charging control

Multi-core microcontrollers with scalable processing performance, connectivity and embedded hardware security, extended by fast, low-power F-RAM for on-the fly data logging

AURIX™ or Traveo™ II plus F-RAM



Calculation of dis-/charging state

Condition prediction

Low power **pressure sensors** with ratiometric analog output and digital SPI interface for int. temperature measurement, self diagnosis

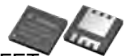
e.g.
KP236N6165 or KP256



Extended battery protection

Embedded motor controls for fans, pumps etc. with inbuilt diagnostic functions for efficient **thermal control** operation. Smallest package form factor and a minimum number of external components allow for **integration close to motor**

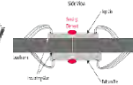
e.g. TLE987x for 3-phase BLDC Motor e.g. MOSFET IPZ40N04S5-3R1



Robust communication

Certified safety components with highest quality standards incl. compliant devel. processes, design, manufacturing, documentation

e.g. dual-die sensors e.g. AURIX™ Semper™ NOR Flash



Thermal management

Transceivers for isolated and robust multi-cell communication between cells and battery main controller or higher performance data links between battery and domain controller (e.g. CAN, BLE)

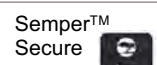
e.g. TLE9015-QU e.g. CAN Trans. e.g. CYW89820



Embedded functional safety measures

Trusted security solutions to support functional safety and protect critical IP for long-term business without bigger impact on embedded functionality

e.g. OPTIGA™ TPM OPTIGA™ Trust Semper™ Secure Flash



Trends and innovation drivers

Innovation trends for battery systems

Topologies and connectivity

- › Multi-string topologies
- › Dynamic serial / parallel switching of battery modules
- › Integration of ultracaps for short-term energy balancing during recuperation (charge) / acceleration (discharge)
- › Advanced communication links on cell- and module level (wireless, powerline)

Diagnostics for metering, condition assessment and health prediction

- › Impedance spectroscopy
- › Accurate current sensing for "coulomb counting"
- › Additional sensing measures for pressure, gas etc. detections

High-performance solid-state protection switches

- › Orders of magnitude faster disconnect times compared to electro-mechanical separators (~0.35kA @ <0.75µs vs. ~1.5kA @ >600µs)

Thermal control solutions for capacity optimization and better lifetime

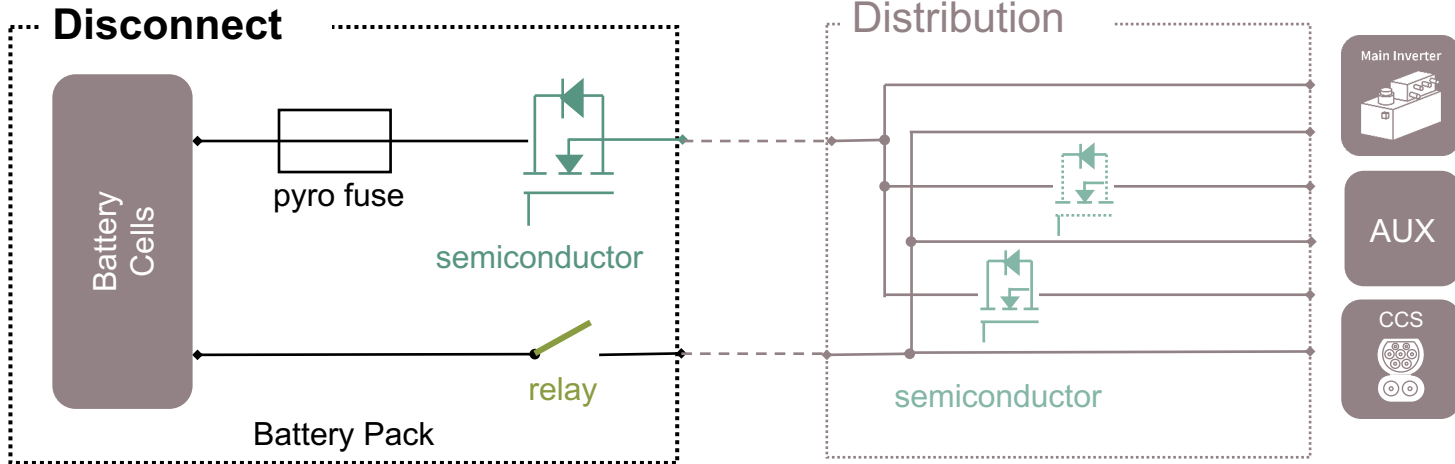
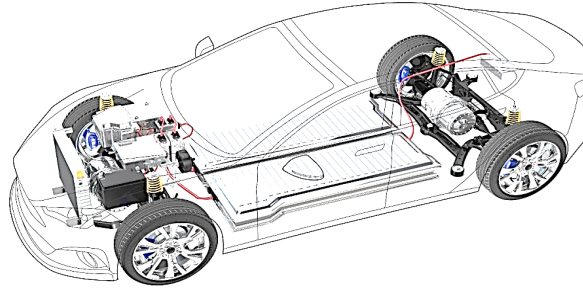
- › Active thermal management via heat pumps
- › Preheating of battery via energy circulation through main inverter

