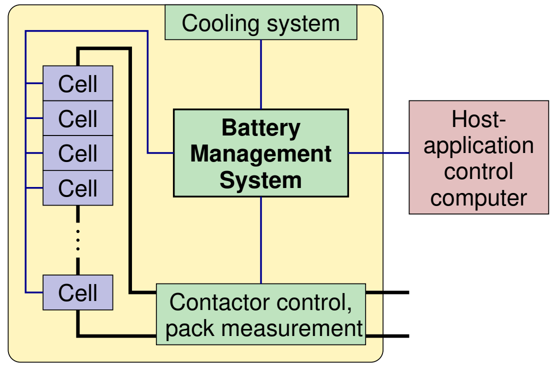
Introduction to week 4

- In week 3, we focused on requirement 1 of a BMS, sensing and high-voltage control
- This week, we turn our attention to the other four requirements
- To review, these were:
  2. Protection
  3. Interface
  4. Performance management
  5. Diagnostics
- In this topic, we consider protection



BMS requirement 2: Protection

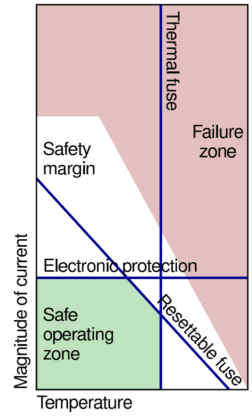
- BMS must provide monitoring and control to protect:
  - Cells from out-of-tolerance ambient operating conditions
  - User from consequences of battery failures
- High-energy storage batteries can be very dangerous:
  - If energy is released in an uncontrolled way (short circuit, physical damage), can have catastrophic consequences
  - In a short circuit, hundreds of amperes can develop in microseconds; protection circuitry must act quickly

What to protect against

- Different applications and different cell chemistries require different degrees of protection
  - Failure in a lithium-ion cell can be very serious: explosion/fire
  - Protection is indispensable in automotive environment
- Protection must address following undesirable events or conditions:
  - Excessive current during charging or discharging
  - Short circuit
  - Over voltage and under voltage
  - High ambient temperature, overheating
  - Loss of isolation
  - Abuse

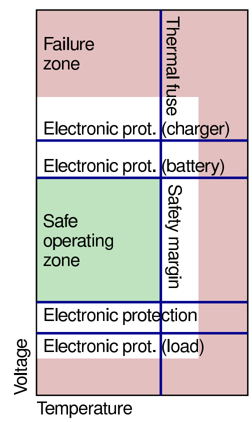
Overcurrent/overtemperature protection

- When possible, fallback protection paths should be implemented
  - Red = cell-manufacturer specified region where cells will most likely be subject to permanent damage
  - Anywhere else "okay" but need margin of error
  - Generally design to limit cell's operating conditions to smaller "safe" region, shown here in green
- Safety devices are then specified to constrain cells to safe region
- White = safety margin



Overvoltage/overtemperature protection

- Similar for voltage limits:
  - But, each protection device added into main current path increases battery impedance, reducing power delivered to load
- Examples of protection devices include:
  - Thermal fuse: Opens contactor when $T > T_{\text{limit}}$
  - Conventional fuse: May not act quickly enough
  - Active fault detection: BMS monitoring for fault conditions



Fault detection/tolerance

- Another aspect of protection is detecting, withstanding, and (when possible) rectifying faults
- State-of-art BMS use processors having dual CPUs that execute the same instructions at slightly different times on different cores, then compare results
- Slaves often can detect most cell faults without intervention of the main processor
  - Cell over/under voltage, over/under temperature, redundant sensing, etc.
  - Serious slave faults should be able to shut pack down without using master microprocessor
- Some more complex faults (for example isolation) must be detected by software
- Link between master and slaves must have high EMI immunity

Standards

- Different applications have different standards for safety
  - Passenger cars having maximum gross vehicle mass up to 3500 kg fall under ISO26262:2011
  - Electric motorcycles fall under ISO/PAS 19695:2015 (similar to ISO26262)
  - Larger trucks over 3500 kg, such as Ford F250, 350, Chevy Silverado 2500, as well as semis, buses, etc...) fall under IEC61508
- While these safety standards have the same goals they are different in application
  - Use different “safety integrity levels” (SILs), evaluated in different ways
  - Very difficult to design to all these standards simultaneously
- Standards are complex—require courses of their own to understand how to comply

Summary

- It is critical to protect battery-pack operator and pack itself
- Good design practice to require multiple protections to fail before pack itself fails
- Redundancy of sensing and processing enables fault detection
- Standards (beyond scope of this specialization) inform best-practices designs, robust fault-tolerant implementations