Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

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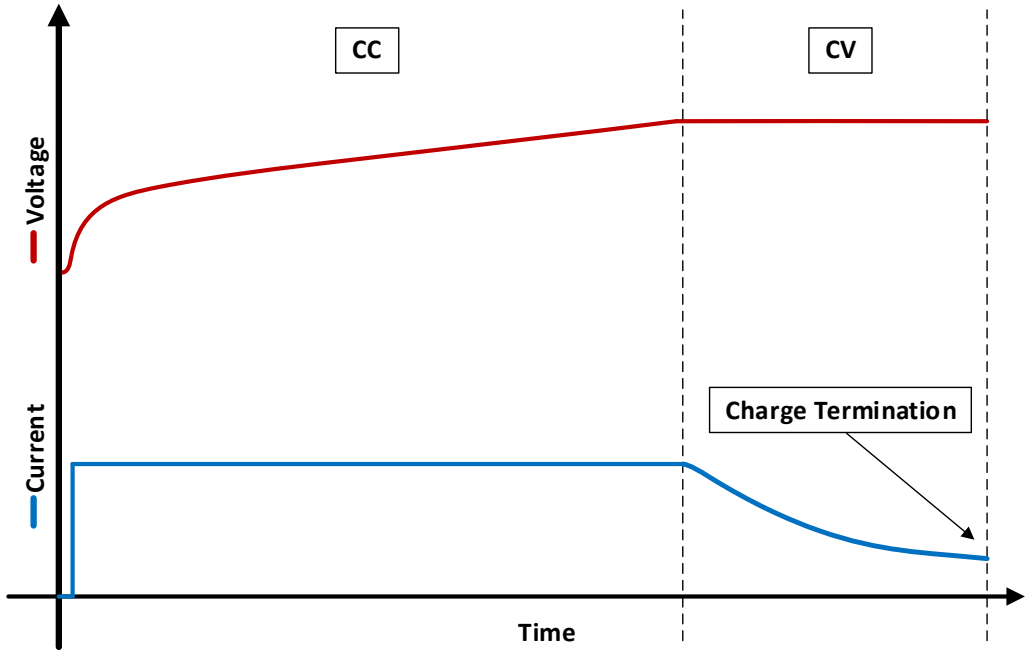
USING TI GAUGES ADVANCED CHARGING ALGORITHM

Agenda

- Charging basics – CC/CV
- Uses and importance of Advanced Charge Algorithm
- Charging compensation and additional features
- Broadcasting charging current and charging voltage
- Examples
- Summary
- Questions

Charging basics – CC/CV

- Constant current/constant voltage (CC/CV) charging is the most common charging method for Lithium-Ion batteries
- Battery manufacturers provide the max charge voltage and max charge current
- One of the quickest and safest charging strategies

