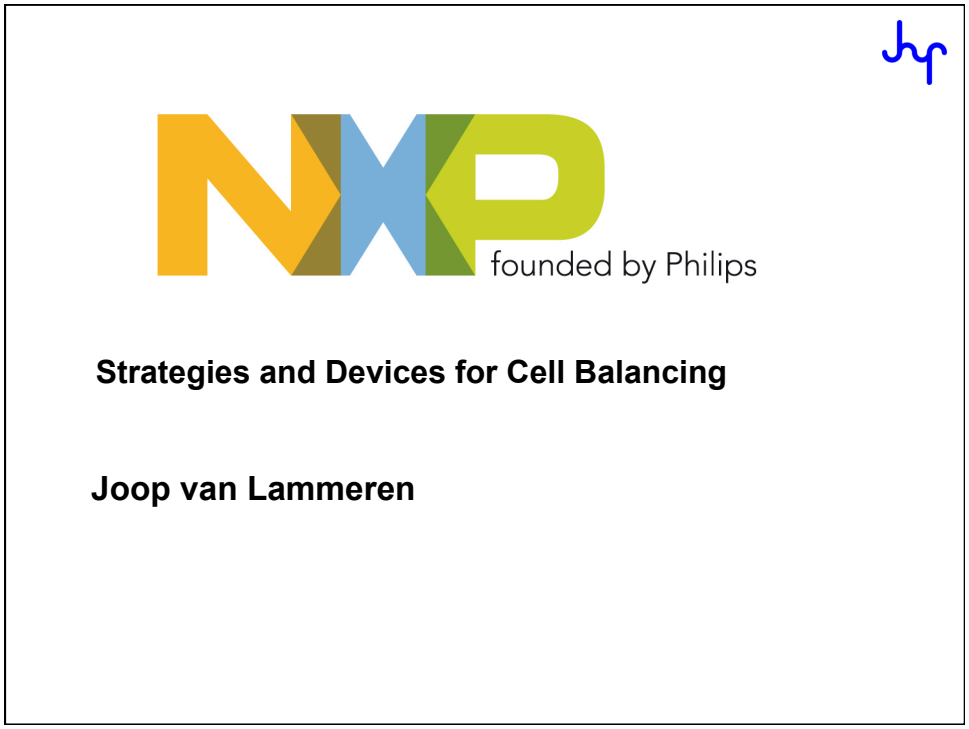
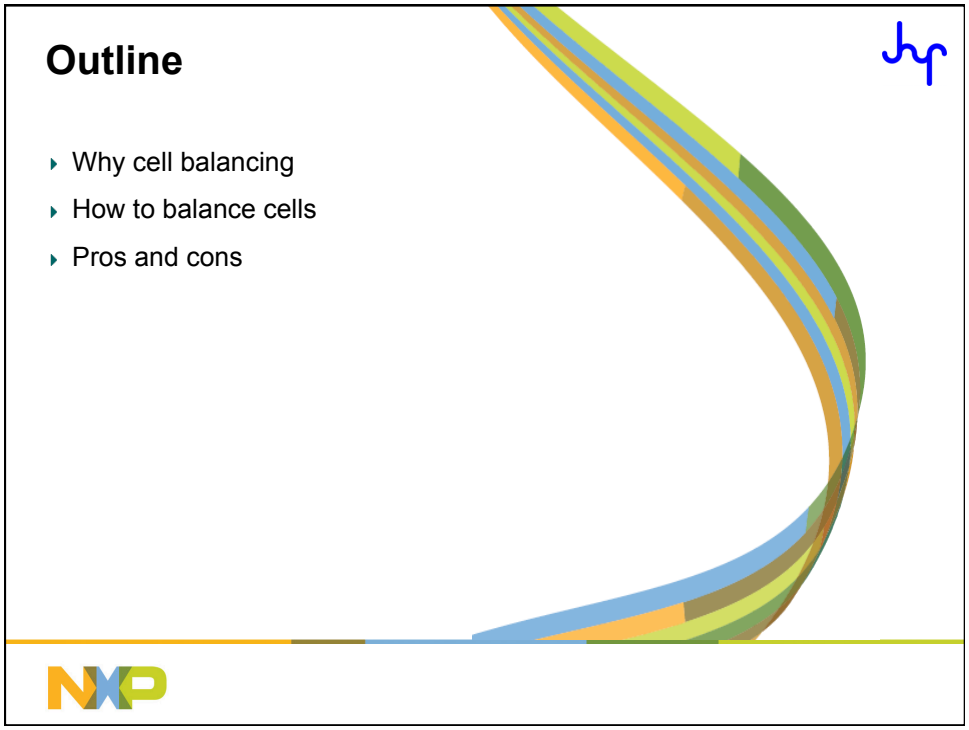
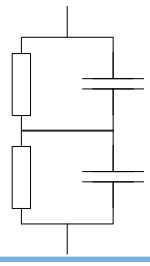

