Safety and Reliability of Lithium-ion Smart Battery Packs

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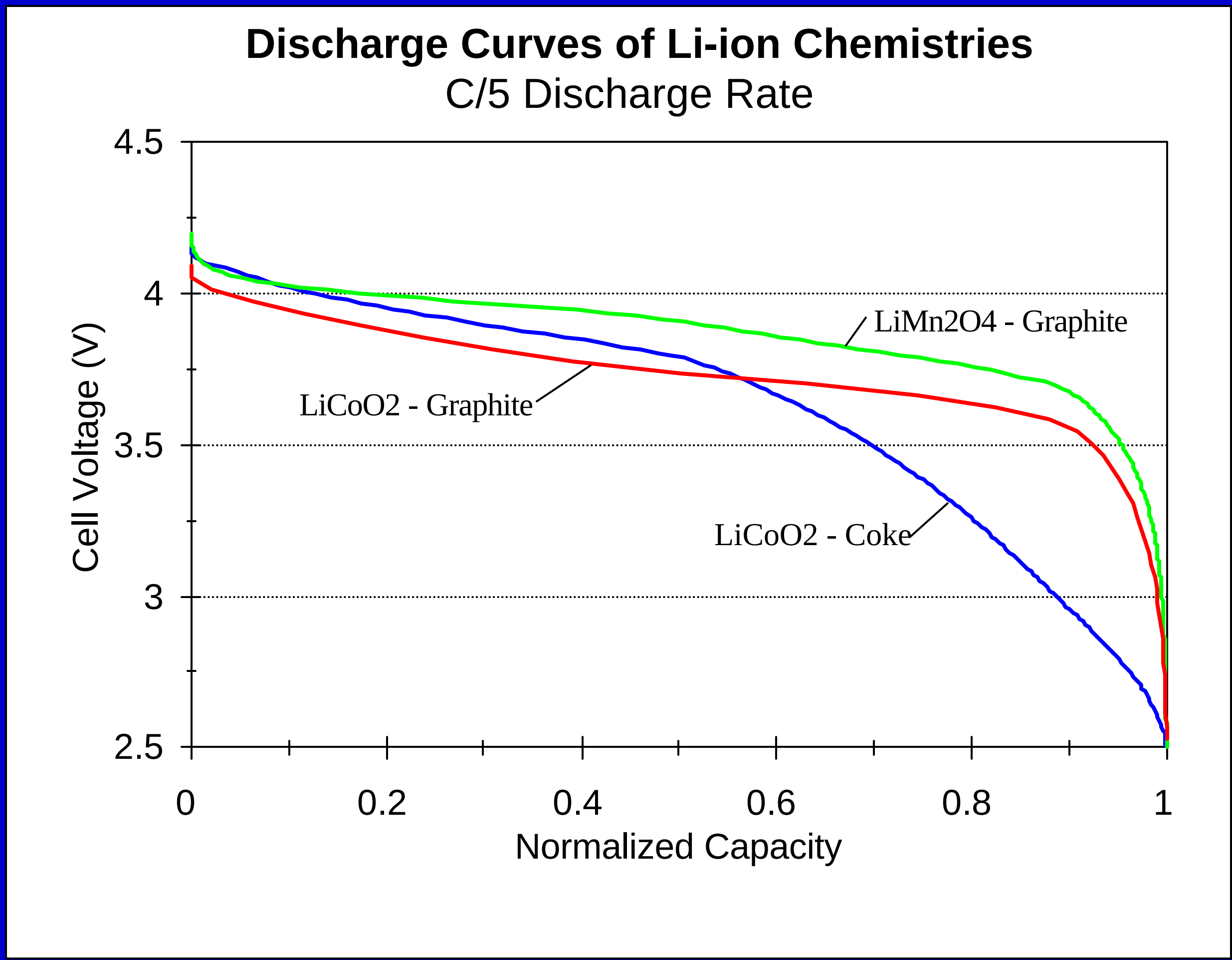
Outline

- Chemistry Differences
- Fuel Gauge and Protection Circuitry
- Data Protection
- ESD Protection
- Voltage / Current Accuracy
- Production Issues
- Standard Pack Issues
- Will my battery ever learn?