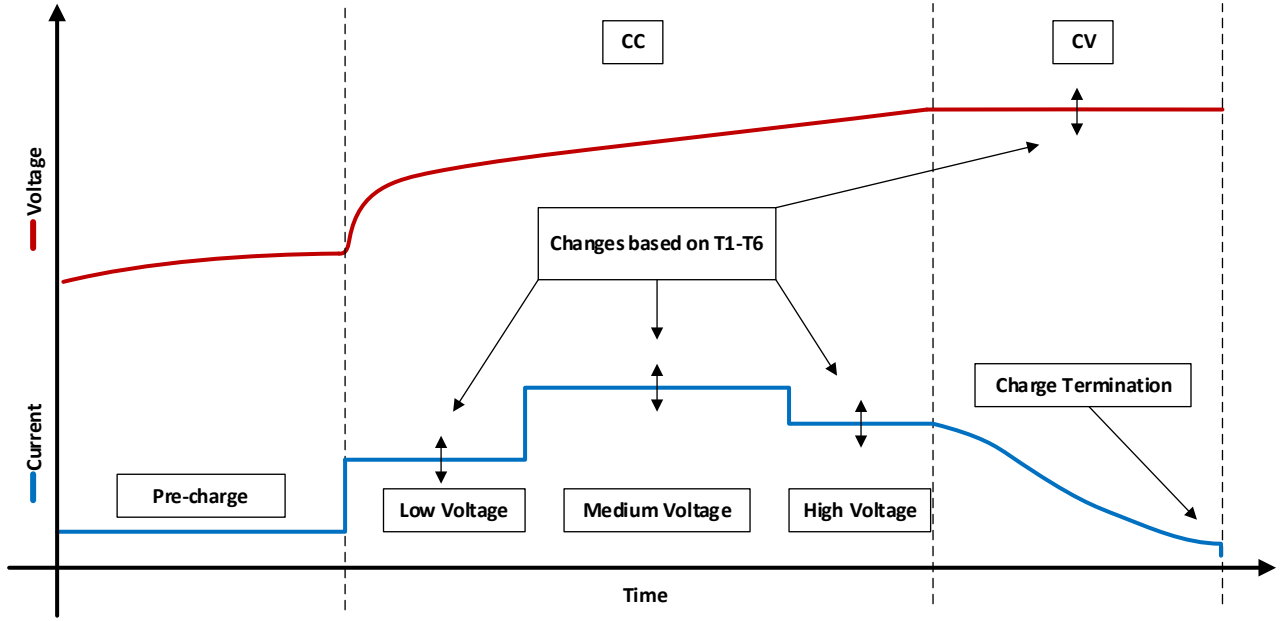


General CC/CV charging graph

Charging basics – CC/CV

- Adjusting the CC/CV using the Advanced Charge Algorithm
- Gauge reports the charging voltage and charging current to the host or charger directly

Advanced Charge Algorithm adjustment graph



Uses and importance of Advanced Charge Algorithm

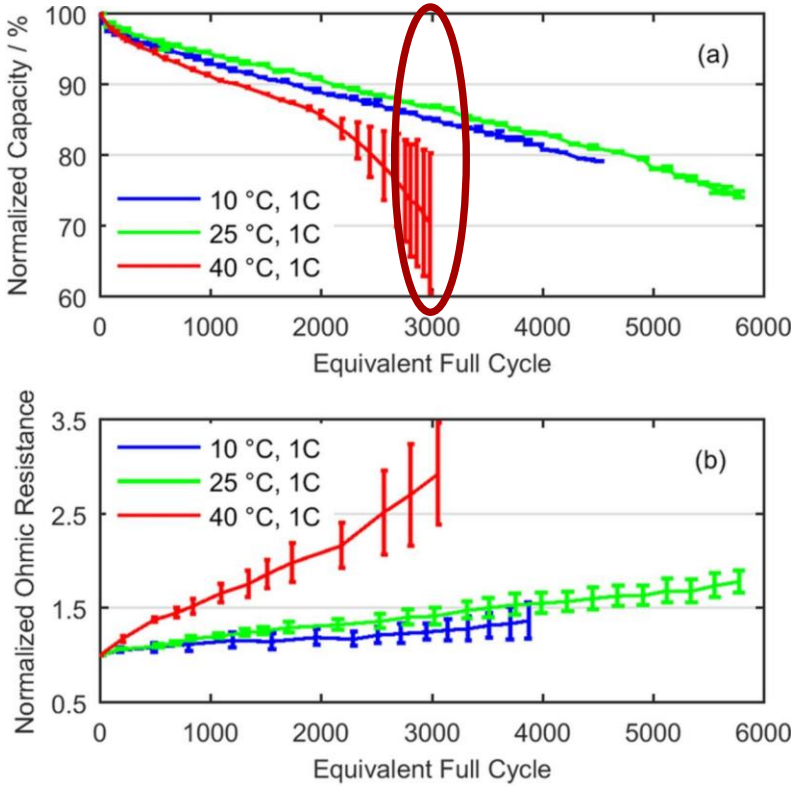
Reasons for using the Advanced Charge Algorithm:

- Cell longevity
  - Reduce heating during charge
  - Reduce voltage depending on battery conditions
- Safety
  - Cell overheating
  - Stop charging when protections are triggered
- Charging flexibility
  - Highly configurable charging current and charging voltage
  - No host firmware needed for advanced charging

Uses and importance of Advanced Charge Algorithm

Cell longevity

- Reduce charge current in high or low temperatures
- High temperature accelerates battery aging
- Reduce charge current with age due to increase of internal resistance

