Green Energy and Battery Management

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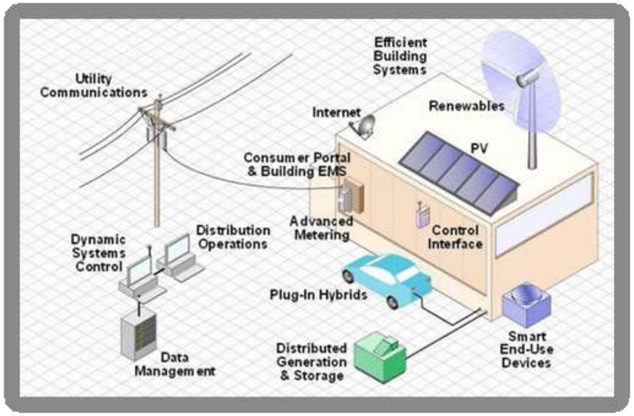
ICT for Energy

- ➢ Green energy
  - Sustainable mobility
    - E-bikes
    - Electric scooters
    - Electric cars
  - Power applications
    - Green sources (Solar, Wind, etc.)
    - Smart Grids
- ➢ ICT technologies fundamental for the development of the applications



Trends for vehicles

- Increased environmental sensibility
- More stringent rules and laws for polluting emissions

Electric and/or hybrid vehicles

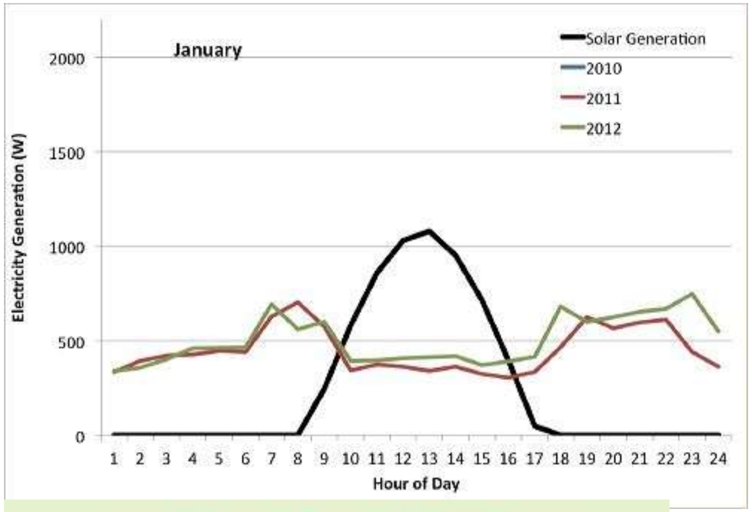
ZEV (Zero-Emission Vehicle)

