# BATTERY MANAGEMENT SYSTEMS FOR DYNAMIC SYSTEMS

Short Overview of Current Work on Battery Management Systems


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Huawei Webinar Battery Technologies

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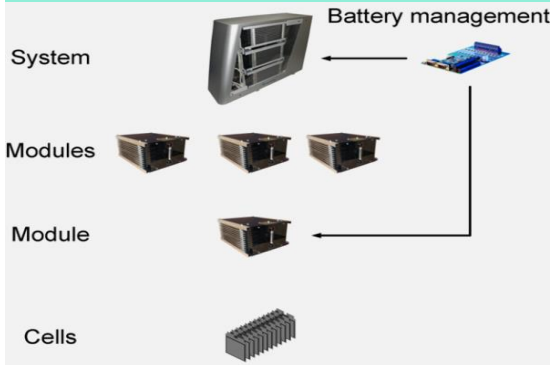
# Fraunhofer ISE – Department Electrical Energy Storage

## Overview

**Battery Cell Technology**
materials, architecture, production

- Development and characterization of materials and battery cells
- Development of process technologies
- Aqueous systems for stationary energy storage
- Lithium ion battery cells
- Solid state battery cells
- Technical and economical analysis
- Life cycle analysis

**Battery Engineering**
from cells to systems




- Cell formation
- Cell and system characterization
- Ageing and performance scrutiny
- System design and engineering
- Thermal management
- Battery management
- Algorithms for state estimation and life time prediction
- Optimized charging and operating control strategies

**Applied Storage Systems** system design, integration and quality assurance

- Realization of lighthouse projects
- Business case development
- Consulting during complete life cycle of storage projects
- System modelling, analysis and optimized system design
- Simulation based storage sizing
- Energy management systems
- Technical due diligence: Site inspection, testing and monitoring

**TestLab Batteries** electrical, thermal, mechanical testing

- Ageing: calendric and cyclic
- Safety: components and systems including functional safety
- Reliability: consideration of operating conditions and system behavior with aged components
- Performance: efficiency and effectiveness
- End-of-line quality control for cell production



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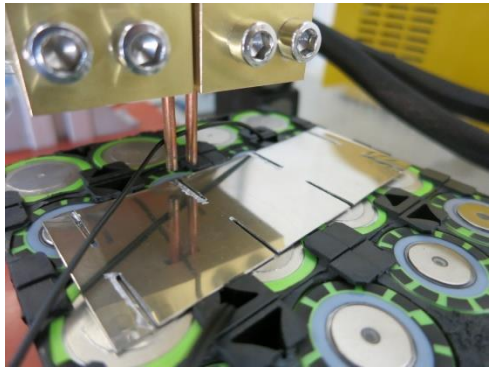
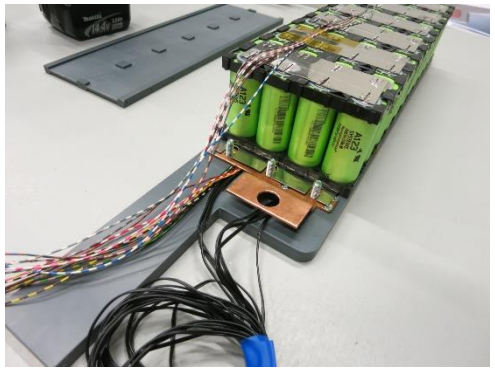
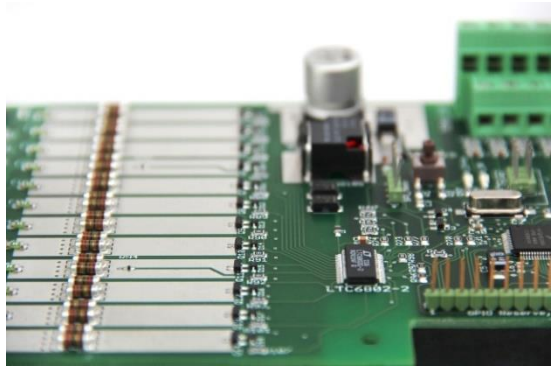
# From Cell to Full System (1/2)