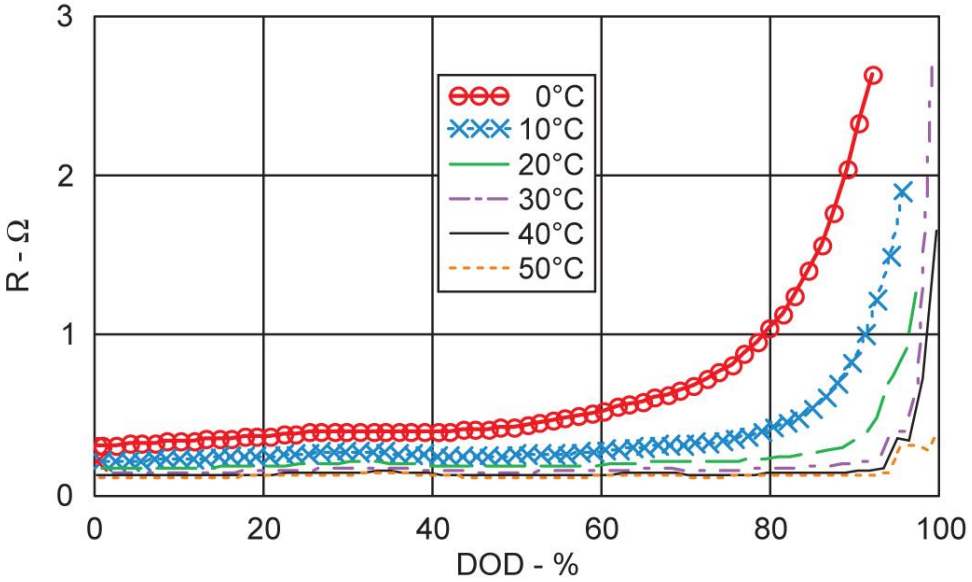


Yao Wu *et al* 2017 *J. Electrochem. Soc.* **164** A1438

Uses and importance of Advanced Charge Algorithm

Safety

- The gauge will request 0 mV and 0 mA if protection is triggered
- Prevents overheating during charging that could lead to damage
- High charge current at low temperatures can damage the battery

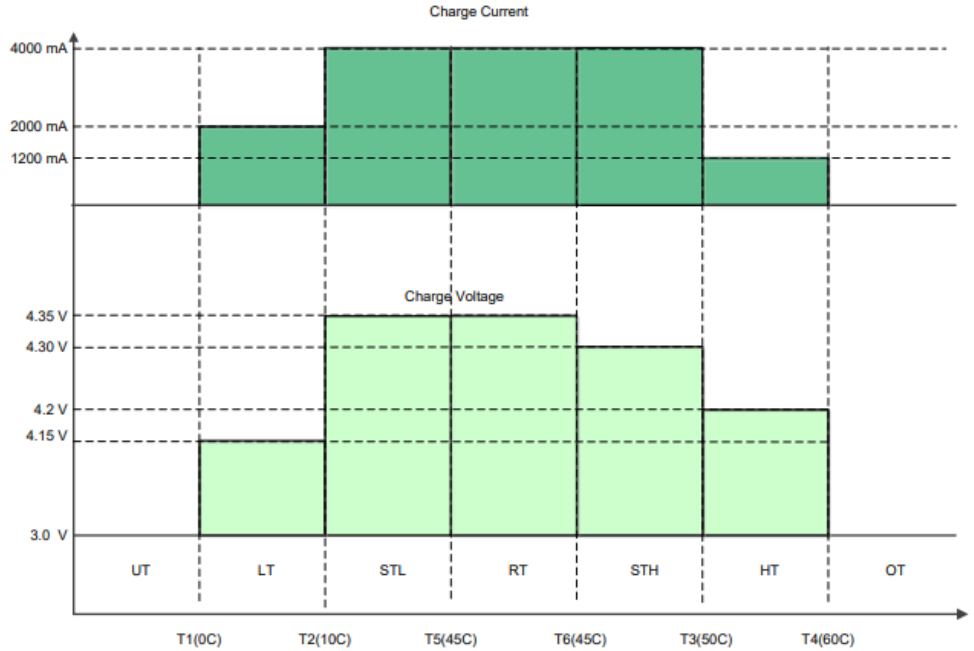


Internal resistance of battery at varying temperatures

Uses and importance of Advanced Charge Algorithm

Charging flexibility

- Adjust the charging current based on voltage ranges and temperature ranges
- No code required on the host side to charge with complex thresholds
- Any SMBus and SBS compliant charger is compatible



