Circuit topologies for balancing

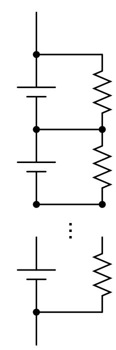
- There are a wide variety of generic electronics strategies that may be used in a cell-balancing system
- The most common topologies are:

Cell Balancing
- Passive
  - Fixed shunt resistor
  - Switched shunt resistor
- Active
  - Charge shuttling
    - Multiple switched capacitors
    - One switched capacitor
  - Energy converter
    - Switched transformer
    - Shared transformer

- We look at each of these over the course of the rest of this and next week

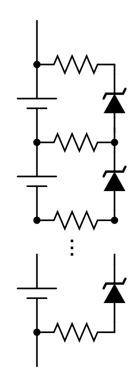
Passive: Fixed shunt resistor

- Primary advantage of any passive-balancing design is simplicity (lower cost) of the circuitry involved vs. active
- General idea is that a resistor is placed in parallel with each cell, and used to drain charge from that cell
- The energy removed from the cell is dissipated as heat
- The simplest design of all is the "fixed shunt resistor design"
- The idea is that high-voltage cells will have greater balancing current, and so will self-discharge more quickly than low-voltage cells
- However, note that the circuit is always dissipating charge, even when the pack is perfectly balanced



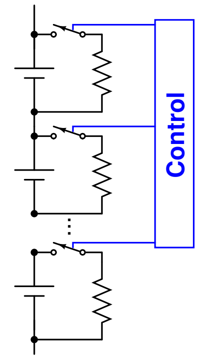
Passive: Variation on fixed shunt resistor

- A variation on the design uses zener diodes to "shut off" balancing when cell voltage drops below some point
- The zener voltages are chosen to correspond to a "100 $\%$ SOC" setpoint. *e.g.,* about 2.2 V for a lead-acid cell
- When a cell's voltage is above the zener setpoint, the resistor path is activated, and that particular cell's charge is depleted until the cell's voltage drops below the zener setpoint
- Note that this design works for chemistries where overcharge is tolerable, and the cell can "float"
  - This includes lead-acid and nickel-based chemistries, but *not* lithium-ion chemistries



Passive: Switched shunt resistor

- A variation that works for Li-ion is to replace zener diode with BMS-controlled switch (some kind of transistor circuit)
- Electronics required to control transistor make this design more complicated; however, allows for much greater flexibility in balancing strategy
- BMS closes switches on cells having too much charge, allowing them to drain
- Added complexity is not as big an issue as it used to be
  - Modern battery-stack monitoring chips have built-in circuitry to control either internal transistor (for slow balancing) or an external transistor (for faster balancing)



Drawbacks of passive balancing

1. Energy wasted as heat, might have been used productively
2. In a balance-at-top design, energy remains in cells when weak cell is completely discharged, might be utilized by active balancing system
3. Heat is generated at power $P \approx V_{\text{nom}} \times I_{\text{balance}} \dots$ fast balancing $=$ more heat
   - This generally imposes a high-wattage requirement on the balancing resistors, and a high-current rating on the balancing transistors
   - Quantity of heat generated by balancing similar to heat generated by normal operation, increases pack cooling requirements, which is a significant expense
4. Battery life could be shorter with respect to pack with active balancing design
   - Pack life is determined by the weakest cell in the pack: active balancing supports weak cells via strong cells, bringing pack to uniform EOL condition

Summary

- Balancing circuits divide between passive and active
- Passive circuits dissipate energy as heat, “short circuiting” cells having too-high SOC through a resistor
- Fixed-shunt-resistor and zener variation not applicable to Li-ion
- But, switched-shunt-resistor design used by essentially all present-day BMS
- Primary advantage of passive balancing is simplicity (therefore, inexpensive)
- Disadvantages include wasted and un-utilized energy, heat generation, and possibly shorter pack life