- Development of complete systems



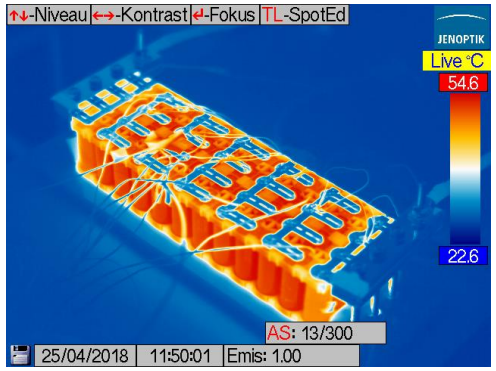




# From Cell to Full System (2/2)

- Testing and certification


Thermal management




Calorimeter testing

Home storage characterisation

Certification & destructive testing lab



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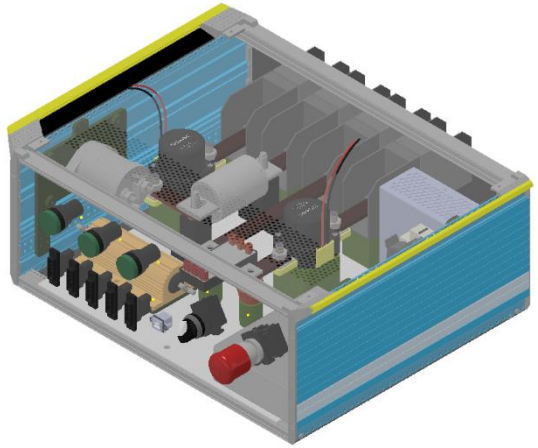
# BMS Development

- Planing and designing of battery management systems
- PCB layouting, assembly and packaging
- Writing embedded software and data analysis

- Selection of peripheral devices
- Construction of battery junction boxes
- Integration into the complete system



# SOC Estimation

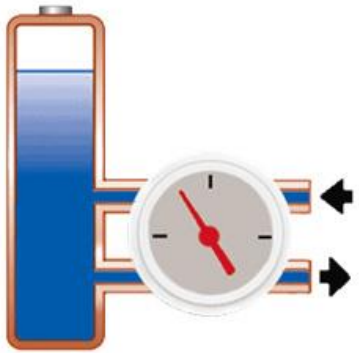
- In general based on coulomb counting
- High accuracy for non-dynamic systems

$$SOC(t) = SOC(t_0) + \frac{\eta}{C_n} \int_{t_0}^{t} I(t)dt$$

η: efficiency, C: nominal capacity, I: current

- Poor results for long time dynamic load profiles
  - 72 h UDDS* test with 3 estimators

| | Impedance Tracking | Kalman Filter | Coulomb Counting |
|---|---|---|---|
| Error | 10.93 % | 1.65 % | 11.17 % |



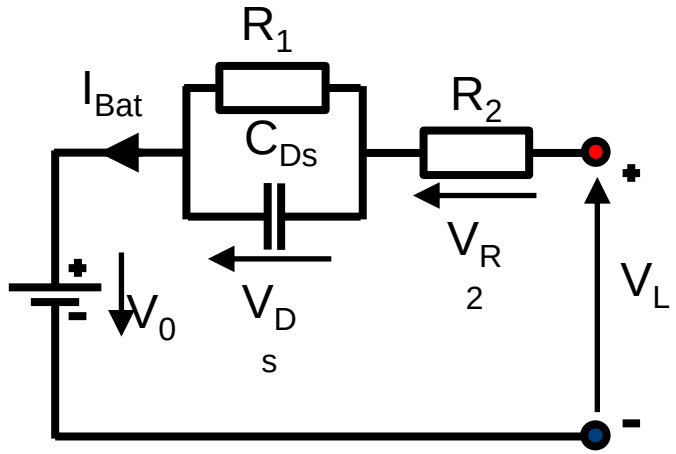
https://batteryuniversity.com/learn/article/battery_diagnostics_on_the_fly

