



Ewald Wachmann

Joint EC / European Green Cars Initiative  
Workshop 2013, Brussels  
10 April 2013



# Energy **ST**orage with lowered cost and improved Safety and **RELI**ability for electrical vehicles

Coordinator/ Partners:

May 2011 – April 2014

Austria:



France:



Germany:



Italy:



# Concerns for electrical cars

Safety



⇒ New Safety sensors

Longterm Battery Lifetime



⇒ New BMS concepts

⇒ Ultra caps

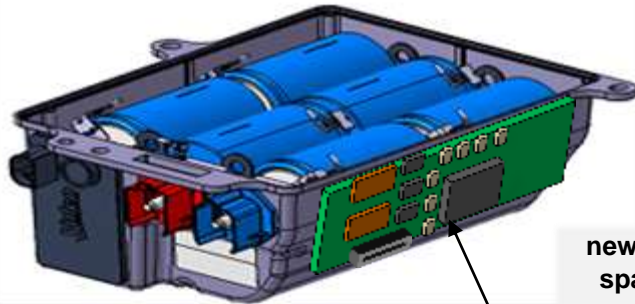
High Costs

⇒ Cost-efficient BMS ICs  
and safety components

# New Developments

## Ultra Capacitor battery pack power pack extension for Li-Ion batteries

New high density  
ultra capacitors



## Li-Ion Battery

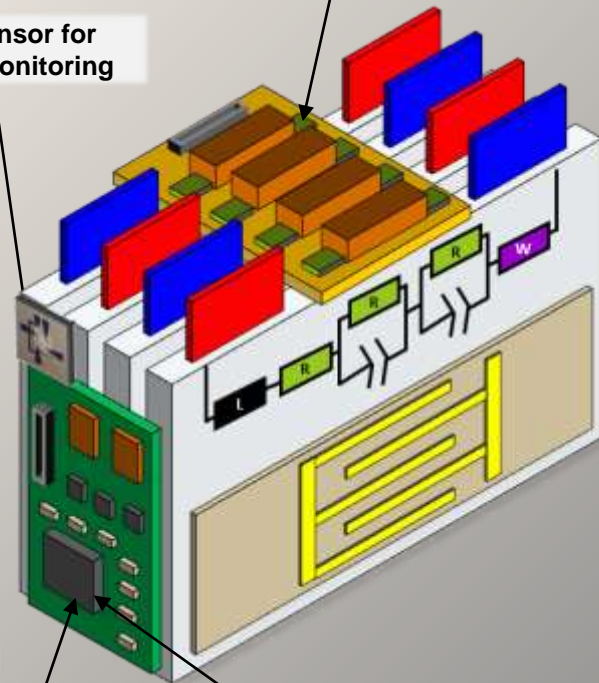
Gas Sensor for  
Safety Monitoring

New low cost  
Power Antifuses



new MEMS based  
spark detection  
sensor

Battery Monitoring  
and  
Active Balancing IC,  
galvanic isolated  
interface IC



