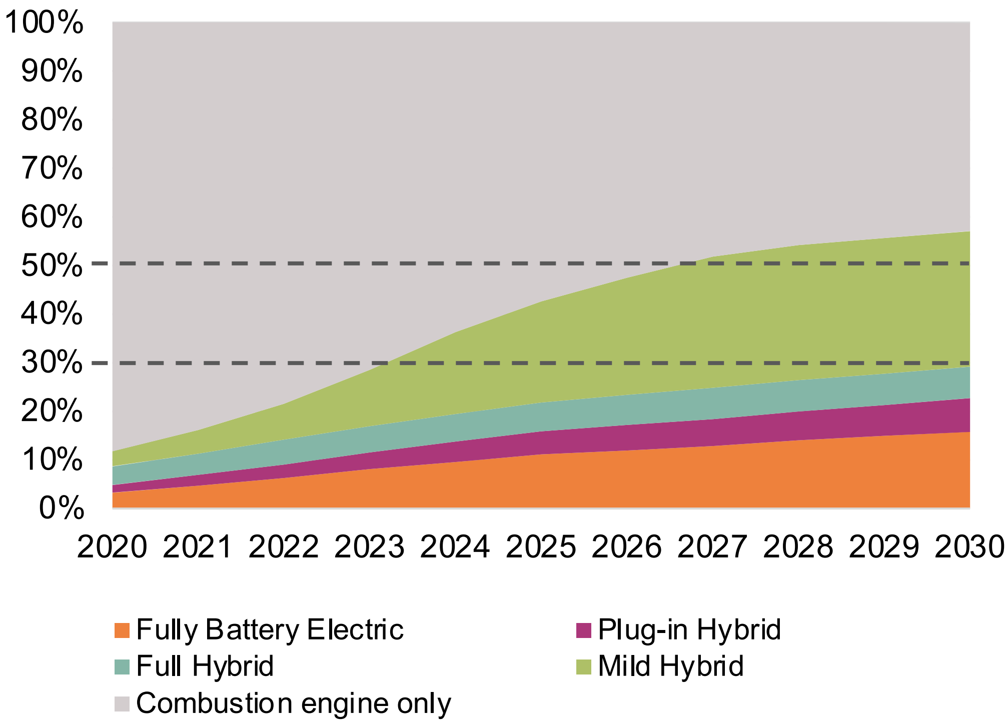
We are the link between the real and the digital world.

Make battery systems safer and more secure

Market considerations for electric vehicles

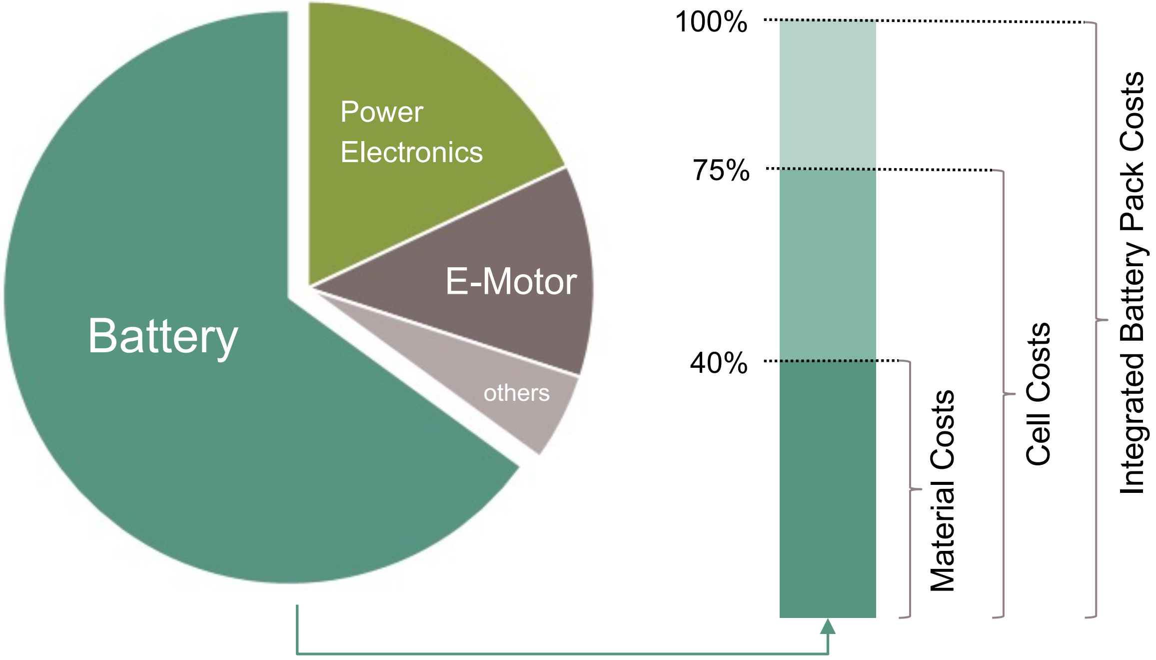
Global market penetration by powertrain type