founded by Philips
Strategies and Devices for Cell Balancing
Joop van Lammeren


Outline
Why cell balancing
How to balance cells
Pros and cons

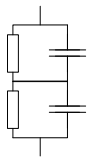
Why cell balancing?

- Super-simple model
- Reality: non-linear, time-variant, temperature-dependent



Causes of cell unbalance

- Self discharge
  - increases with age, cycles, and temperature
- Capacity loss
  - increases with age, cycles, and temperature



- Charging process itself produces heat, not cell unbalance
  - Coulombic efficiency of a LiIon cell >99.9%
  - power efficiency of charging process is 70-95%

Balancing and redistribution

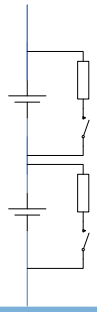
- Self-discharge mismatch compensation
  - can be done while driving
  - bad cell will leak up to 10mA
  - required balance current level: up to 100mA
- Capacity mismatch compensation
  - must be done while driving
  - capacity mismatch can go up to 10%
  - traction motor can draw tens of amps
  - required redistribution current level: 1A and up

Balancing vs redistribution

- Balancing
  - prevents range-decrease-over-time of the vehicle
  - all cells are full at the end of charging
  - 99 cells @ C = 100%, 1 cell @ C = 90% --> range = 90%
  - $Q_{bat} = N * Q_{worstcell\ @\ bestcellf}$
- Redistribution
  - maximises the range of the vehicle
  - all cells are full at the end of charging and empty at the end of discharging
  - 99 cells @ Q = 100%, 1 cell @ Q = 90% --> range = 99.9%
  - $C_{bat} = \sum_{i=1}^{N} C_i$

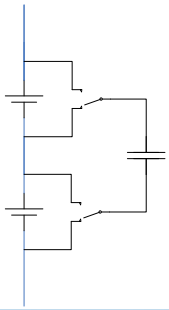
Resistive balancing

- At rest: up to 100mA to bleed all cells except lowest-charged one
- During charging: several amps to bypass charge current of full cells



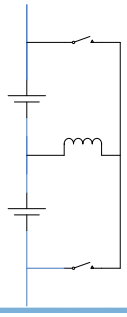
Capacitive balancing

- Equivalent cell capacitance: ~1MF
- Series resistances of cells and switches: ~0.1Ω
- Time-constant ~1 day



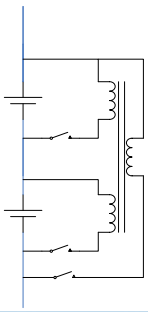
Inductive balancing/redistribution

- Energy ripples through cells from source to destination
  - reduces efficiency and speed



Transformer balancing/redistribution

- Energy can be moved direct from source to destination



Balancing approaches: pros and cons

- Resistive
  - no efficiency
  - simple, fast
- Capacitive
  - very slow
  - simple, high efficiency, no measurement necessary
- Inductive
  - cost
  - high efficiency, fast
- Transformer
  - cost
  - high efficiency, fast