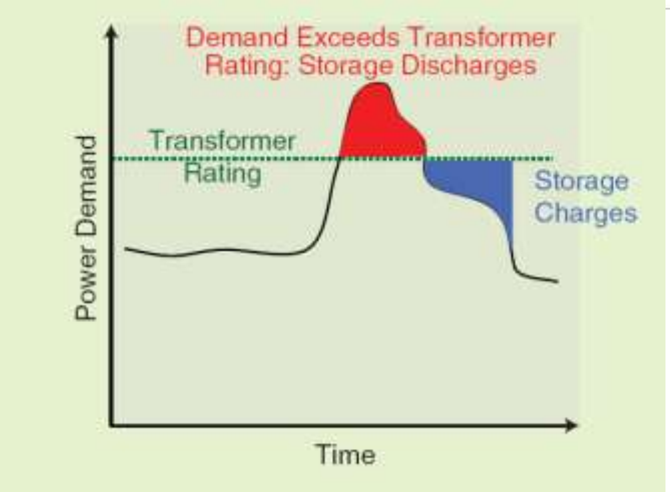
Energy production

➢Production from renewable sources is variable and unpredictable in time

➢User demand also is variable in time

➢Energy storage can compensate the difference



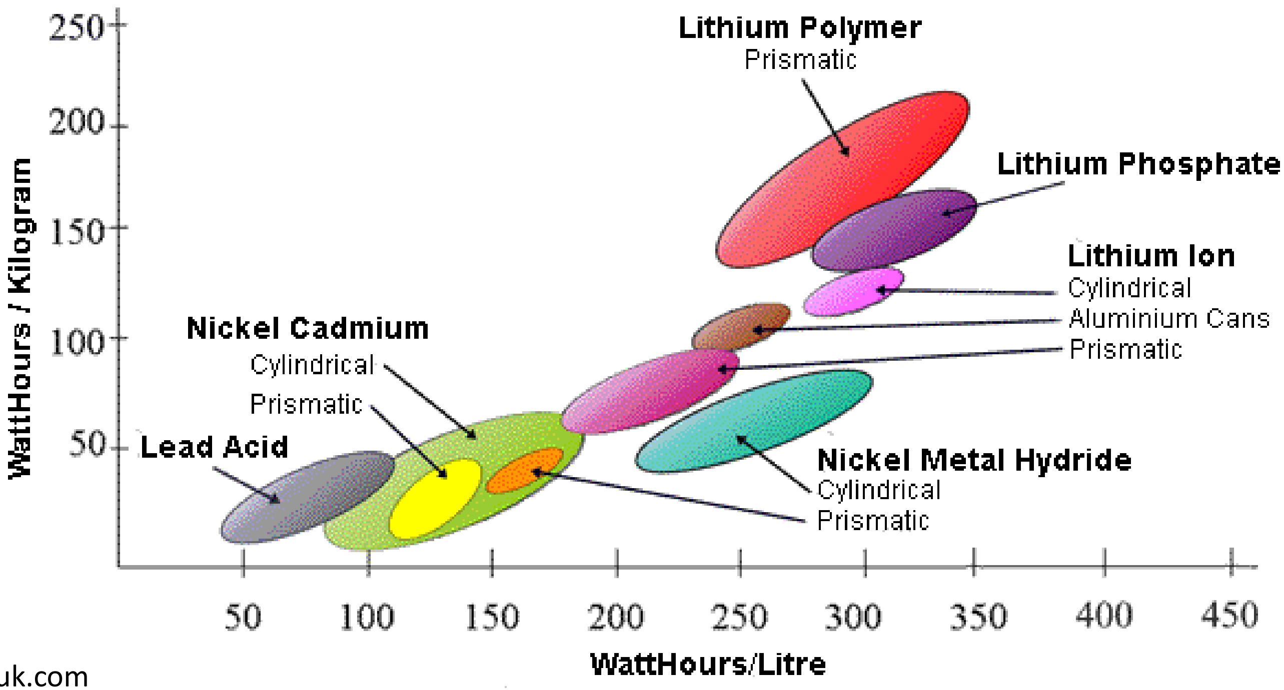


Energy storage

Energy Storage Systems

Batteries

- ➢Rechargeable batteries are up-to-date solution for storage
- ➢Lithium-ion batteries provide best performance



Source:
www.mpoweruk.com

Lithium chemistry

- Very hi… very low … c.
- Very se… …arge and to exceedir…
  - Ce… …osion
- Differe…
  - Dif…
    -
  - Lot…
- Battery…
  - Sa… …agement sys… …BMS)

NEWS

1.3 MILLION

NUMBER OF HOURS BOEING TESTED BATTERIES IN FLIGHT

A COMPLEX SYSTEM: Boeing's fuel-efficient 787 Dreamliner involved design input from many suppliers. The plane went to customers two years late.

BOEING'S BATTERY BLUES

Despite fires in the 787's lithium-ion batteries, planes will become more dependent on electricity and batteries

IN JANUARY, regulators in Japan and the United States grounded the worldwide fleet of Boeing 787 Dreamliners after lithium-ion batteries caught fire in two of them—one in the air over Japan and the other on the ground in Boston. As *IEEE Spectrum* went to press, authorities were tracing the proximate cause of the Boston fire to a short-circuit in one of the batteries. The ultimate cause remained unclear.

What is clear, though, is that lithium-ion batteries in commercial airliners are probably here to stay. Airliners are going to keep electrifying previously mechanical systems like those used for braking and de-icing, because doing so makes the aircraft much lighter and more efficient, says Cosmin Laslau, an electrochemistry expert and technology analyst for Lux Research.

A heavy reliance on electrical systems, together with extensive use of ultralight carbon composites, is what cuts the 787's fuel consumption by 20 percent versus the competition's—its main selling point. (The batteries are mere backup to the six—count 'em, six—generators that supply the 787 with a whopping 1.5 megawatts, about five times as much as in any comparable airliner.) And lithium-ion batteries are likely to remain the technology of choice for new airliner

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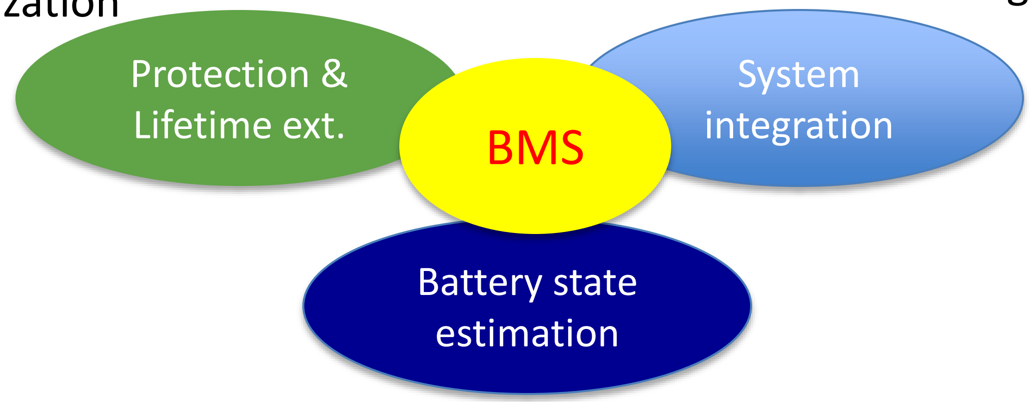
IEEE Spectrum, Mar 2013

BMS Functions

- Cell voltage, temperature and current measurement
- Main switch control
- Thermal management
- Charge equalization

- Logging
- Communication w/ external systems
- Diagnostics



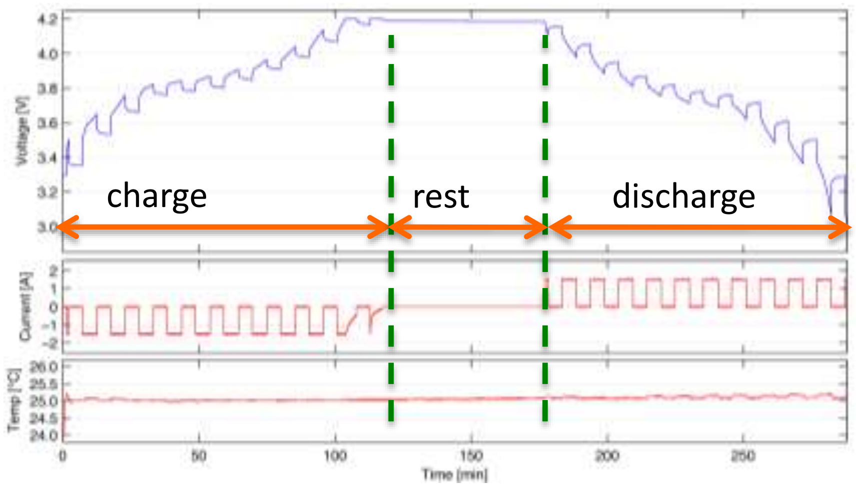
- State-of-Charge estimation (SoC)
- State-of-Health estimation (SoH)
- Residual useful life (RUL)