- Growth drivers for electro-mobility are
  - Increasingly strict CO_2 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

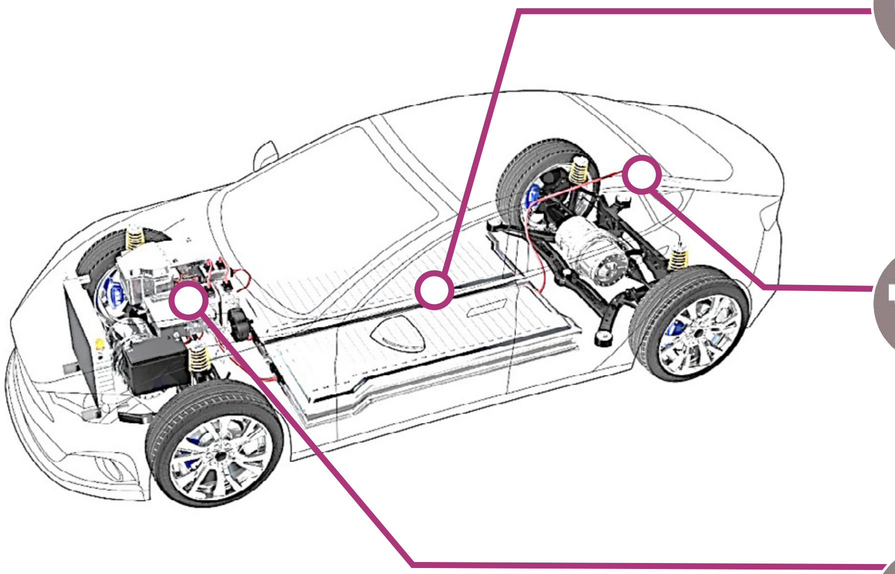
20+ traditional OEMs — **Past**

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



Battery Management System (BMS)

The energy for electric powertrain primarily comes from Lithium-based battery systems. They need to be closely controlled in order to achieve long battery lifetime, maximum energy provisioning and highest functional safety.