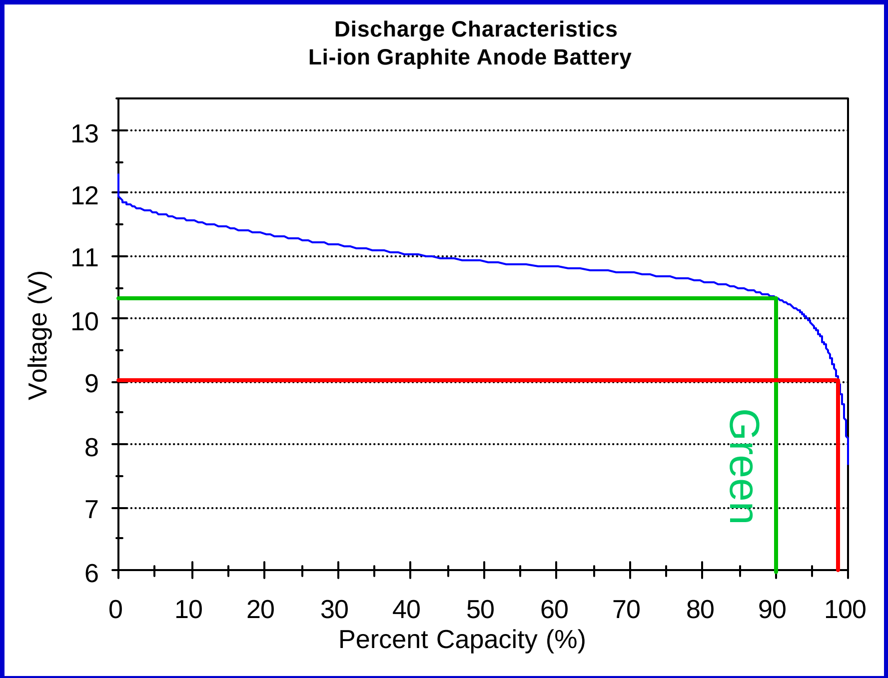
Lithium-ion Chemistry Differences

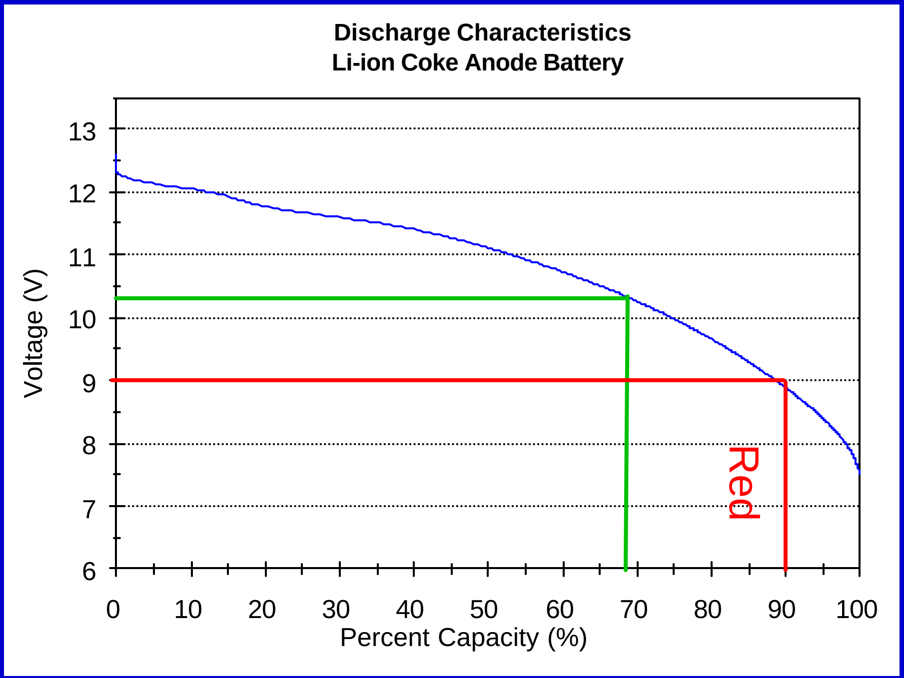
- There are presently a number of different Lithium-ion chemistries available
  - Anode Materials
    - Hard Carbon, Coke, and Graphite
  - Cathode materials
    - Mn_20_4 and $LiCoO_2$
- Charging voltage considerations
  - Some battery packs charge to 4.2 volts per cell others use 4.1 volts per cell.
  - Over charging of lithium ion cells may lead to a reduction in safety and cycle life.