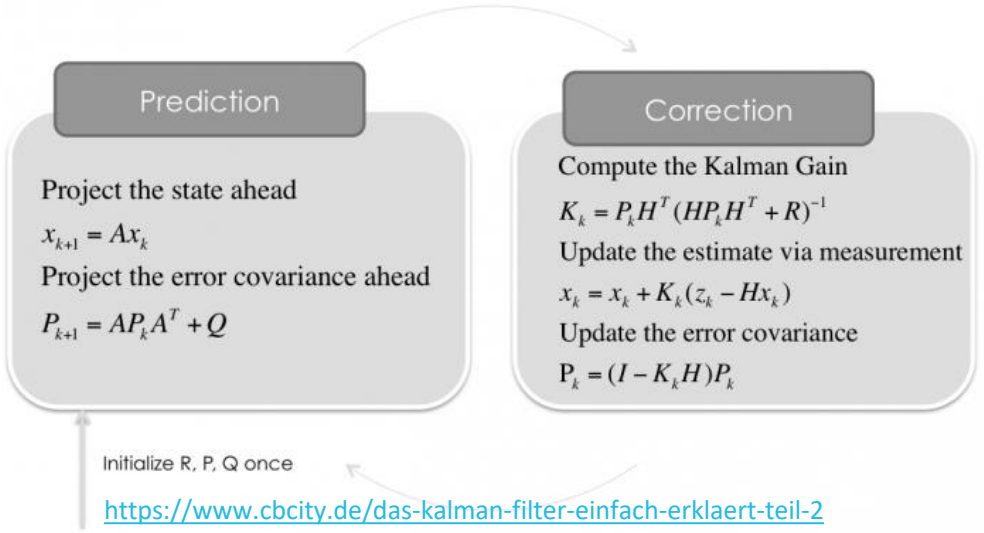
- Better results for model driven approaches

*UDDS = Urban Dynamometer Driving Schedule

# Kalman Filter SOC Estimation (1/2)

- Based on battery model, e.g. Thevenin circuit
  - Calculate V, R and C out of pulse fitting test
- KF accuracy depends on model quality
- Optimal for linear systems with gaussian noise
- You need to model the behaviour of the battery
- Predict the next state with the battery model
- Correct the prediction with a measurement




https://www.cbcity.de/das-kalman-filter-einfach-erklaert-teil-2



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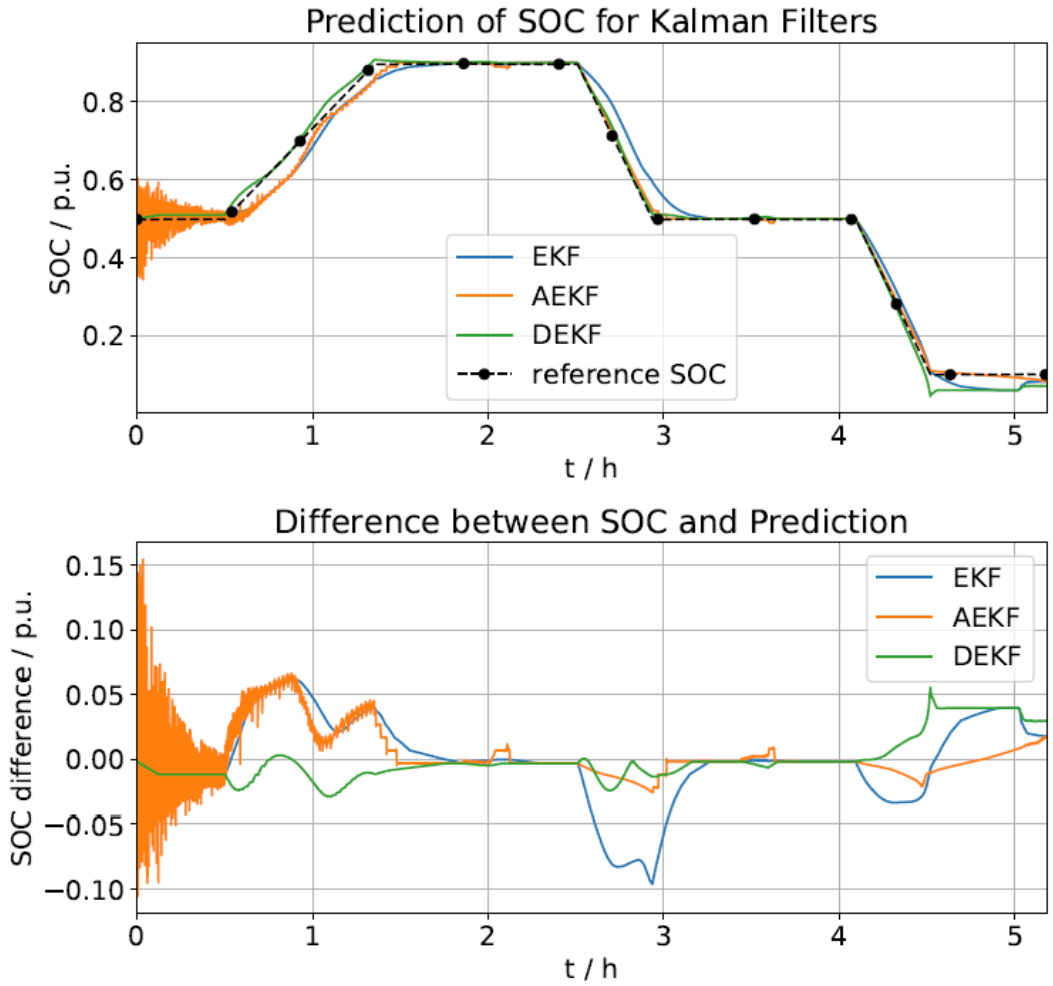
# Kalman Filter SOC Estimation (2/2)