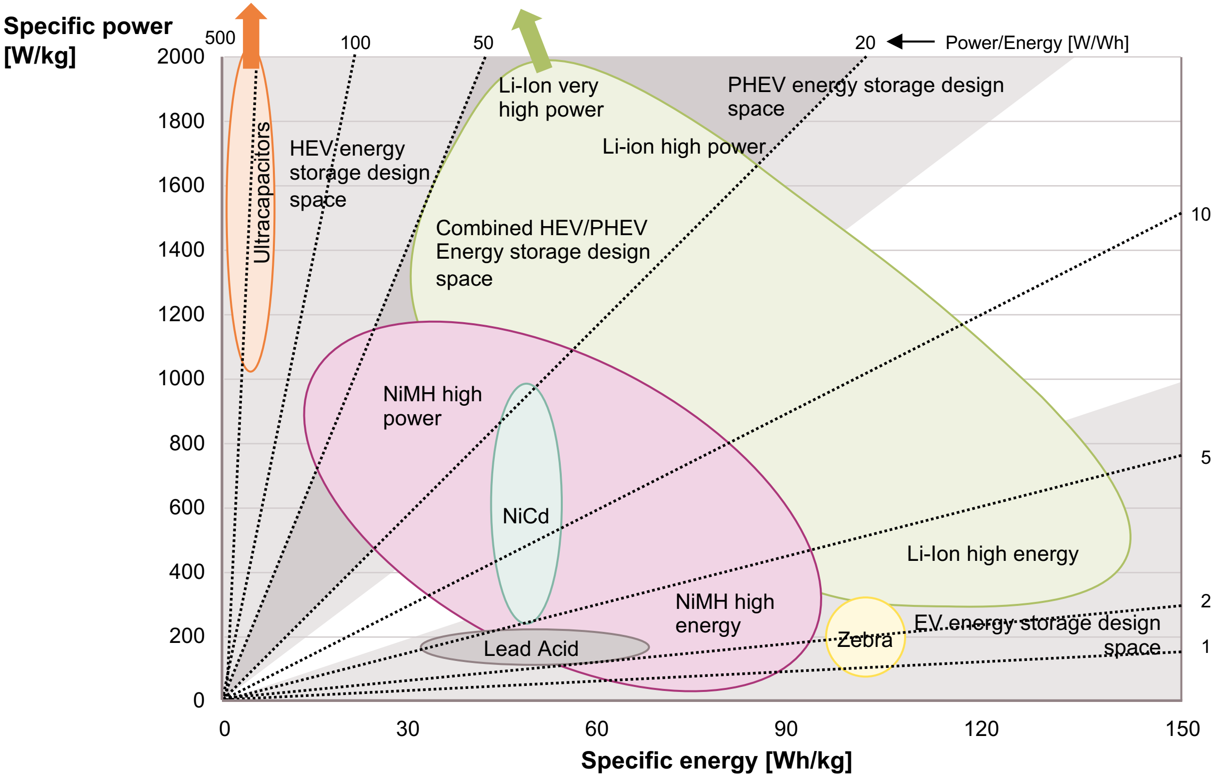
On-Board Charger (OBC)

The battery is charged via an AC-DC or DC-DC converter module. If required charge-current/-voltage is not provided from outside (e.g. wall box) an OBC provides the necessary electrical energy according to battery specific charging profile.

Main Inverter (INV)

The main inverter drives the electric motor and feeds back energy to the battery in case of regenerative braking.

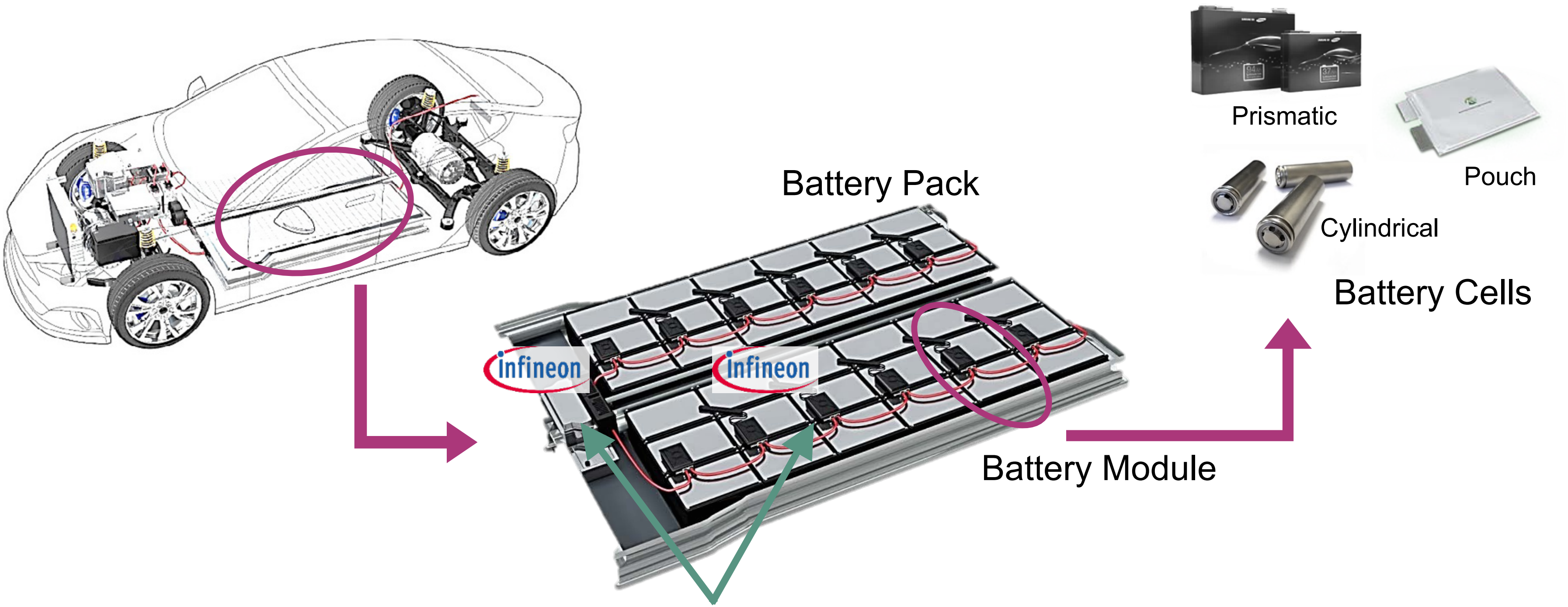
The battery technology challenge: Compromise between high storage capacity and short transfer times of engery