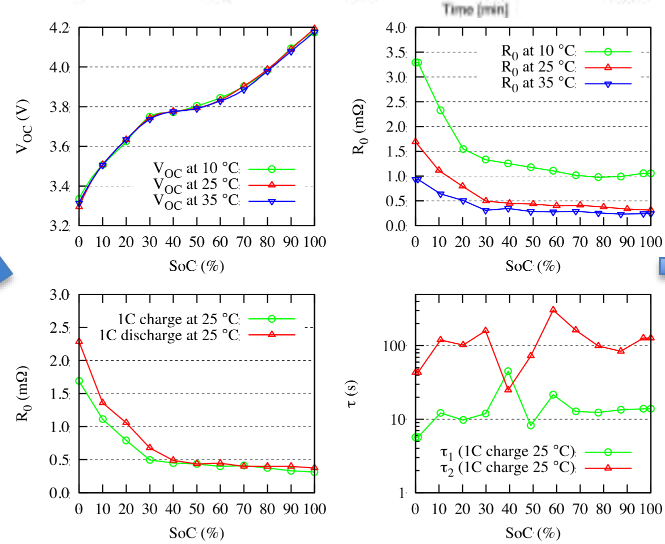
Our expertise

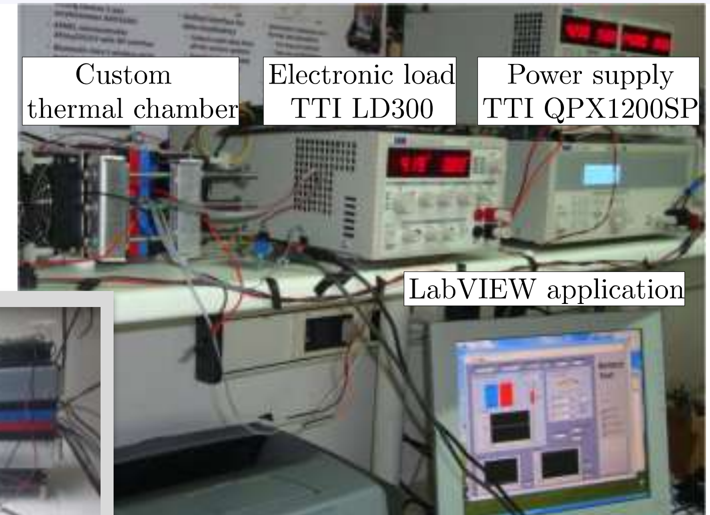
- Battery testing and modeling
- Algorithms for battery state estimation
- BMS architecture definition and hardware/software design of the building blocks
- Active charge equalization
- Battery pack prototyping and testing

Battery testing and modeling

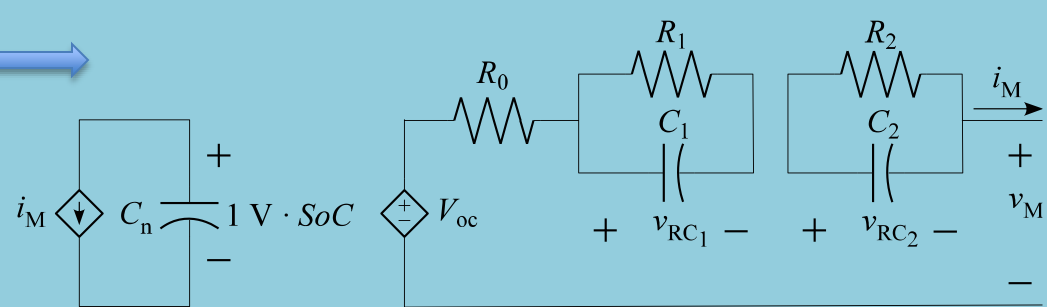
Tests carried out on an 1.5 Ah Li-Po cell