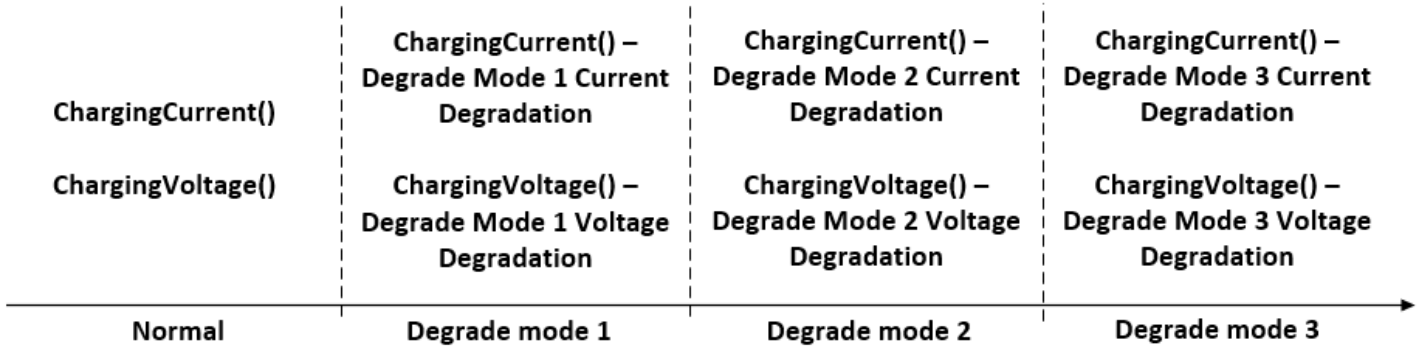
Temperature and voltage adjustment regions

Charging compensation – aging

Example degradation methods based on BQ40Z50-R4

- SOH based degradation
- Cycle count degradation
- Runtime degradation

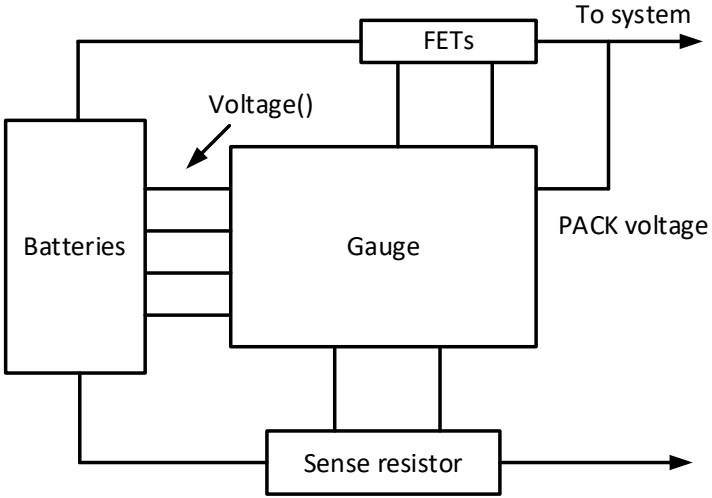
Degrade modes 1,2,3 slowly decrease ChargingCurrent() and ChargingVoltage()



Charging compensation – IR losses

Charging Current Compensation (CCC)

- Modify the ChargingVoltage() to compensate for IR losses in power path
- Gauge increases ChargingVoltage() by using direct voltage measurement of battery cells and PACK voltage
- ChargingVoltage() = Charging Algorithm + (PACK voltage – Voltage())