Lithium-ion Chemistries Differences



End of Discharge Voltage





10.2V = 10% (*Green*)

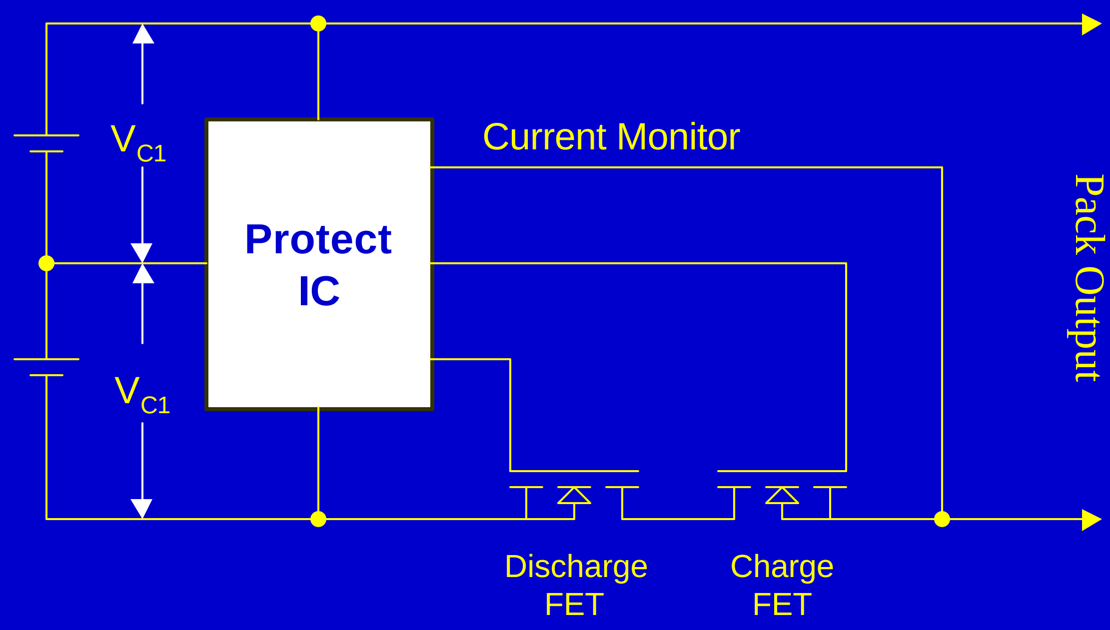
9.0V = 10% (*Red*)

- Cobalt Oxide Cathode
- '202 Form Factor (3s3p)
- 15 Watt Discharge
- 21 Deg. C

Using SBS Data to Overcome Chemistry Differences.

- Prevent Overcharge
  - Use ChargingVoltage() (0x14)
- Use Wh not Ah Comparisons.
  - BatteryMode() (0x03) (CAPACITY_MODE bit)
- User Warnings / Suspend
  - RemainingTimeAlarm() (0x01)
  - RemainingCapacityAlarm() (0x02)
  - Do not use voltage based alarms or suspend commands.