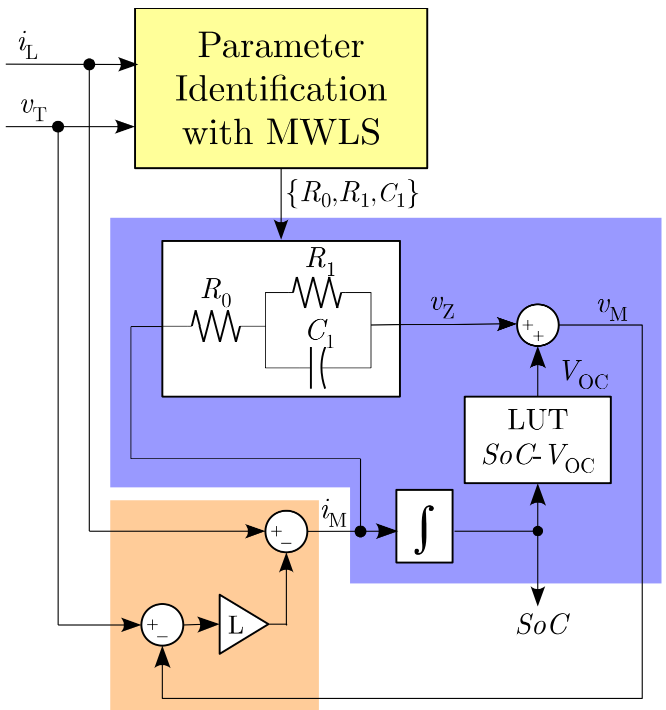
Equivalent electric cell model

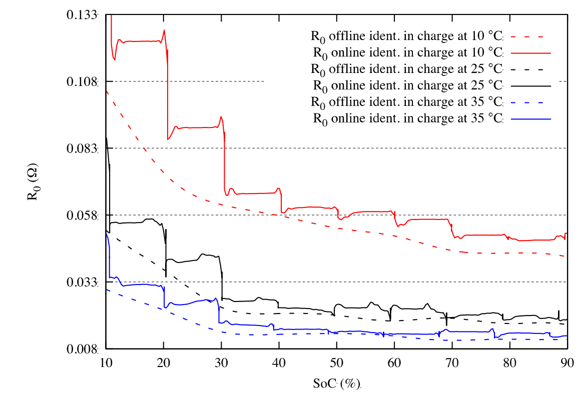


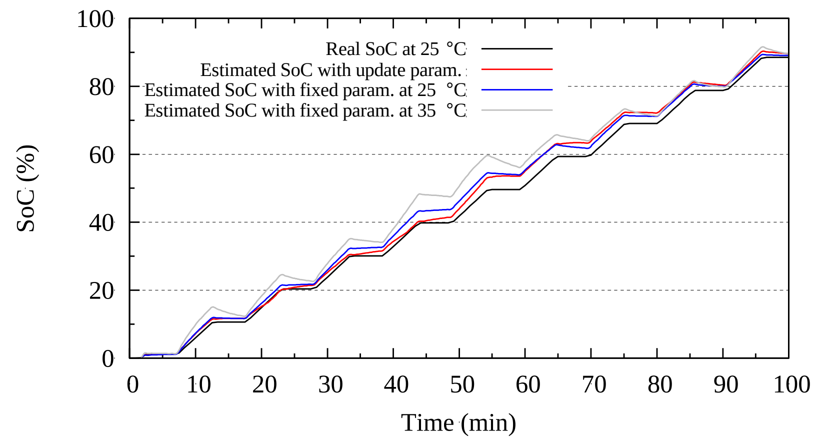
SoC and parameter co-estimation

- Coulomb-counting with compensation based on a battery model and a feedback loop
- Online identification of the model parameters

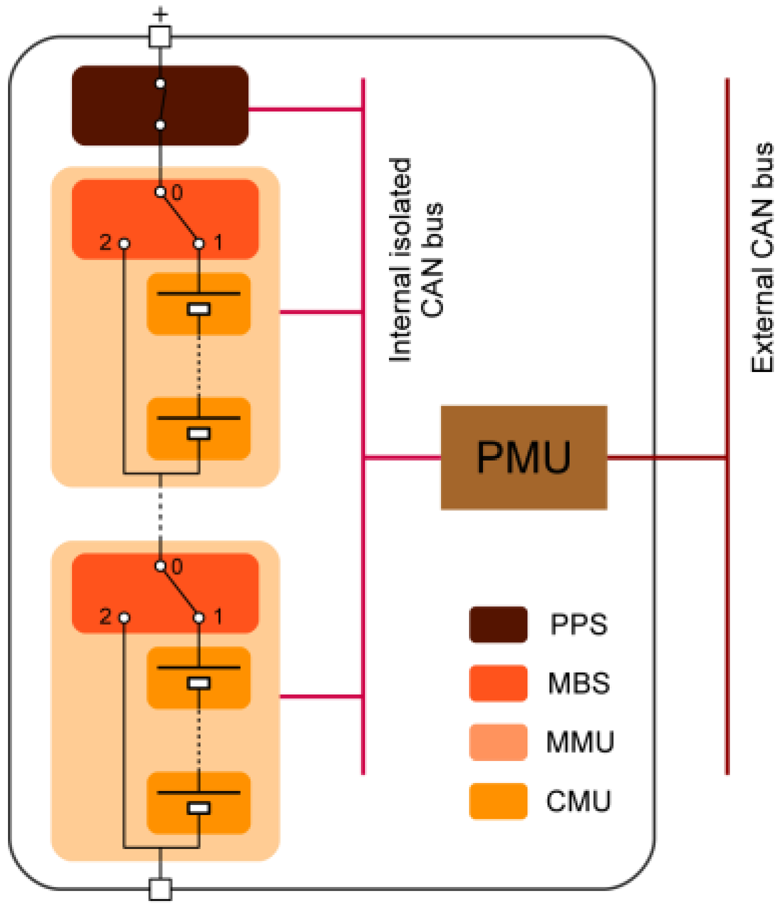
$$SoC(t) = SoC_0 - \frac{\int_0^t i_L(t)\,\mathrm{d}t}{Q_n}$$

