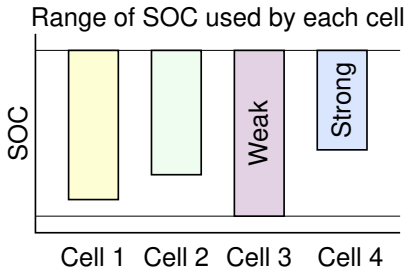
Balancing around maximum SOC

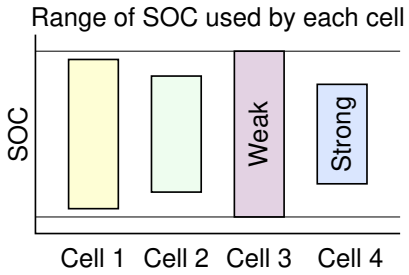
- "A balanced battery pack is one in which, at some point in its cycle, all the cells are at exactly the same SOC."[1]
  - Other definitions are possible where this condition is never met. However, this definition will be sufficient for now
- But, what should that SOC be?
- One choice is to balance at top SOC
  - Maximizes energy that can be stored by the battery pack (good for EV)
  - But, some cell aging mechanisms accelerated at high SOC (bad)



[1] Andrea, D., Battery Management Systems for Large Lithium-Ion Battery Packs, Artech House, 2010, p. 23.

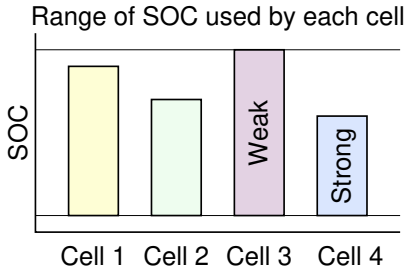
Balancing around mean SOC

- Or, could balance at a mid-SOC point
- For example, when one cell is at 50 % SOC, all other cells are also at 50 % SOC
  - Reduces energy somewhat (cells at lower voltages), but some applications don't care
  - Maximizes pack's ability to accept or deliver power (good for HEV)
  - Slows degradation for stronger cells since they do not dwell at high SOCs, but does not slow degradation for weakest cell(s)
    - So, cell capacities tend to diverge



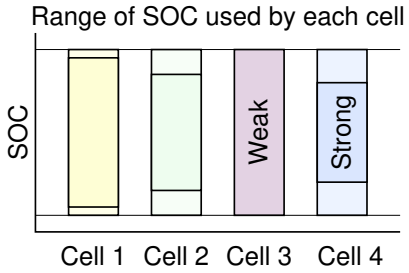
Balancing around low SOC

- Or, could balance at a minimum SOC
  - Again, results in somewhat lower energy than balancing at the top
  - Also minimizes high-SOC-based aging on some cells
  - However, the weak cells still experience the high-SOC-based aging, so we probably don't want to do this as it accelerates divergence between cells (weak cells age faster).



Balancing around a dynamic SOC point

- If fast active balancing is used, the setpoint becomes dynamic, and the entire range of every cell can be used
  - "Strong" cell experiences greater total load, so ages more quickly
  - This is a self-regulating effect
- Balancing point is a *design choice*
- There isn't a one-size-fits-all answer
  - The controls engineer will need to consider the pros and cons corresponding to each alternative for every new application



Summary

- Controls engineer needs to make a number of design choices related to cell balancing
- One is a choice regarding the balancing setpoint
  - Can balance all cells at high SOC
  - Can balance all cells at middle SOC
  - Can balance all cells at low SOC
  - Can choose dynamic SOC balancing setpoint if active balancing used
- There are advantages and disadvantages to each approach that need to be considered