Advanced security

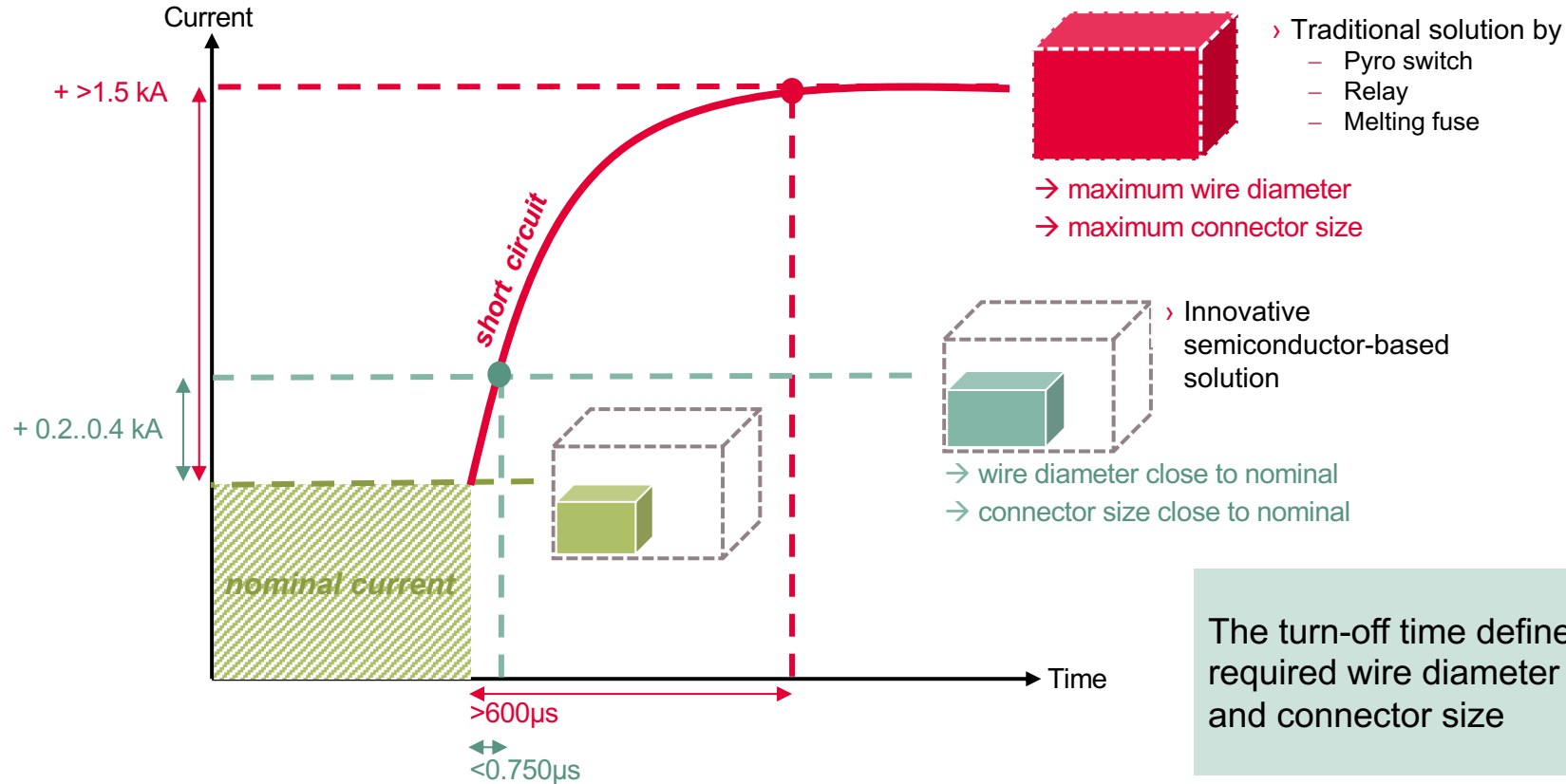
- › Pack-/module-identification of battery setup and configuration supporting safety case
- › Genuine / authenticated parts / components
- › New use cases and biz models based on protected usage data ("flight recorder", pay-per-use etc.)