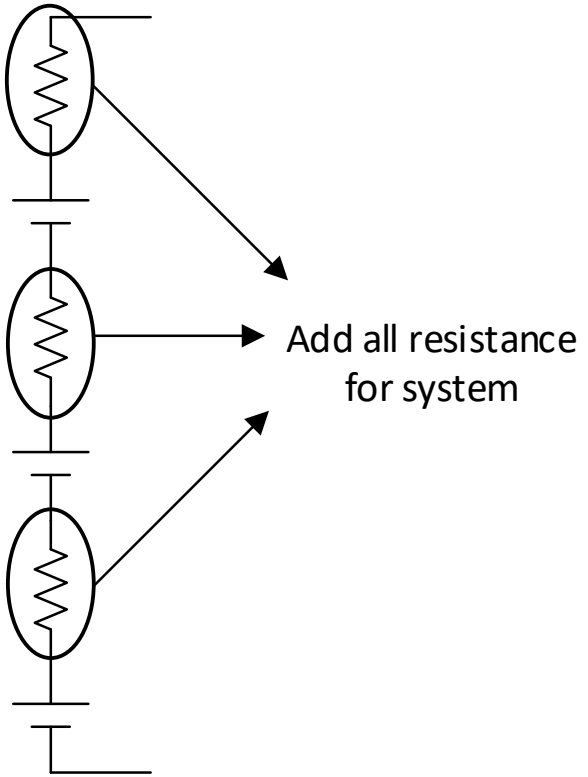


Charging compensation – system impedance

- Apply a fixed system resistance to use for compensation
  - Gauge does not adjust the compensation
  - User must calculate/measure the resistance to set in the gauge

- SBS.ChargingVoltage() = ChargingVoltage + SBS.ChargingCurrent() × SystemResistance

- Cell interconnect resistances can help offset the I×R drop caused by higher current applications

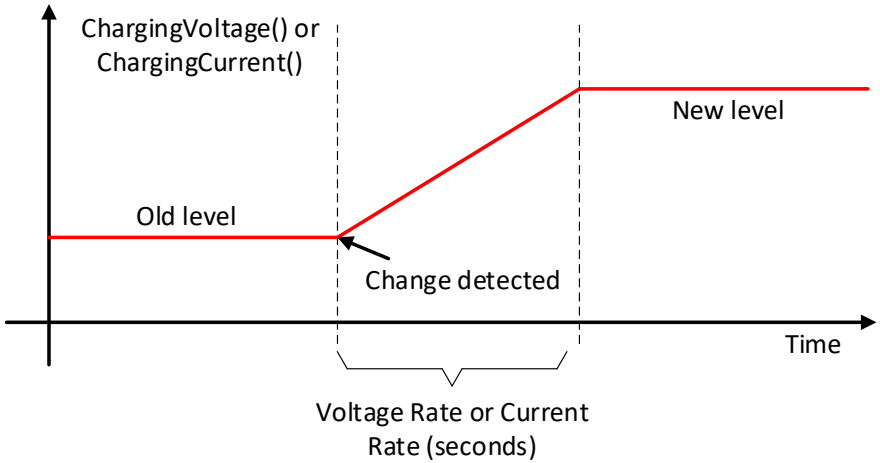


Charging compensation – elevated charge degradation

- Elevated RSoC mode (ERM) and elevated RSoC elevated temperature mode (ERETM)
  - In the BQ40Z50-R4 or newer firmware this feature is available
- Accumulates hours spent in high voltage or high RSoC regions and high temperature
  - User specified time and voltage/RSoC/temperature thresholds
- ERM - After time spent in high voltage/RSoC exceeds the thresholds:
  - Set a flag to indicate to the host that the ERM degradation as been entered
- ERETM - After time spent in high voltage/RSoC and temperature exceeds the thresholds:
  - Set a flag to indicate to the host that the ERETM degradation as been entered
  - Reduces the ChargingVoltage() to a fixed preset value

Rate of change for charging jumps

- Allows for current and voltage ramp functions to be applied so there is no voltage or current jump between modes
- Voltage rate and current rate data flash parameters
- ChargingVoltage() = Old + n × (New – Old)/Voltage Rate
  - Old = present ChargingVoltage()
  - New = the target ChargingVoltage()
  - n increments in steps of one per second
- Host needs to poll at 1 Hz to properly update



Broadcasting charge information

- The SMBus standards provide a strict rule set for power management systems
- SMBus specifies that the charger must be on address 0x12
- SMBus chargers can be used with SMBus TI gauges using the Advanced Charge Algorithm to report the charging voltage and charging current to the charger

Slave Address	Description	Specification
0001 000	SMBus Host	System Management Bus Specification[1] v 1.0 February 1995
0001 001	Smart Battery Charger	Smart Battery Charger Specification[1] v 0.95a February 1995