Battery Monitoring and  
Management Software for  
dynamical configuration

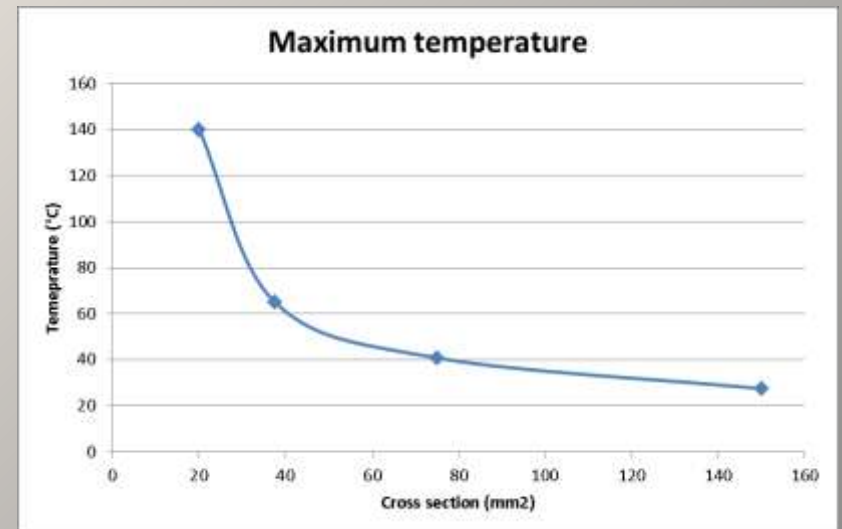
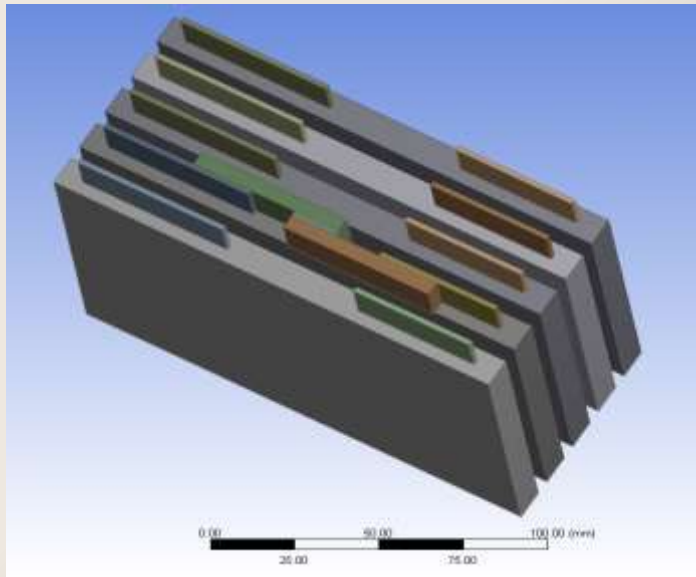
# Development of new antifuse devices

Result of the study with simulations and first test samples:

The integration of the antifuse on a battery cell element is possible

The structure of the device has been defined to enable antifusing

Voltage inversion of the battery cell provides enough current to activate antifusing





# Development of new antifuse devices

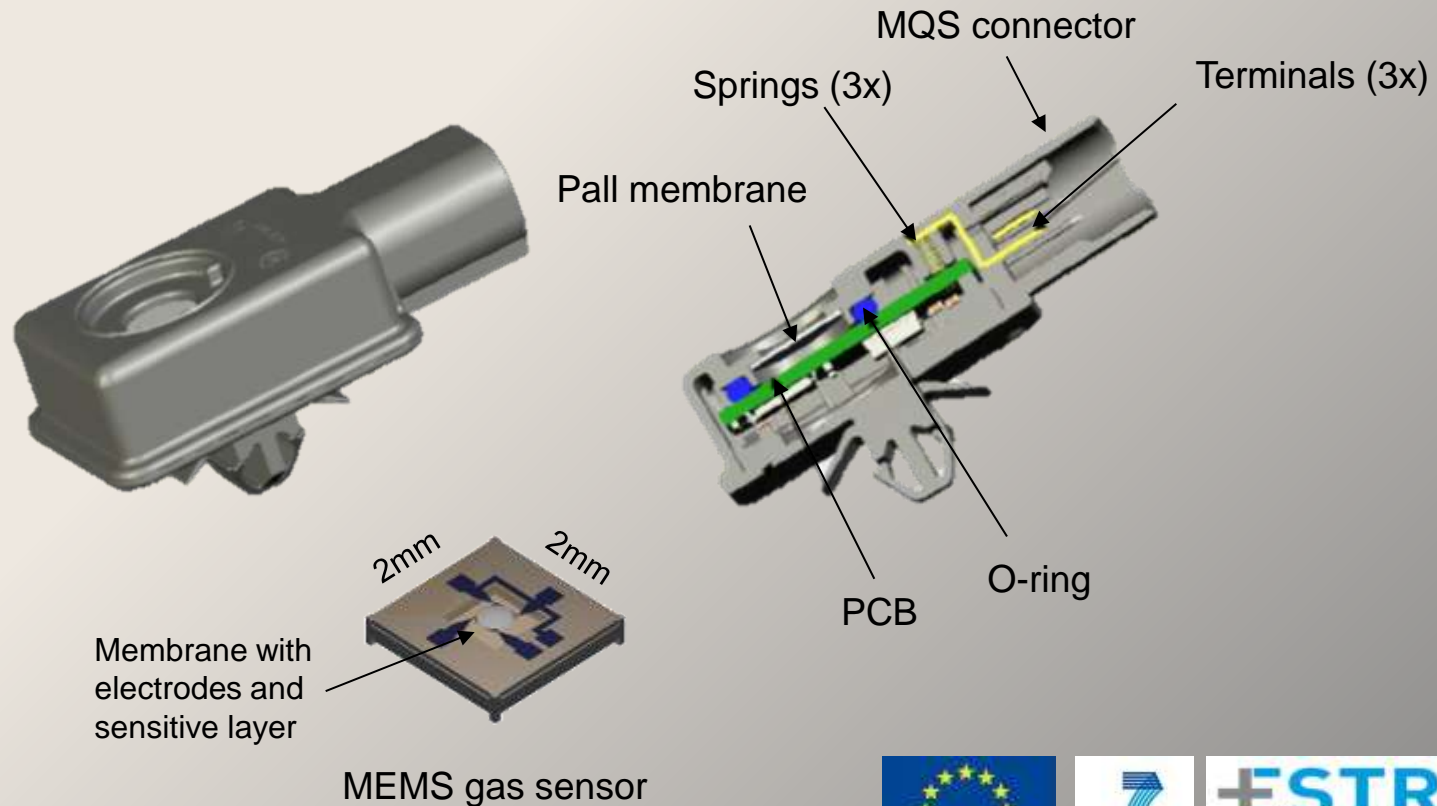
## Specifications:

Category	Value	Comment
Maximum current	100 A	
Maximum leakage / self discharge current	<5 mA	10% self discharge per month for a 40Ah cell
Maximum series resistance	1 mOhm	10 W dissipation at 100 A
Assembly and contacting section	5.3 mm <sup>2</sup>	20mm long Aluminum: a wire of 0.1mΩ requires a X-section of 5.3mm <sup>2</sup>
Untriggered antifuse fusing technology		Aluminum spiking
Externally triggered antifuse fusing technology		Exothermic reaction
Material costs	< 0.20 €	



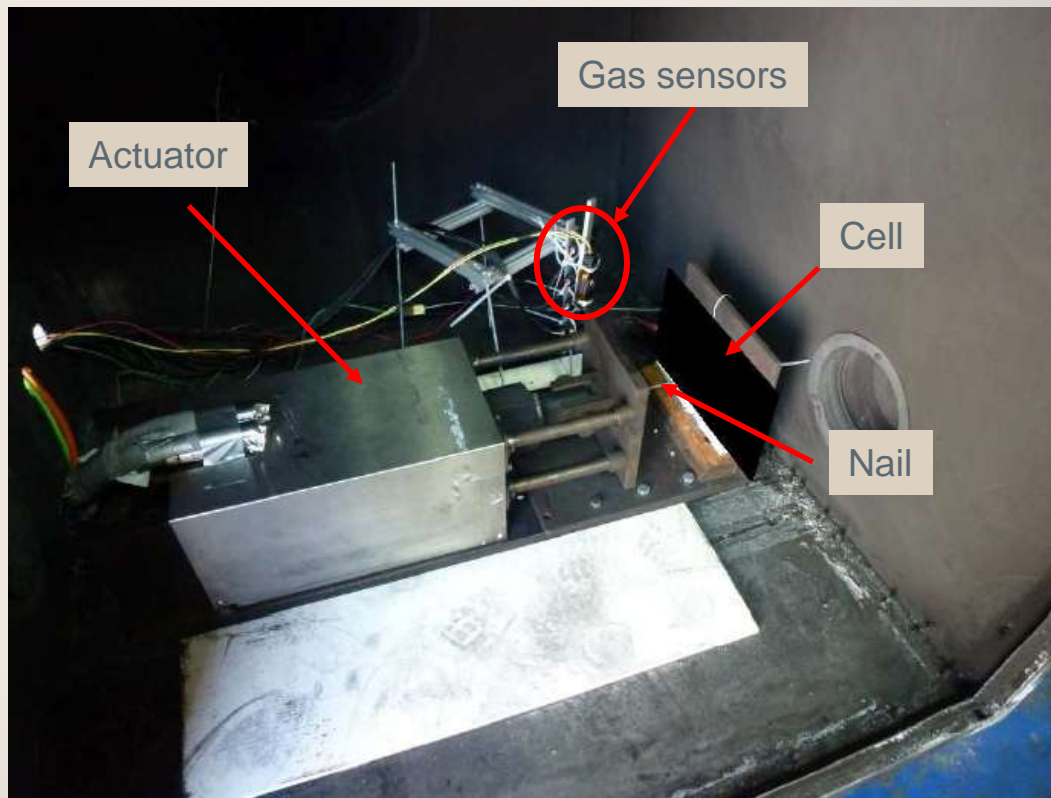
# Development of Li-Ion battery emission sensor

based on Air Classification Module (ACM)