- Three types of Kalman Filters compared

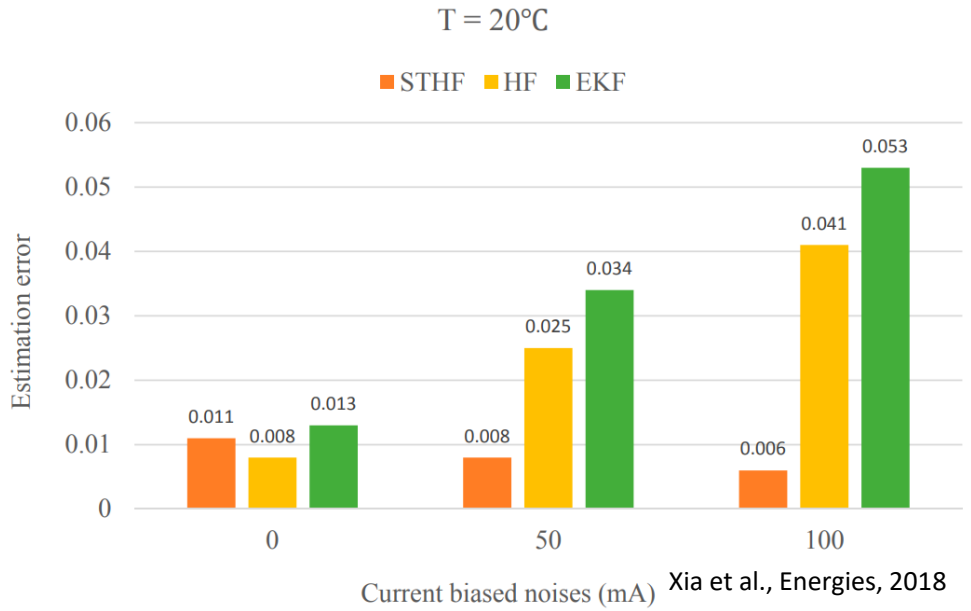
- Extended Kalman Filter
- Adaptive Extended Kalman Filter
- Dual Extended Kalman Filter