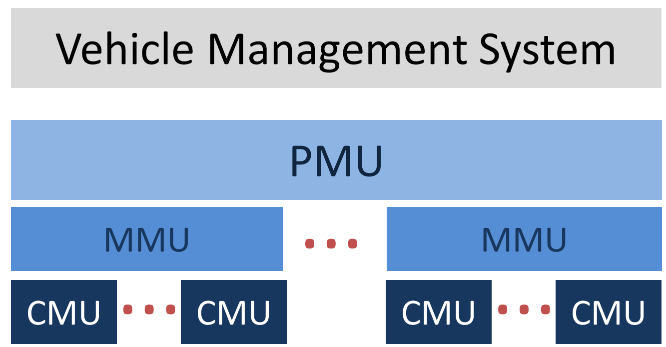






BMS hierarchical platform

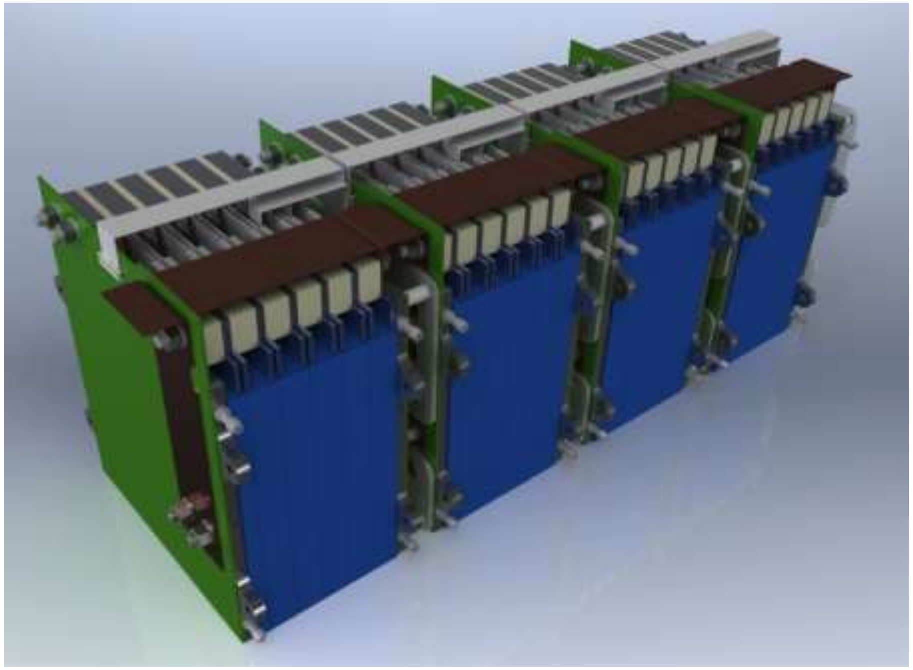


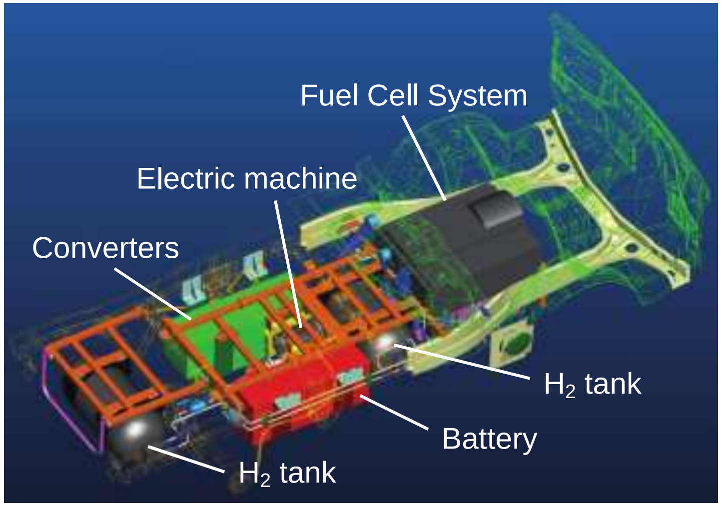


- PMU (Pack Management Unit)
- MMU (Module Management Unit)
- CMU (Cell Monitoring Unit)
- PPS (Pack Protection Switch)
- MBS (Module Bypass Switch)

BMS example #1

- Hydrogen Fuel Cell Hybrid Electric Vehicle (H2FC-HEV) in the framework of "Filiera Idrogeno" project
  - – 14.4 kW hydrogen fuel cell
  - – 160 V - 40 Ah LiPo battery pack