# Development of Li-Ion battery emission sensor

## Gas sensors at Li-cell abuse tests



### Stress Tests

- Nail penetration test
- Overcharging
- Short-circuit

### Automotive sensors

- Volatile organics sensor
- Hydrogen sensor

### Automotive pouch cells

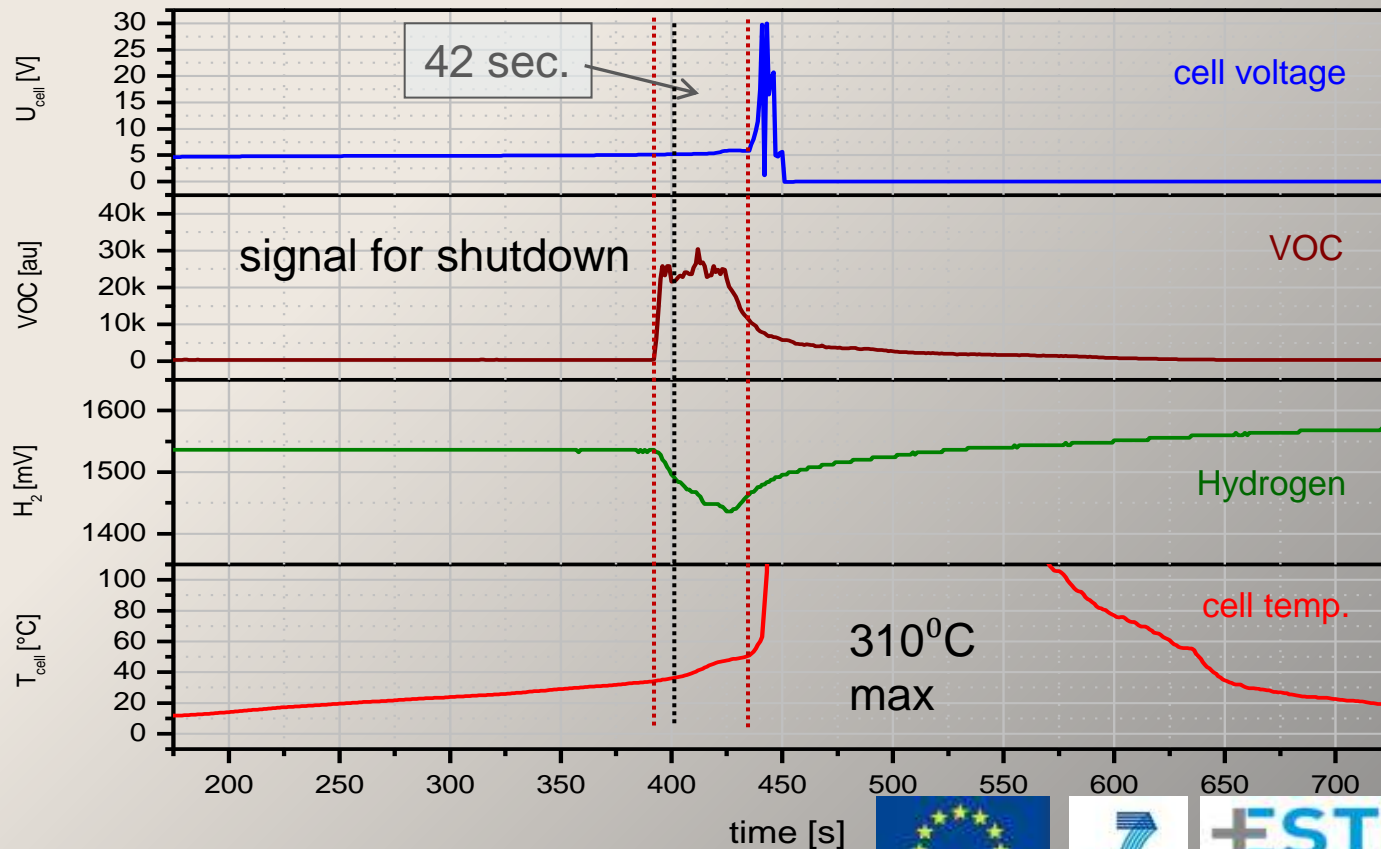
- LiFePO<sub>4</sub>, 10Ah
- LiMnO<sub>2</sub>, 20Ah
- LiCoO<sub>2</sub>, 5Ah