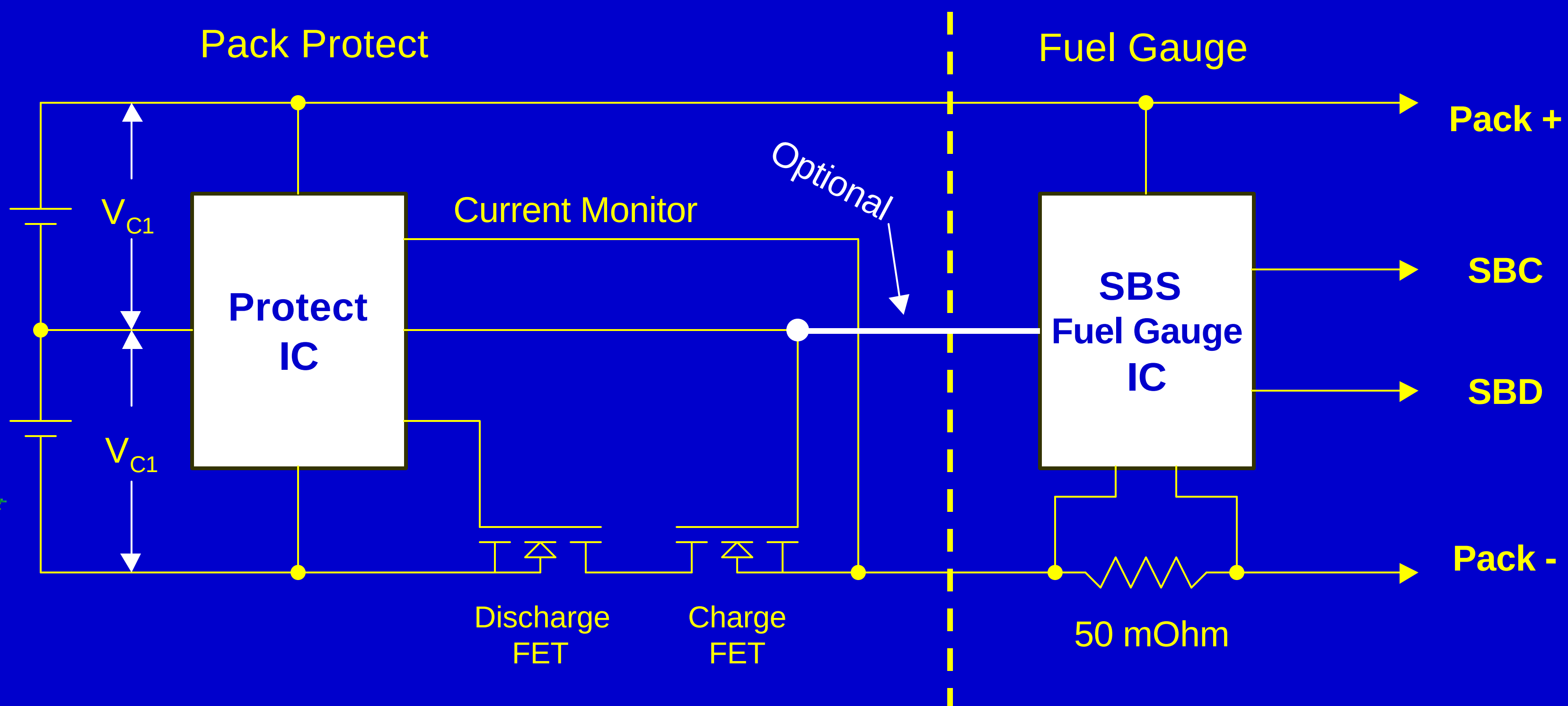
Protection Circuitry



- Each Cell is monitored Individually (V_{C1}, V_{C2})
- Current is monitored through FET's **(SAFETY)**
- One FET Disconnects on **Over Charge** **(SAFETY)**
- Another FET Disconnects on **Over Discharge** **(RELIABILITY)**

Protection / Fuel Gauge Circuitry

- Redundancy
  - Always use an independent pack protect IC
  - SBS Gauge may monitor FET status (Optional)
    - i.e. BQ2040 PSTAT input



Data Protection

- First Priority
  - Calibration Information
    - Current, Voltage, Temperature
  - Pack Default information (Safety Related)
    - DeviceChemistry(), ChargingVoltage(), ChargeCurrent(), DesignCapacity()
- Second Priority
  - RemainingCapacity()
  - CycleCount()
  - FullChargeCapacity()

