UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Integrated Robotics Battery/BMS

Electrical & Computer Engineering

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Manufacturing of a battery pack can be dangerous.

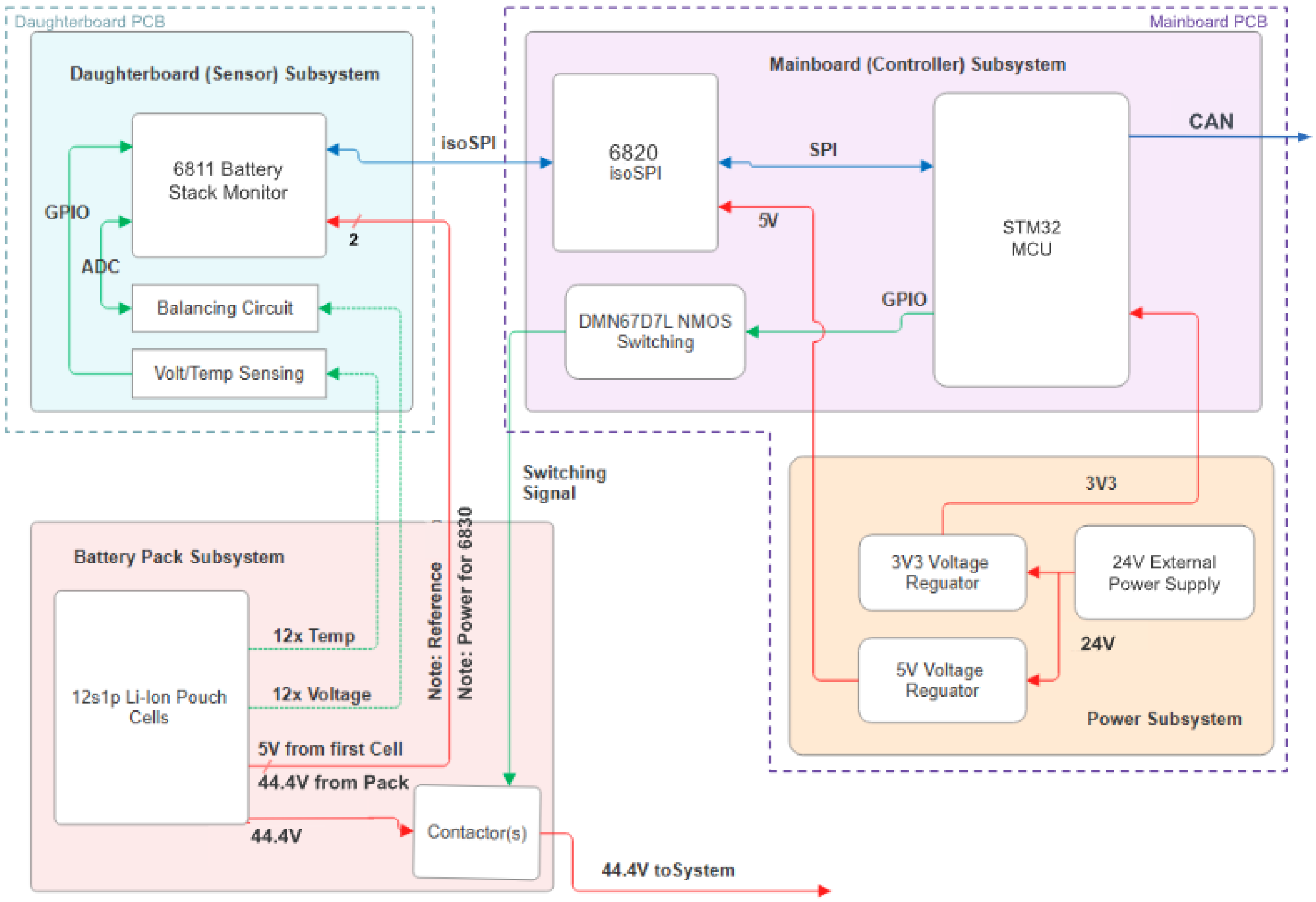
Objectives:

- Manufacturing a lightweight and inexpensive battery pack
- Develop a BMS system to detect and react to any faults in the cells

High Level Requirements:

- **Communication:** BMS shall communicate with a “ground station” and transmit updates every 100 ms.
- **Balancing:** BMS shall be able to maintain cell voltages in the pack to within 100 mV via balancing.
- **Sensing & Faulting** BMS shall monitor the temperature and voltage of cells in the pack and shall take immediate corrective actions when any fault conditions are detected.