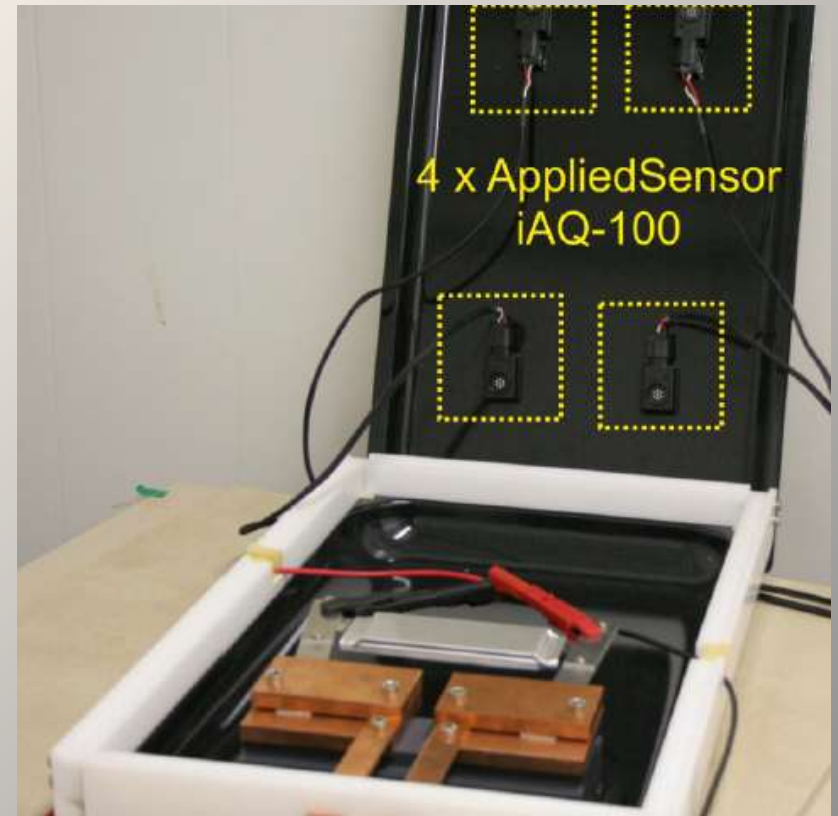
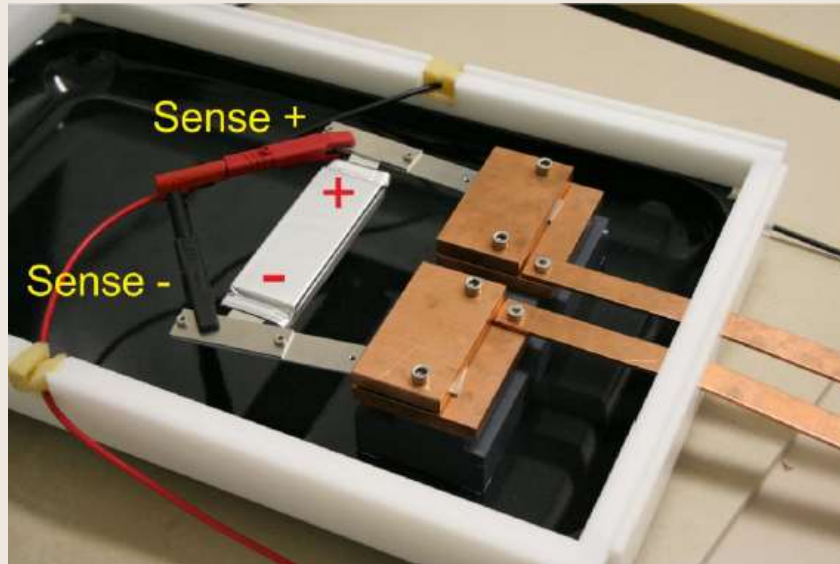
# Development of Li-Ion battery emission sensor

## Overcharging

LiCoO<sub>2</sub> pouch cell, 5Ah, I=60A



## Further tests ongoing and show promising results



Tests @ FhG and in final demonstrator ongoing ...