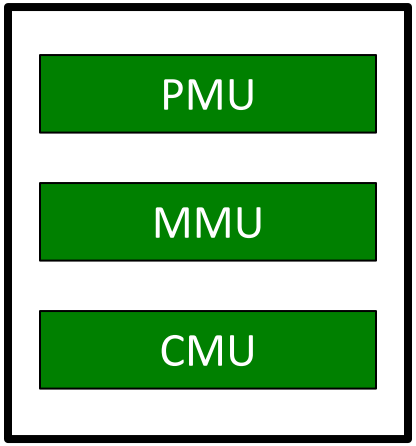




M. Ceraolo, "Experiences of realisation and test of a fuel-cell based vehicle," *SPEEDAM 2010*

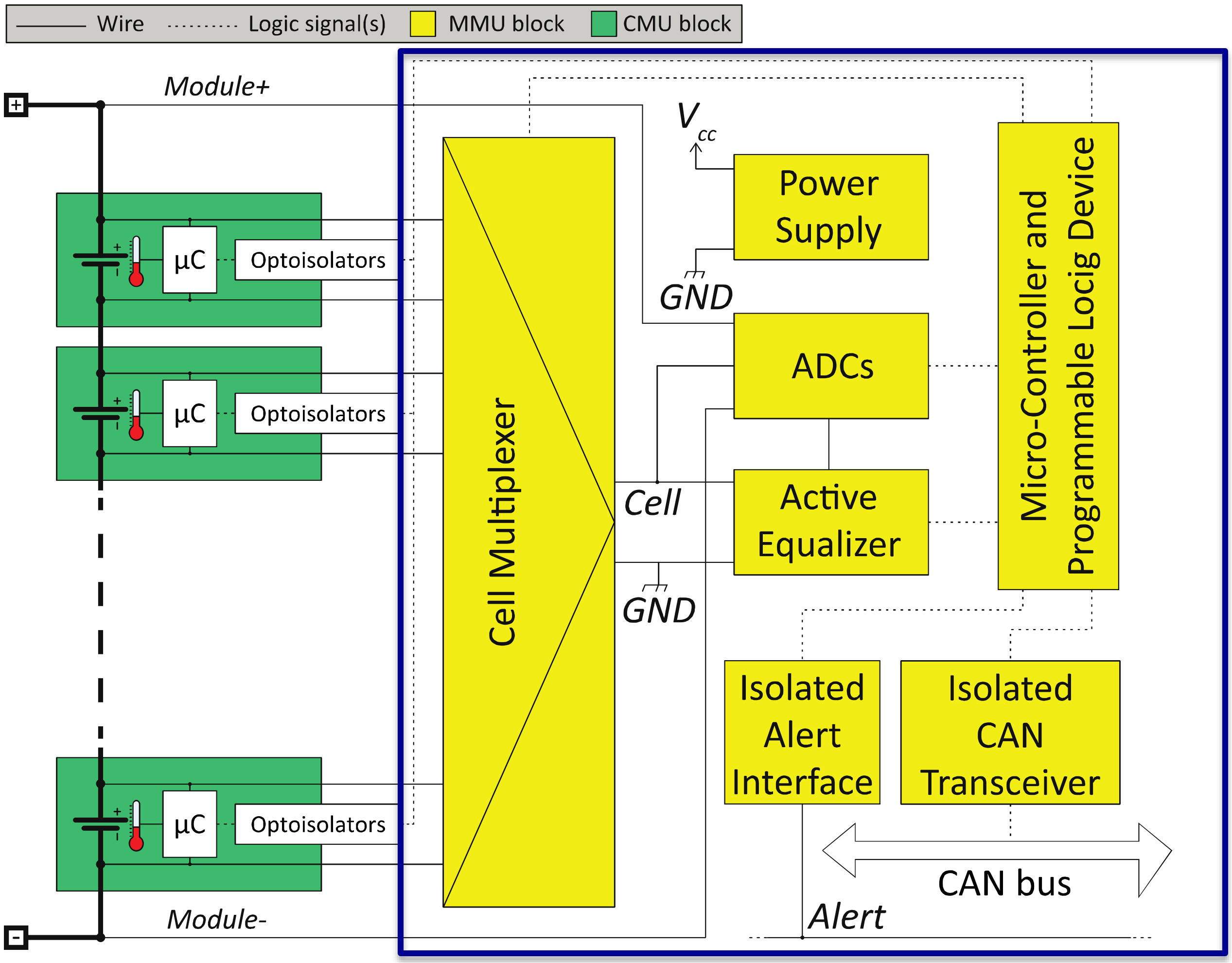
BMS example #1

- Battery pack consists of 44 40 Ah LiPO cells
- Battery pack partitioned into 4 modules
- Each module manages 11 40 Ah LiPo cells with:
  - 11 CMUs
  - 1 MMU
  - 1 MBS