High-performance solid-state protection switches: Where could they be placed?



High-performance solid-state protection switches: Why do they make a difference for systemlevel design?



The turn-off time defines
required wire diameter
and connector size



High-performance solid-state protection switches: What is possible?

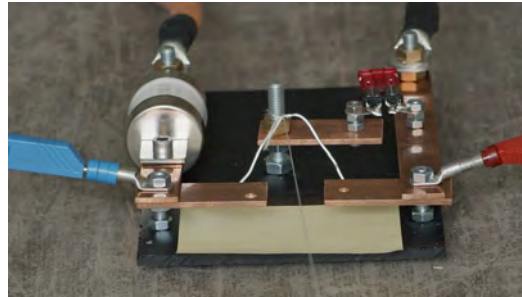
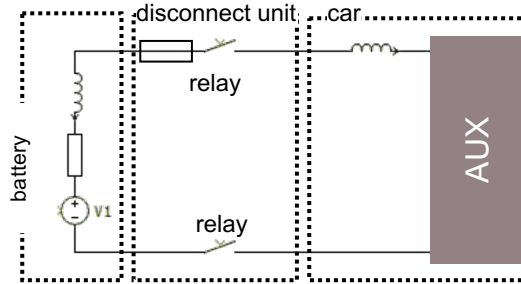
Assumed short-circuit
scenario constraints:

$$\Delta I \sim \frac{V_{bat}}{L} \Delta t$$

here:

$$\sim 0.85 \mu\text{H}, 400 \text{ V} \rightarrow 472 \text{ A}/\mu\text{s}$$

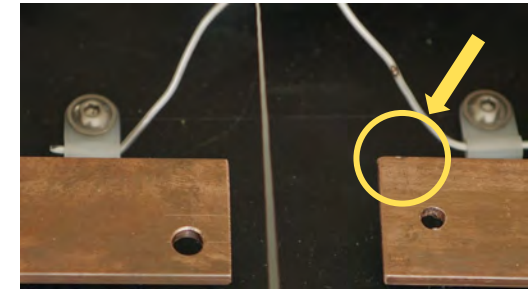
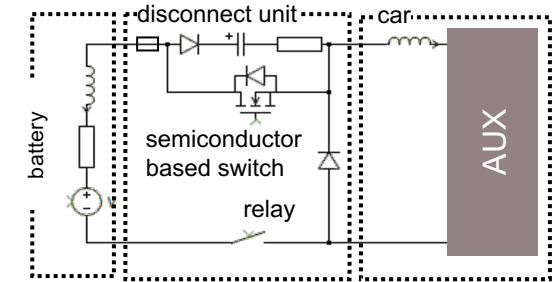
Current relay solution:



Turn-off time $> 600 \mu\text{s}$

$600 \mu\text{s} \rightarrow \sim 1.5 \text{ kA}$

Semiconductor based solution:



Turn-off time $\leq 0.750 \mu\text{s}$

$0.750 \mu\text{s} \rightarrow \sim 354 \text{ A}$



We make OUR CUSTOMERS' battery systems better!

Get the most out of your battery with electronics from Infineon for:

- › Advanced cell monitoring, balancing and metering
- › Robust communication
- › Efficient thermal control
- › Maximum safety
- › Secured IP



Find out more about BMS solutions by Infineon:

- › Visit our website @ www.infineon.com/bms for more information on relevant products and evaluation kits



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