# Li-Ion cell demonstrator with BMS, sensors & fuse cells



Li-Ion battery  
module assembly



# New cell balancer and monitor IC

## EMC critical environment

### ⇒ Split communication in 2 domains

Daisy Chained direct action signals for Diagnosis, Trigger, Clock

Daisy Chained low speed serial communication for cell voltage broadcast and to read cell data at widely spaced time slots

### ⇒ Go for autonomous balancing through simultaneous comparison of cell voltages with a reference

more accurate compared to sequential measurement

synchronization with current not needed

### ⇒ Either passive or active balancing through integrated switches







## New cell balancer and monitor IC

# AS8506 Specifications

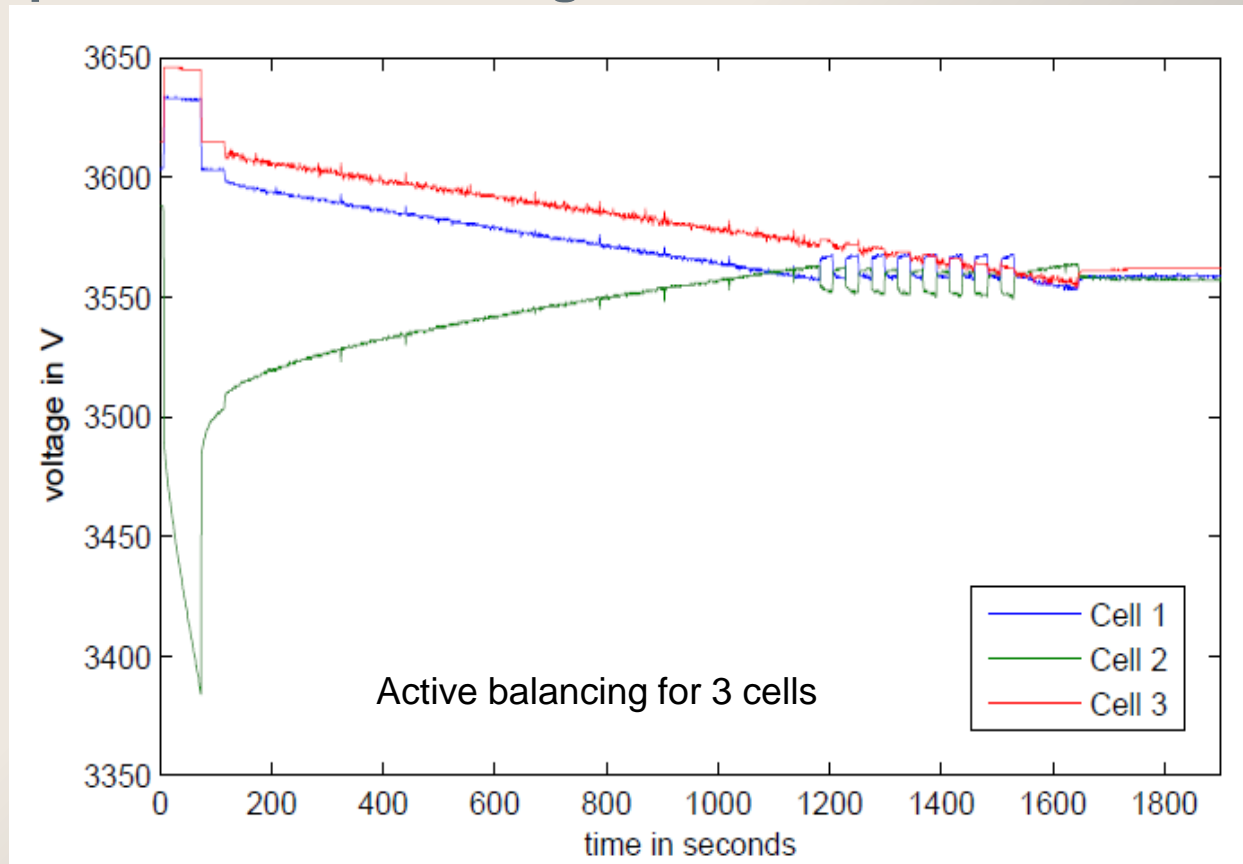
Operating Supply Range [V]	6 to 32
Operating Temperature [°C]	-40 to +85 Ambient
Number of cells per IC	3-7
Typical standby quiescent current [μA]	10
Balancing current [mA]	typically 100
Balancing target accuracy over full temperature range [mV]	10
Cell voltage target accuracy [mV]	10
2 temperature monitoring thresholds	
Cell voltage range [V]	1,5 – 4,5
12 bit ADC for cell voltage capture. Accuracy target [mV]	±5
8 bit ADC for temperature capture. Accuracy target [°C]	±3