All the three layers of the hierarchical platform have been used

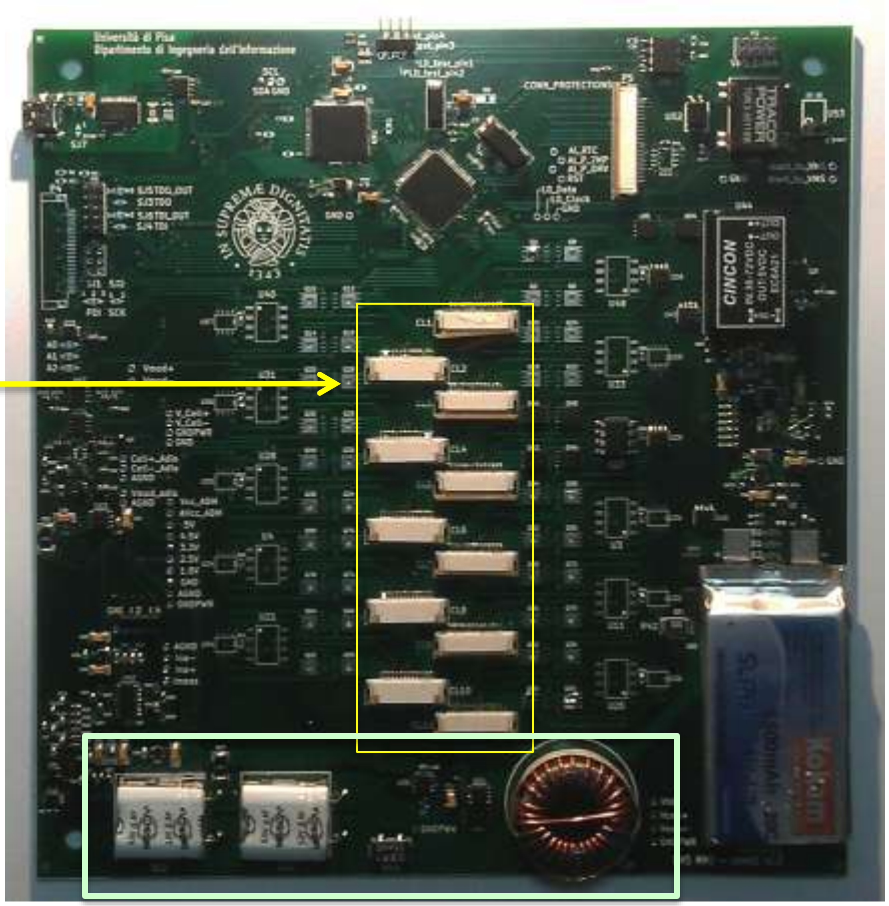
MMU design



Wire
Logic signal(s)
MMU block
CMU block
Module+
μC
Optoisolators
μC
Optoisolators
μC
Optoisolators
Module-
Cell Multiplexer
V_{cc}
Power Supply
GND
ADCs
Cell
Active Equalizer
GND
Micro-Controller and Programmable Locig Device
Isolated Alert Interface
Isolated CAN Transceiver
CAN bus
Alert

MMU implementation

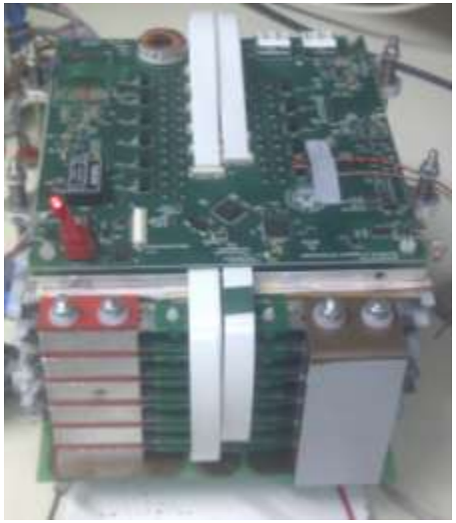
Connectors
to the CMUs



Active charge equalizer based on a Buck-
Boost Converter w/ supercapacitor

Module prototyping and testing

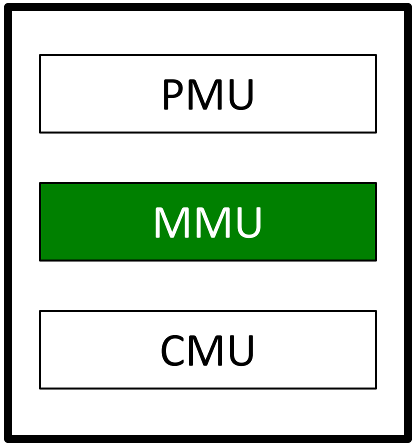
- A complete module implemented and tested
- The module has been used to power an e-bike as demonstration.
- The e-bike was rided by public in 2012 Green City Energy with remote telemetry of BMS data