http://smbus.org/specs/smbus110.pdf

Broadcasting charge information

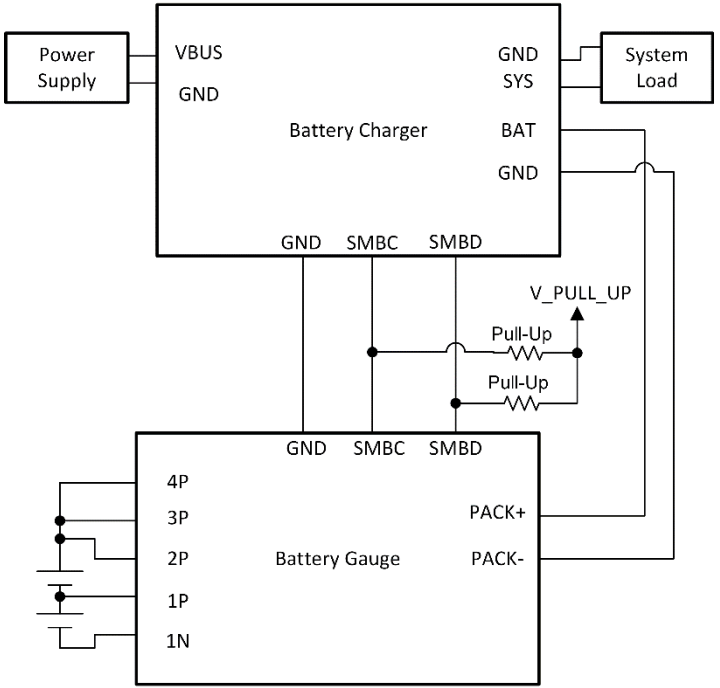
- Smart battery system (SBS) specifications define the ChargingCurrent() and ChargingVoltage() addresses as standard addresses
- Setup only on gauge side – no setup on the charger needed
- Simple system that can decrease the BOM and cost