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

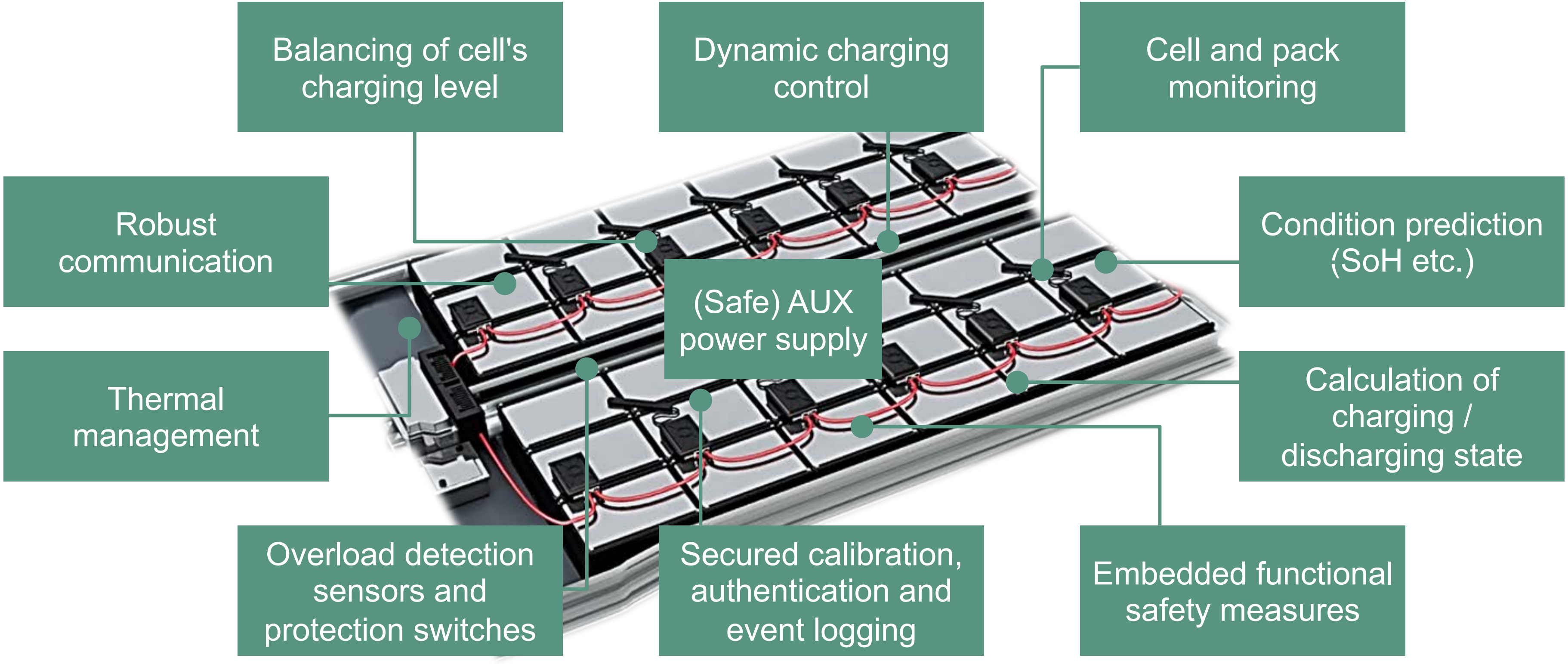
- Energy storage capacity important for range maximization w/o recharging ("specific energy")
- Short energy transfer times determine the battery's ability to support fast charging, recuperation, and peak engery provision for e.g. acceleration ("specific power")
- Li-Ion is the predominant cell technology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