Test board for autonomous battery balancing with AS8506

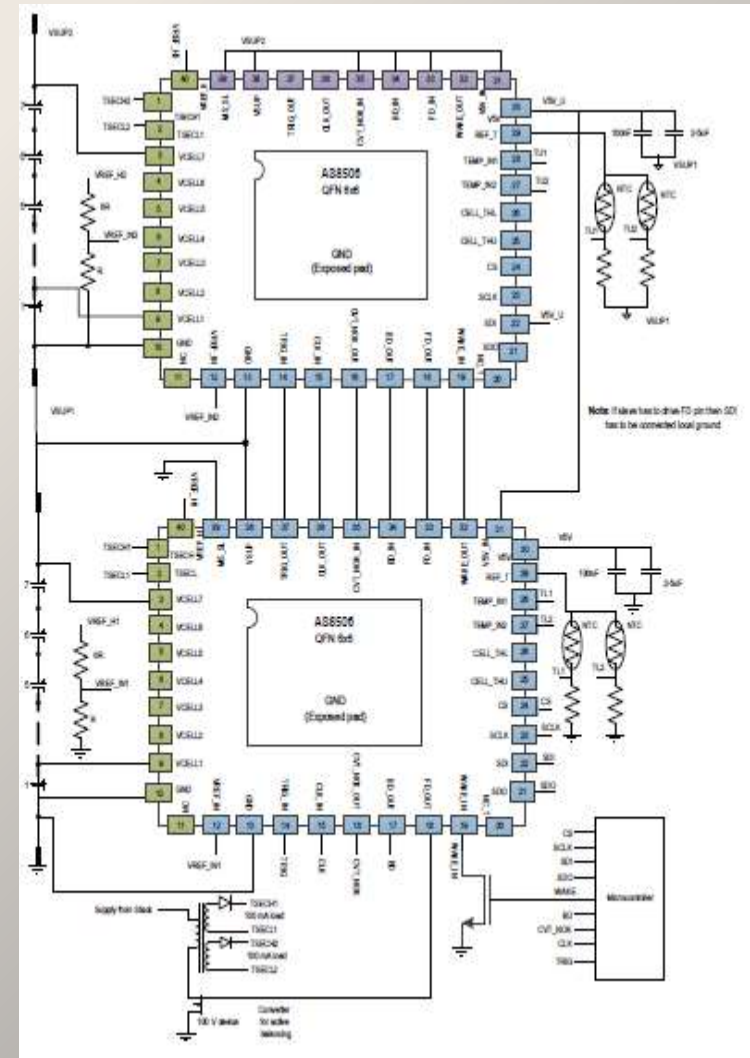
# New cell balancer and monitor IC

## Example of 3 cell balancing



## Stacked BMS ICs

- Most bottom IC is configured as Master, others are Slaves (up to 31 slaves)
- Communication through Master SPI
- Chained 3 wire SPI communication from master to slaves
- Synchronized autonomous monitoring and balancing on Trigger
- When active balancing:
  - One transformer for up to 14 cells
  - Charge redistribution if energy is taken from pack
  - Isolated driver for slaves >14 cells



## 14 cell application example



# Electro kart: daisy-chain communication demonstrated!



# Development of Ultra Caps

	Capacitance	Diameter	Height
<i>Units</i>	F	cm	cm
<i>Corning lot Average</i>	<b>&gt;2700</b>	<b>6.07</b>	<b>10.2</b>
<i>Commercially Available</i>	<b>2000</b>	<b>6.07</b>	<b>10.2</b>