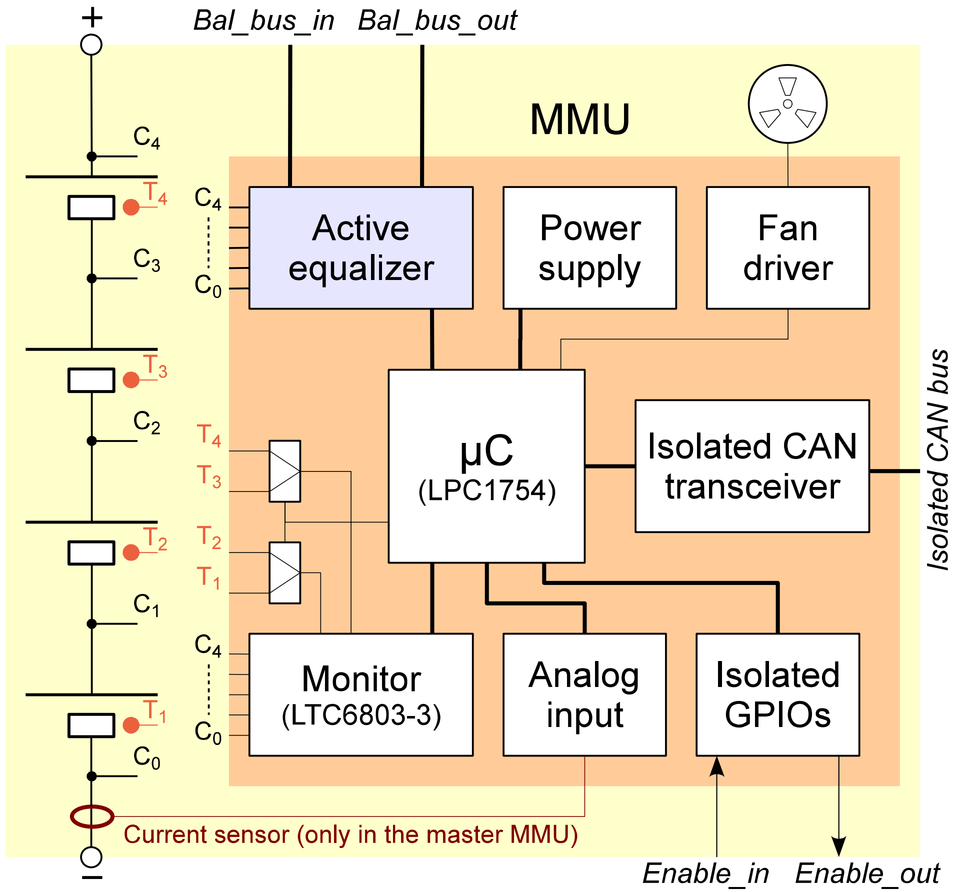
BMS example #2

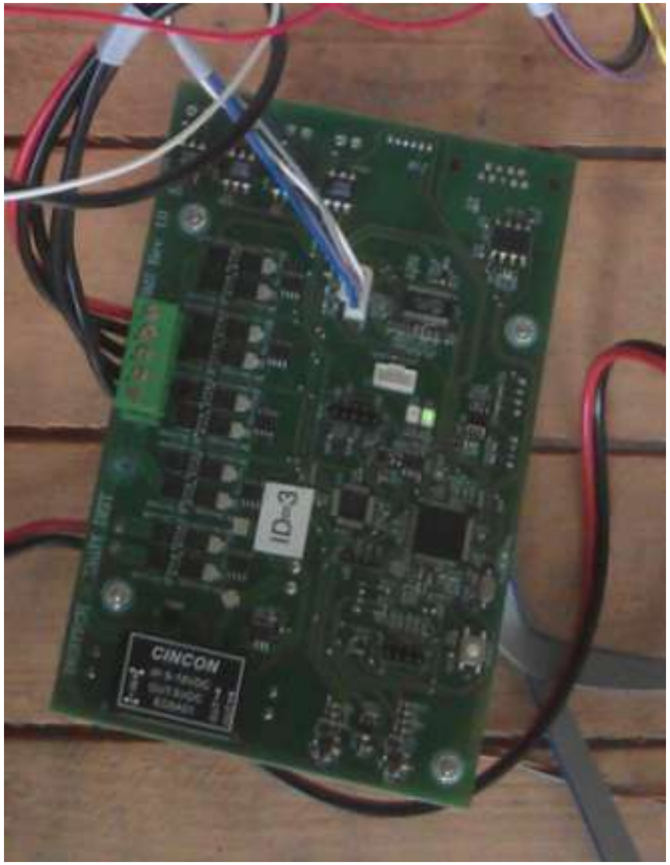
- Standard 12 V battery module
- 4 series-connected $LiFePO_4$ cells
  - Nominal voltage = 12.8 V
  - 3 capacities: 30 Ah, 60 Ah, and 100 Ah
- To replace VRLA batteries used in cars and off-road vehicles
- Simple BMS architecture

Only the MMU layer of the hierarchical platform is used



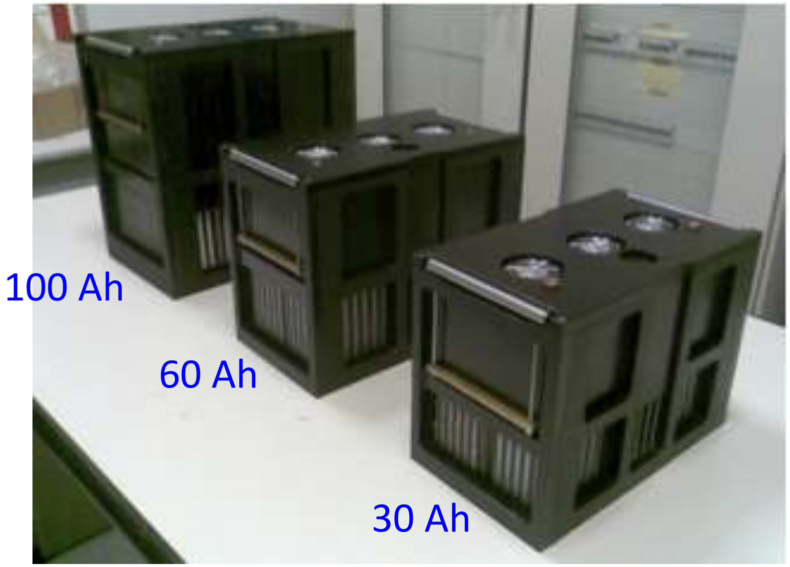
MMU design and implementation

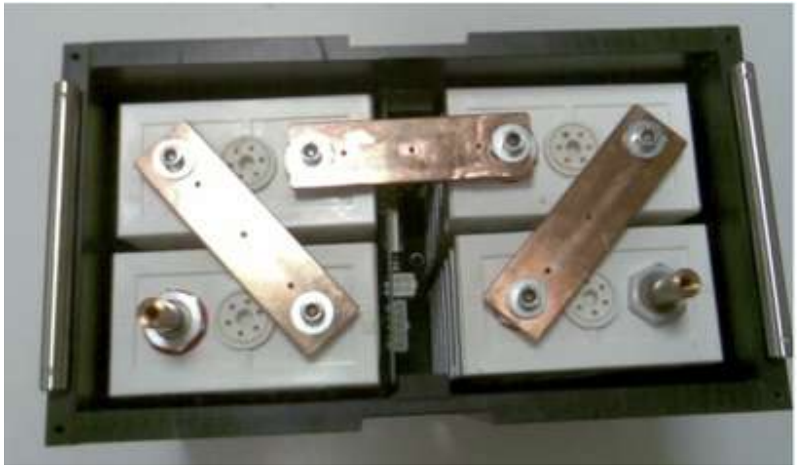




Standard battery module assembly

Module capacity (Ah)	Module size (mm^3)	Module weight (kg)	Module energy density (Wh/kg)	Cell energy density (Wh/kg)	Module power density (W/kg)
30	277x160x208	8.3	46.3	83.5	231.3
60	297x166x236	12.3	62.4	94.1	312.2
100	310x186x318	19.1	67.0	94.1	335.1





Conclusions

- Expertise available in applications of ICT to the energy field
- Battery characterization and modeling
- BMS architectural choice and design
- Prototyping and testing
- Open to cooperation with academic and industrial partners