Structure of an electrical vehicle's battery



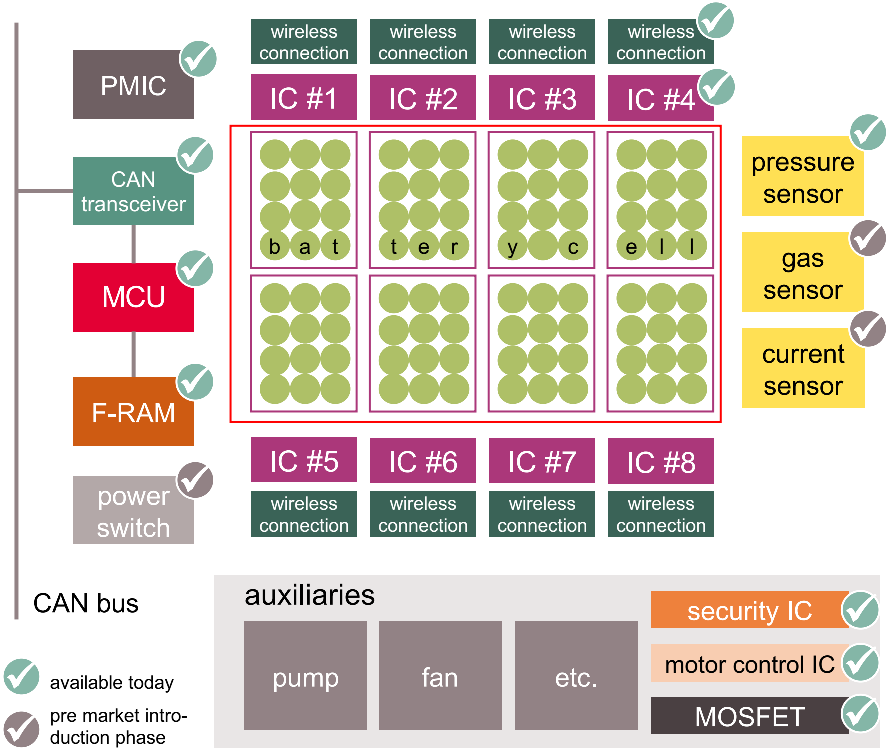
Battery management functions covered by Infineon product portfolio

Infineon'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 (H_2 or HCO_3)
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** ±5.8mV 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 <150mA or control for external switches beyond; external resistors for optimized power consumption

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

Key Challenges in BMS	**Functional Safety**	**Security**	**Time to market**	**Energy efficiency**	**Zero downtime**
Matching AURIX™ TC3xx features	Implementation of safety measures in HW (LBIST)	Integrated HSM & EVITA FULL: Symmetric & asymmetric crypto accelerators	Scalable portfolio & seamless migration between generations and applications	8-bit standby controller with extremely low current consumption	Software Over The Air (SOTA) update
	ISO26262 certified from TÜV, ASIL-D supported by whole family	Protection against unauthorized battery manipulation	Reuse of multiple concepts (SW, FuSa / security concept)	Battery SOC/SOH* checks over long parking periods	Downtime reduction & SW fallback solution supported