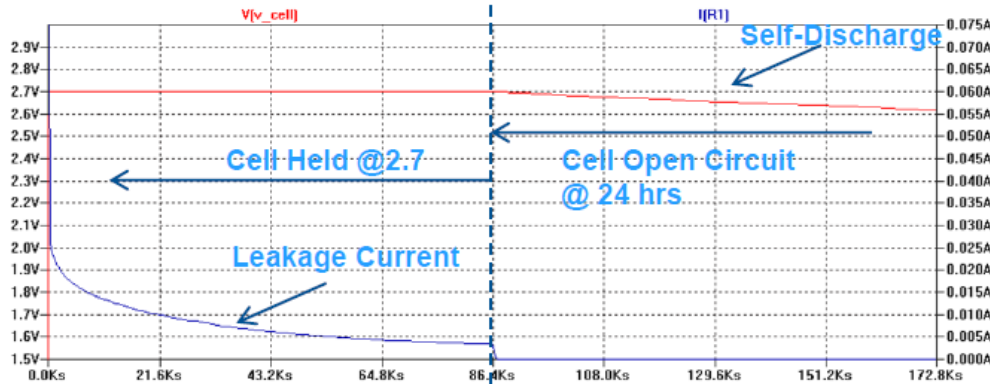
New Ultra Cap cells delivering energy densities in the range of 7-9 Wh/l



Final module assembly started

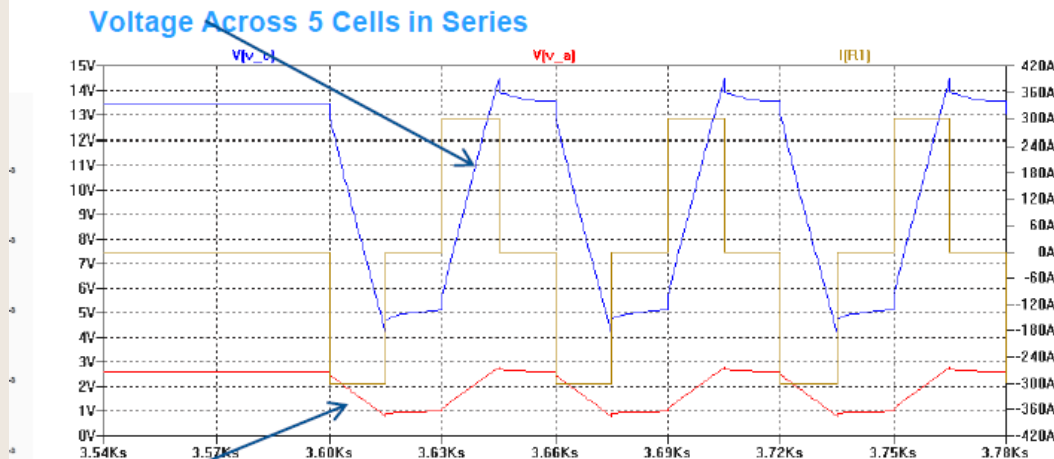


# Development of Ultra Caps



**Self-Discharge and Leakage Current Simulation**

- Measurements taken for delivered cells
- Model matches leakage current and self-discharge behavior of cells @ 25C
- Single cell model can be integrated into overall system electrical simulation
- Pack simulation implemented by placing multiple cells in series.



**Single Cell Voltage Current Cycling Simulation 5 Cells in Series**



- **New BMS ICs** for an integrated flexible battery management system enabling simultaneous cell compare and **active cell balancing** for ultra capacitors and Li-Ion cells:  
daisy-chaining demonstrated  
assembly into demonstrator
- new cost effective **power antifuse** for dynamical configuration of energy storage units:  
prototype building
- **safety sensors**: new **gas sensor** with high sensitivity and fast response and new MEMS based **spark detection sensor** to improve safety monitoring of energy storage systems:  
tests demonstrating early sensing capability
- new **ultra capacitor power cell** with 50% higher energy density:  
prototypes available
- new high voltage (several kV) capable test and characterization equipment and **galvanic isolated** BMS driver ICs:  
verification tests ongoing



# Thank you for your attention!

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