Data Protection

- E^2PROM
  - All calibration and safety related default data should be stored in E^2PROM.
  - Other Values that would benefit from E^2PROM storage:
    - Cycle Count
    - Last learned Full Charge Capacity
    - Remaining Capacity

Data Protection

- RAM
  - Although RAM may be an alternative for storing data, lithium ion packs present a challenge due to the requirement for Over Discharge Protection.
  - Maintaining power to the SMB fuel gauge after the cells have reached the lower cutoff voltage is not recommended.
    - Discharging Lithium Ion cells below the recommended cutoff voltage may result in capacity loss.
  - An over discharge condition should remove **ALL** load from the Cells.

Standard Pack Incompatibility Issues

- Some laptops accept SMBus battery packs but still use “dumb” chargers.
  - Lithium-ion batteries with upper charge voltages of 4.1 volts may be overcharged.
    - Reducing Pack Safety
    - Reducing Long Term Performance (Cycle Life)
  - Batteries with higher charging voltages may be undercharged.
    - Won’t learn a capacity
    - Give less than rated performance

Production Issues

- Production Sequence
  - Assemble PCB
    - Program Fuel Gauge
  - Test and Calibrate PCB
    - All PCB functions related to safety should be 100% tested.
  - Assemble and Test Battery Pack
    - Confirm Protection operation
    - Check Fuel Gauge function

Production Issues

- Performing Learning Cycles
  - 'W' = DisChg, Full Chrg, Full DisChg, Chrg
    - Gauge 'sees' a Full Charge and Full Discharge
  - 'N' = Chrg, Full DisChg, Chrg
    - Gauge only 'sees' a Full Discharge
  - Following the recommended learn cycle is essential for a reliable FullChargeCapacity()
  - Performing learn cycles requires a large amount of time and equipment. ($$$)

ESD

- **IEC 61000-4-2 (1995-01)**
  - Electrostatic discharge immunity test.
- Pack protect
  - Pack protection must pass IEC test without malfunction.
- Fuel Gauge / Clock and Data Lines
  - Device capacitance
    - Excessive capacitance could seriously effect communications reliability
  - Transorb
    - Sensitive to heat when soldering. Capacitance increases significantly if over heated.

Current Accuracy Issues

- Current is monitored by measuring the voltage developed across a low resistance shunt.
- To accurately measure the small voltage drop;
  - Requires careful layout of the PCB to minimize offset errors and noise.
    - Decoupling capacitors
    - Short runs on PCB
- Current accuracy will ensure a reliable FullChargeCapacity().

Voltage Accuracy Issues

- Charger Accuracy
  - A battery pack charged to a lower voltage will give less than the rated capacity.
  - Lithium ion cells require a taper termination.
    - Termination = ChargeVoltage() & (Current() < 100mA/cell)
  - A low voltage can cause the battery not to recognize a full charge.
- Gauge Accuracy
  - Premature full charge detection will give less than rated capacity.
- Voltage Accuracy will ensure a reliable FullChargeCapacity().

Will My Battery Ever Learn?

- Full Charge Capacity Detection
  - Battery must recognize a full charge.
  - Battery must see a full discharge.
- Infrequent Full Discharges
  - Users will often shutdown their laptop when they get a low battery warning.
  - People are starting to understand that Lithium-ion batteries do not suffer from memory and therefore short cycle their batteries.
- This may not allow the battery to detect a full discharge.

Will My Battery Ever Learn?

- What will users think if the laptop informs them they should perform a learning cycle. Is this acceptable to the user?
- A battery that requests a learn cycle might be mistaken for a pack developing 'memory effect'.
- Fuel Gauge and Battery Manufacturers must come up with creating methods of tackling these issues.

Summary

- There are many significant factors which affect the reliability, safety and production of Smart Battery Packs.
- These issues should be considered when developing applications and batteries based on SMbus technology.
- When implemented correctly, smart batteries are an ideal way of enhancing your applications performance.