Battery Management System with an Individual Cell Controller for a High-Power Battery

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Background

The popularity of **Lithium-Ion** Battery is growing in these years thanks to its high power density and efficient energy efficiency.

A **B**attery **M**anagement **S**ystem (**BMS**) is required to prevent over-charge and over-discharge.

Objective

The proposed individual cell controller isolates the weak cells in a battery pack, keeping other cells functional.

- CC can switch individual cells to charging, discharging, or isolated.
- The system will identify and isolate cells with problems.

Method

High-Level Control:

Battery Management System (BMS)

- Displaying the status of the whole battery pack.
- Sending control commands.

Middle-level Control:

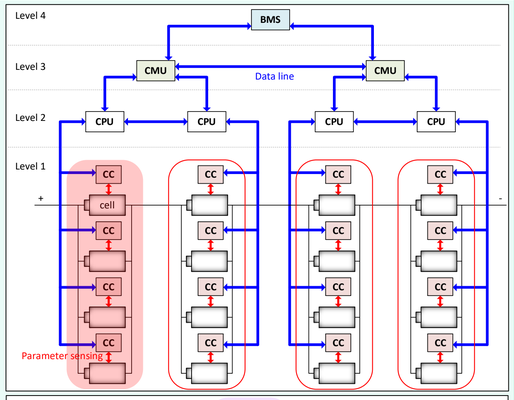
Cell Management Unit (CMU) and Central Processing Unit (CPU)

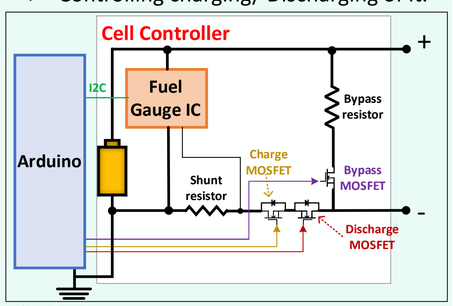
- Linking CCs and BMS.

Low-level Control:

Cell Controller (CC)

- Monitoring a single cell.
- Controlling charging/ Discharging of it.

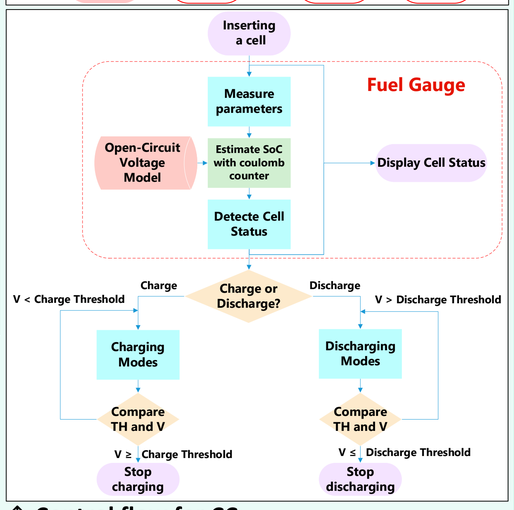




↑ **CC Structure**:

A CC consists of a **Fuel Gauge** IC and three MOSFETs for cell control.

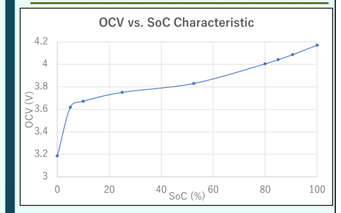
- Fuel Gauge estimates **SoC** (**S**tate **o**f **C**harge) based on **OCV** (**O**pen-**C**ircuit **V**oltage) Model using Coulomb-Counter.
- The Arduino as the upper system, communicates with Fuel Gauge IC over the I2C bus and controls MOSFETs.



↑ **Control flow for CC:**

- Fuel Gauge frequently measures and reports Cell Status.
- CC controls charging or discharging and disconnects batteries when parameters reach their threshold.

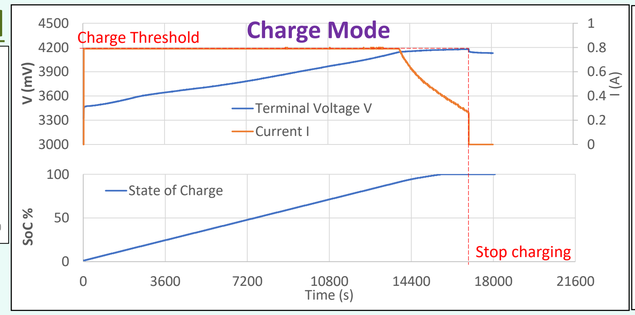
Result for One-cell



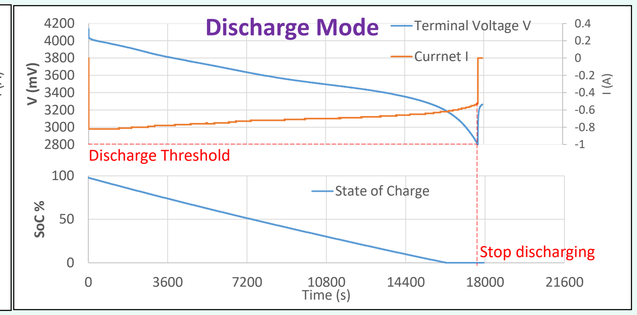
Batteries:

- NCR18650B
  - Capacity 3350mAh
  - Nominal Voltage 3.6V

The figure above shows the specific OCV model used for this battery

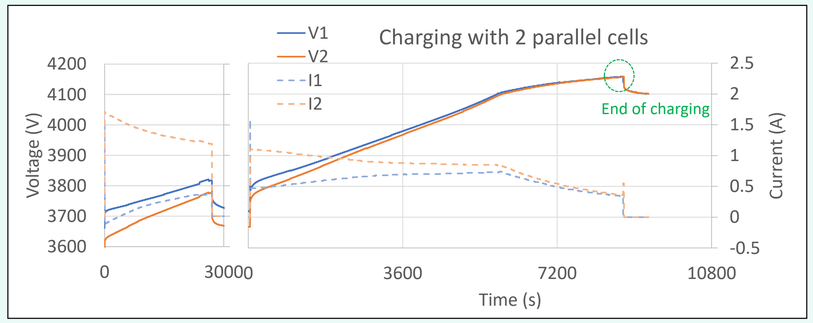


- Constant Current Charging (0.76A)
- Constant Voltage Charging (4.2V)
- CC charges the cell based on its measured voltage. When the maximum threshold of 4.2V is reached, CC stops charging, as shown in the upper graph.
- The lower graph shows SoC in charge mode.



- A 4.7Ω resistor (20W rated) is connected to a cell as load.
- CC discharges the cell based on its measured voltage. When the minimum threshold of 2.8V is reached, CC stops discharging, as shown in the upper graph.
- The lower graph shows SoC in discharge mode.

Result for Two-cells

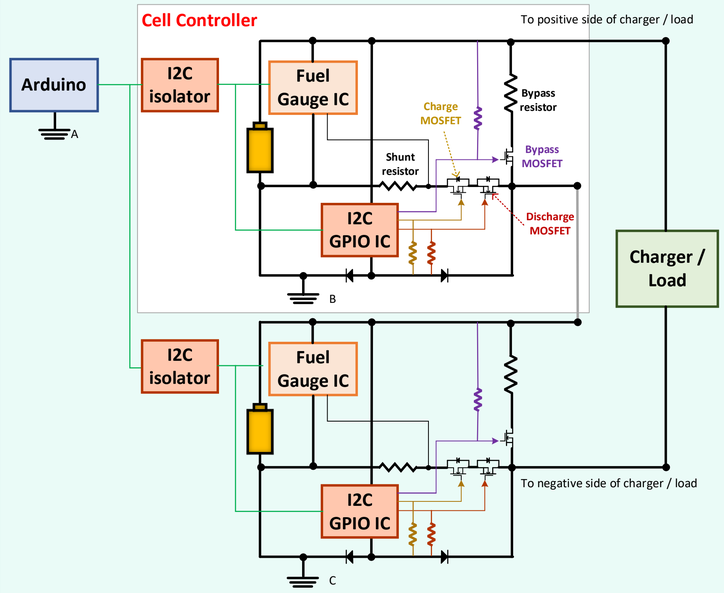


- When charging two cells with different SoCs, the cell with a lower SoC is charged at a larger current than the other one.
- At the end of charging, the terminal voltages of both cells become equal.

Conclusion

- In a single cell, the prototype can monitor SoC and control its charge/discharge by switching MOSFETs through I2C.
- In a parallel cell combination, the prototype can control each cell individually in both charging and discharging.
- When two or more individual cells are connected in series, I2C isolators provide the required isolation among cells.

Next step for Two-cells



- When cells are put in series, each CC will have a different reference point (Ground).
- To connect more than one CC to Arduino, I2C isolators are required.
- I2C GPIO chips connected to Arduino by I2C, can provide control for three MOSFETs in the CC.

Main reference: P. Weicker, ***A Systems Approach to Lithium-Ion Battery Management*** , Artech, 2013

X. Gong, R. Xiong and C. C. Mi, ***Study of the characteristics of battery packs in electric vehicles with parallel-connected lithium-ion battery cells. 2014 IEEE Applied Power Electronics Conference and Exposition*** - APEC 2014, Fort Worth, TX, USA, 2014, pp. 3218-3224