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

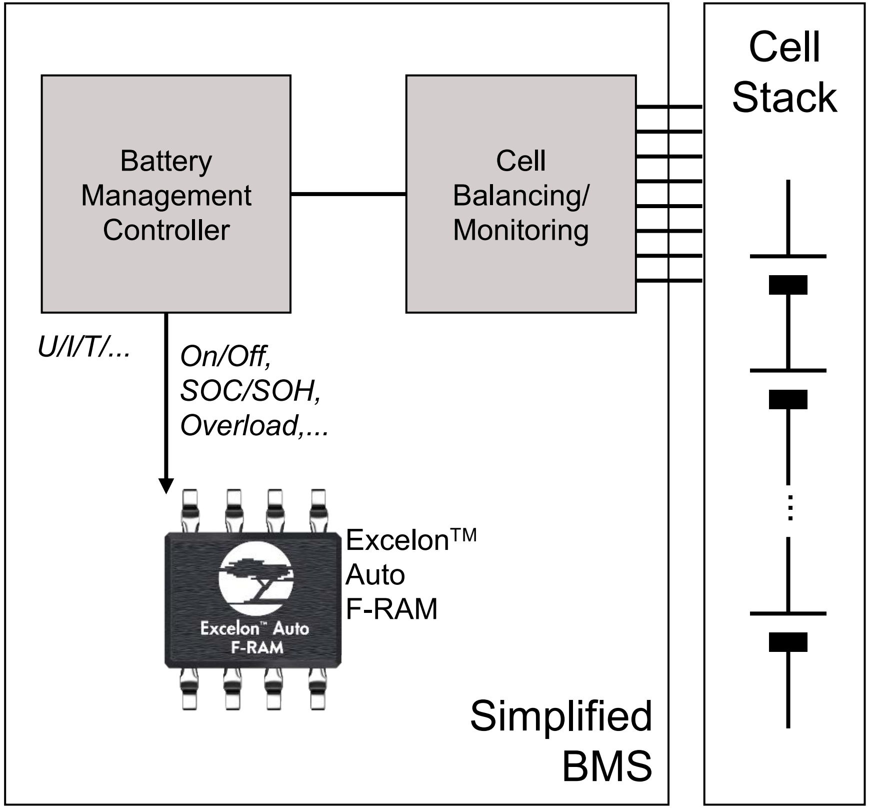
BMS functionality beyond basic cell control to improve battery lifetime and to enable new business models

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
Excelon™ 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



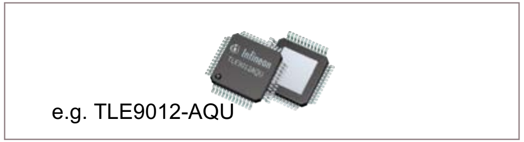
Highlevel Infineon portfolio overview for improved BMS solutions

Battery function

- Cell pack monitoring and balancing
- Dynamic charging control
- Calculation of dis-/charging state
- Condition prediction
- Extended battery protection
- Robust communication
- Thermal management
- Embedded functional safety measures
- Secured calibration, logging and authentication

Examples

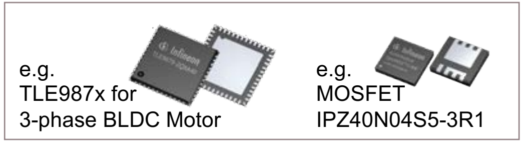
Multi-channel battery monitoring and balancing system ICs covering functions such as accurate **cell voltage** and **temperature measurement**, **cell charge balancing,** or robust daisy-chained **communication** across cell clusters



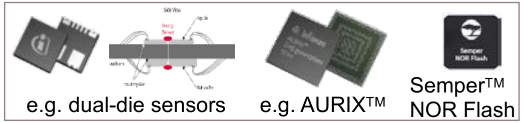
Multi-core microcontrollers with scalable processing performance, connectivity and embedded hardware security, extended by fast, low-power F-RAM for on-the fly data logging

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

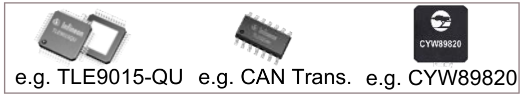
Embedded motor controls for fans, pumps etc. with inbuilt diagnostic functions for efficient **thermal control** operation. Smallest package form factor and a minimum number of external components allow for **integration close to motor**



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



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)



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

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)

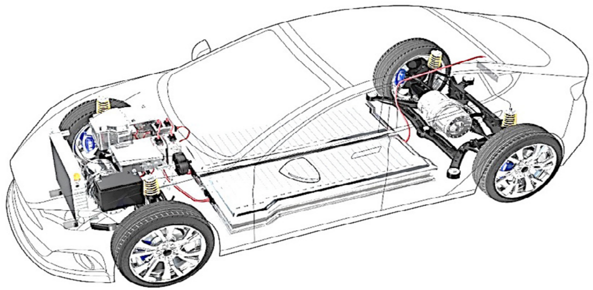
Thermal control solutions for capacity optimization and better lifetime