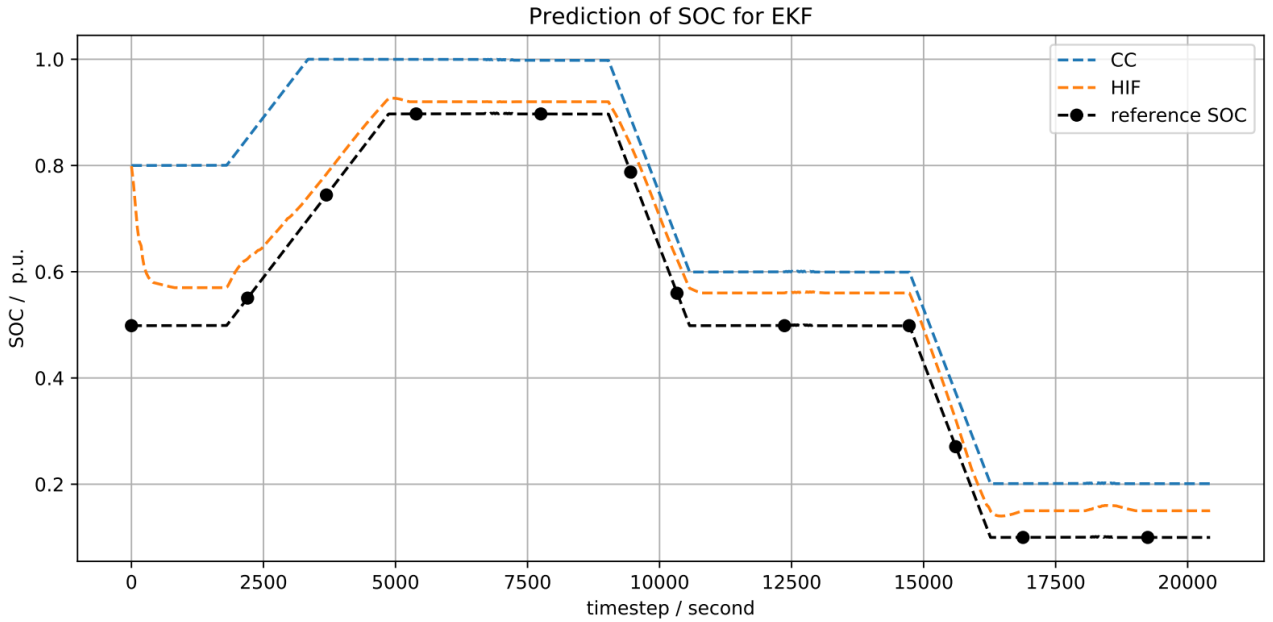
# H-Infinity Filter

- Robust controller for linear and nonlinear systems
- Less sensitive for model, measurement and noise errors
- Similiar structure as Kalman Filter

- Current work:
  - Testing with batteries in the lab
  - DSP Implementation
  - Evaluation against other filters



Xia et al., Energies, 2018




DSP: Digital Signal Processor



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# Future Work: State of Energy Estimation

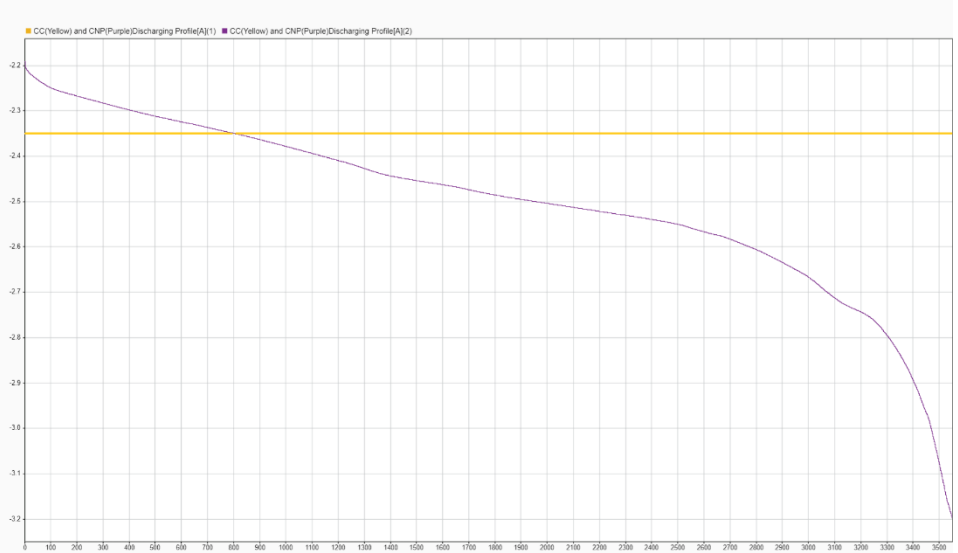
- Ratio between remaining energy to total energy
- Temperature, ageing, current rate is connected with voltage

$$SOE(t) = SOE(t_0) + \frac{\int_{t_0}^{t} P(\tau)\mathrm{d}\tau}{\mathrm{E_N}}$$

P: power, E: nominal energy

- SOE is an important value for energy optimization and energy operation

- Current work:
  - Applying Kalman Filter for SOE estimation
  - Predict energy loads from previous profiles
  - Developing Simulink model



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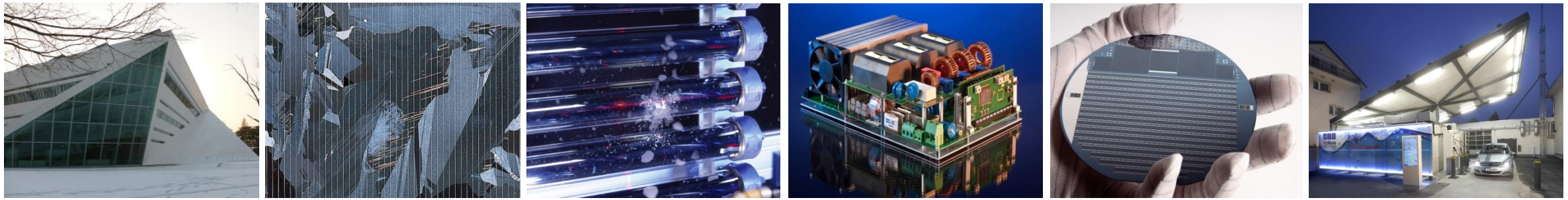
# Thank you for your Attention!



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