5.1. Smart Battery Charger Slave Functions (battery or host-to-charger)

5.1.1. ChargingCurrent() (0x14)

5.1.2. ChargingVoltage() (0x15)

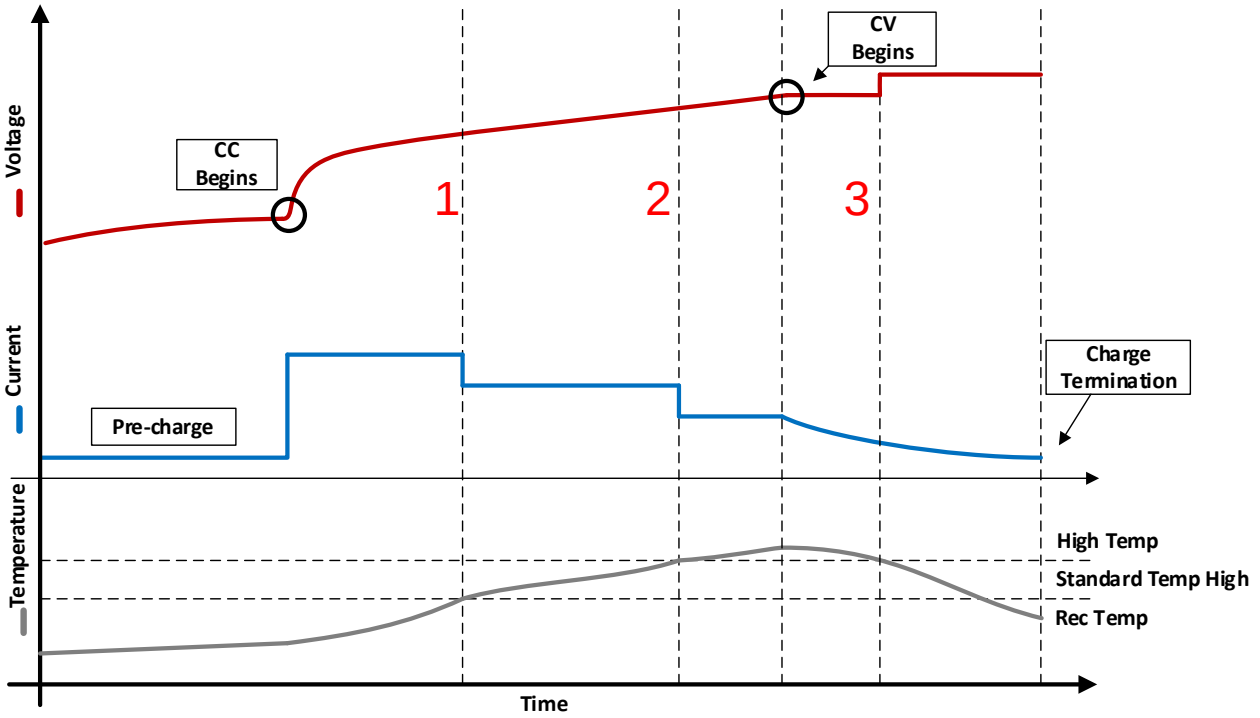
http://sbs-forum.org/specs/sbdat110.pdf



Smart battery system with no host needed

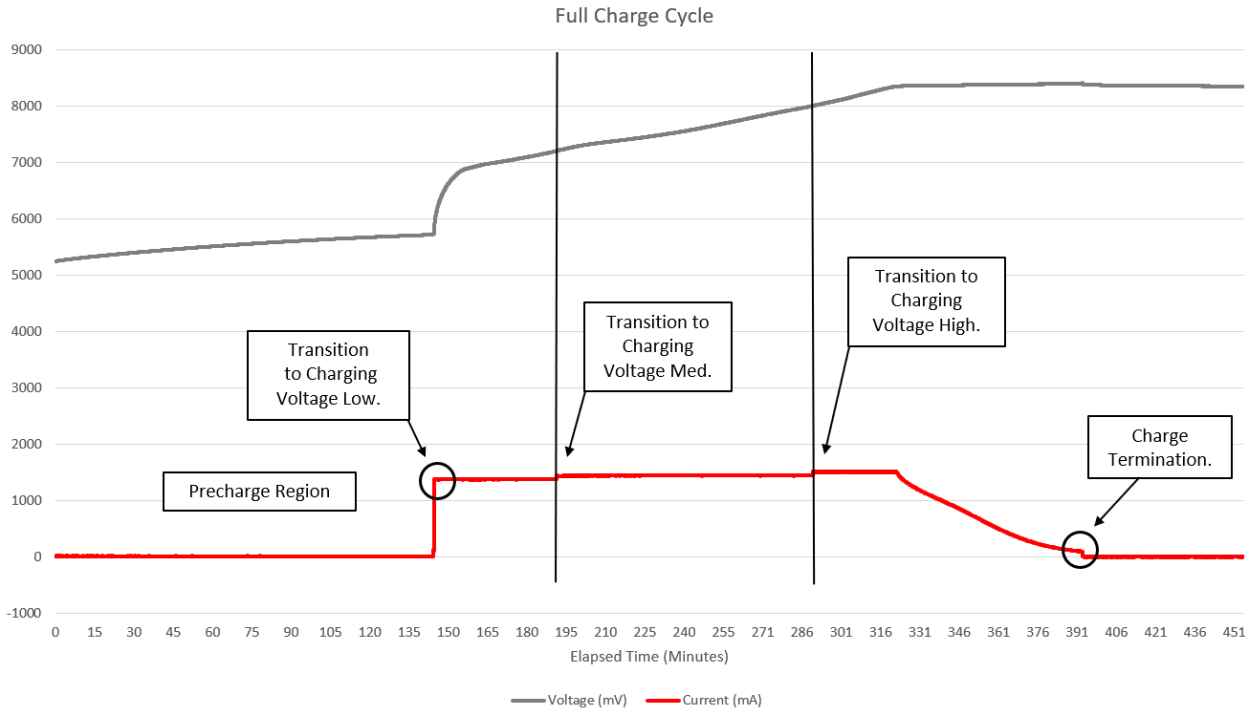
Example: Temperature regulation

- Regulation of both the current and voltage during charge based on temperature
- Flexibility of temperature ranges and charge control for any application



Example: Voltage regulation

- Real data log collected using BQ40Z50 gauge EVM and BQ25710 charger EVM
- Gauge in conjunction with charger controlling the charge cycle with no host
- Gauge controls the charge termination



Summary

- The Advanced Charge Algorithm can allow for autonomous charging with only gauge and charger
  - The algorithm will work with a host or without a host
- High degree of flexibility to accommodate different applications
  - No need to write a custom charging profile using the host FW
  - Gauge saves and reports out the adjusted charging voltage and current
- Increased safety and degradation features
  - Prevents charging at high current in high or low temperatures
  - Reduce charging voltage and current with age to increase longevity

Questions?

Resources

- BQ40Z50-R4 TRM
- Advanced Charge Algorithm Application Note
- Autonomous Smart Battery Guide
- https://iopscience.iop.org/article/10.1149/2.0401707jes
- http://sbs-forum.org/specs/sbdat110.pdf
- http://smbus.org/specs/smbus110.pdf

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