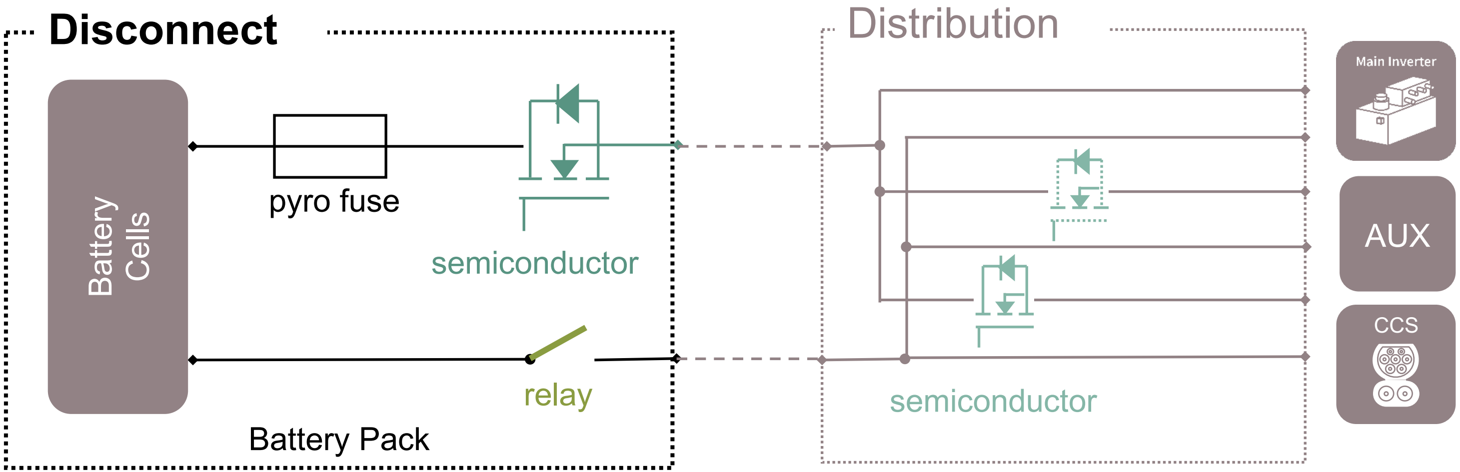
- Active thermal management via heat pumps
- Preheating of battery via energy circulation through main inverter

Advanced security

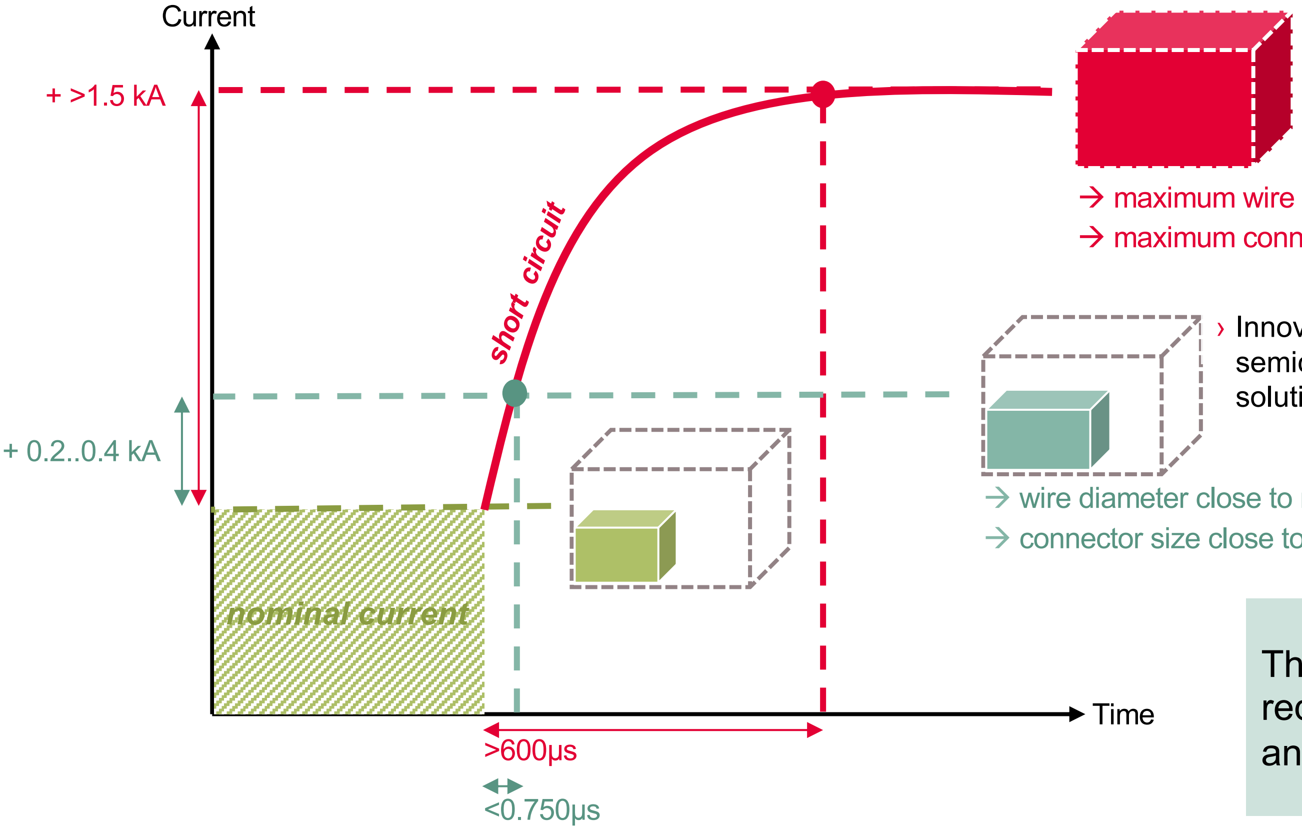
- Pack-/module-identification of battery setup and configuration supporting safety case
- Genuine / authenticated parts / components
- New use cases and biz models based on protected usage data ("flight recorder", pay-per-use etc.)

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?



- Traditional solution by
  - Pyro switch
  - Relay
  - Melting fuse

→ maximum wire diameter
→ maximum connector size

- Innovative semiconductor-based solution

→ wire diameter close to nominal
→ connector size close to nominal

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

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

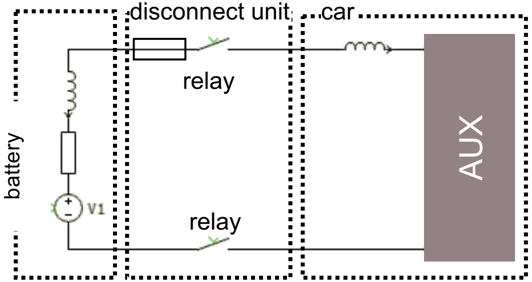
Assumed short-circuit scenario constraints:

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

here:

~0.85µH, 400 V ⟶ 472A/µs

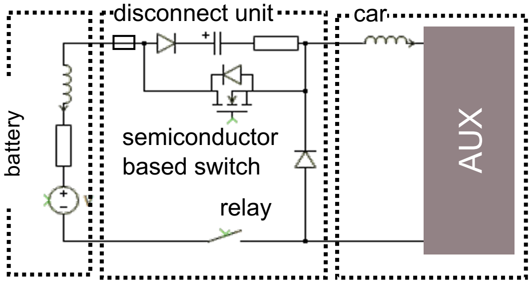
Current relay solution:

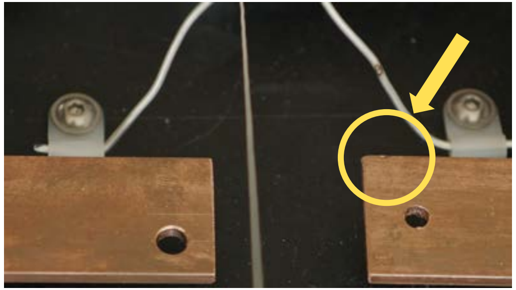


Turn-off time >600µs

600µs ⟶ **~1.5 kA**

Semiconductor based solution:





Turn-off time ≤0.750µs

0.750µs ⟶ **~354 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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