Design Overview



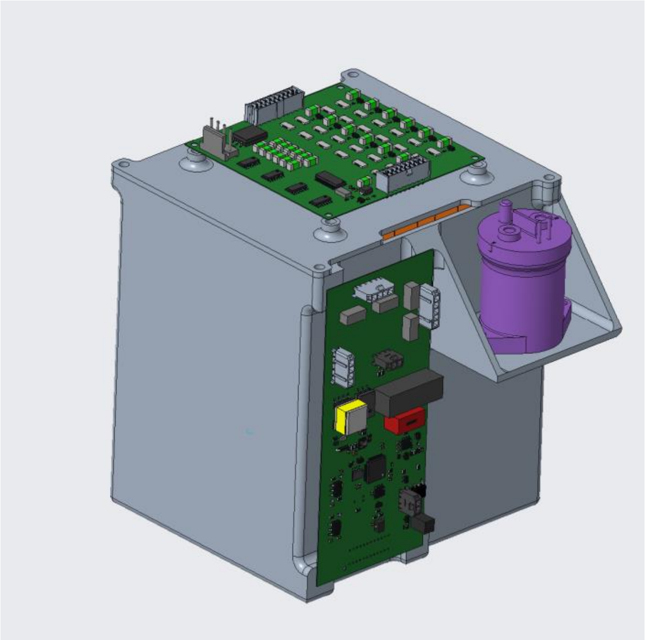
Design Changes:

- Adjusted the external power supply from 12 V to 24 V
- Switched the battery stack monitor from the 6830 to 6811
- Added an external NMOS to the circuit between the NMOS switching circuitry and the contactor

Battery Pack Subsystem

Battery Pack Subsystem Overview

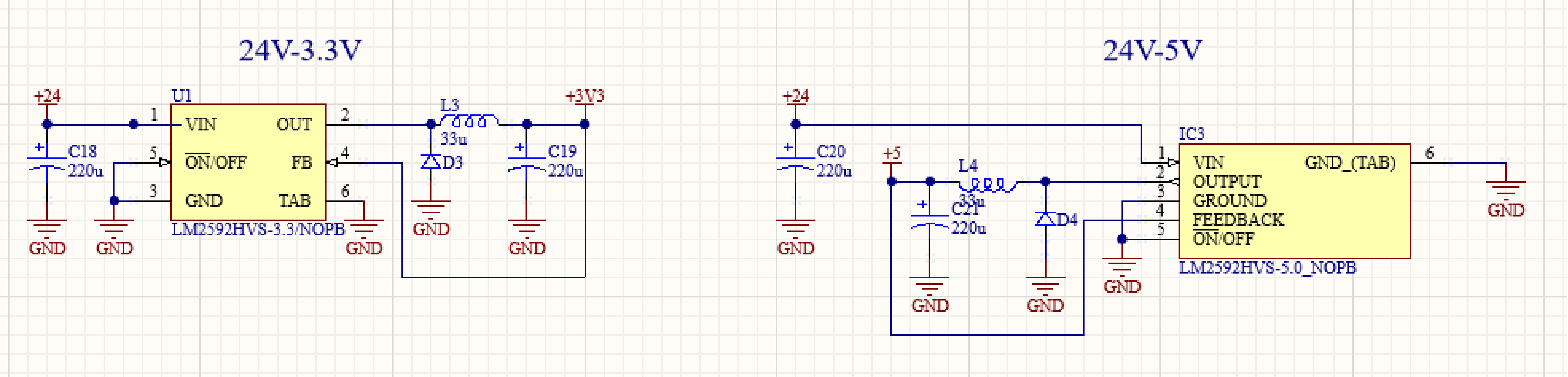
- 13Ah pouch cells in a 12s1p configuration
- 44.4V nominal voltage
- Cells rigidly bolted (with voltage and temperature sensing wires)
- Disconnect from rest of system if a fault signal is received



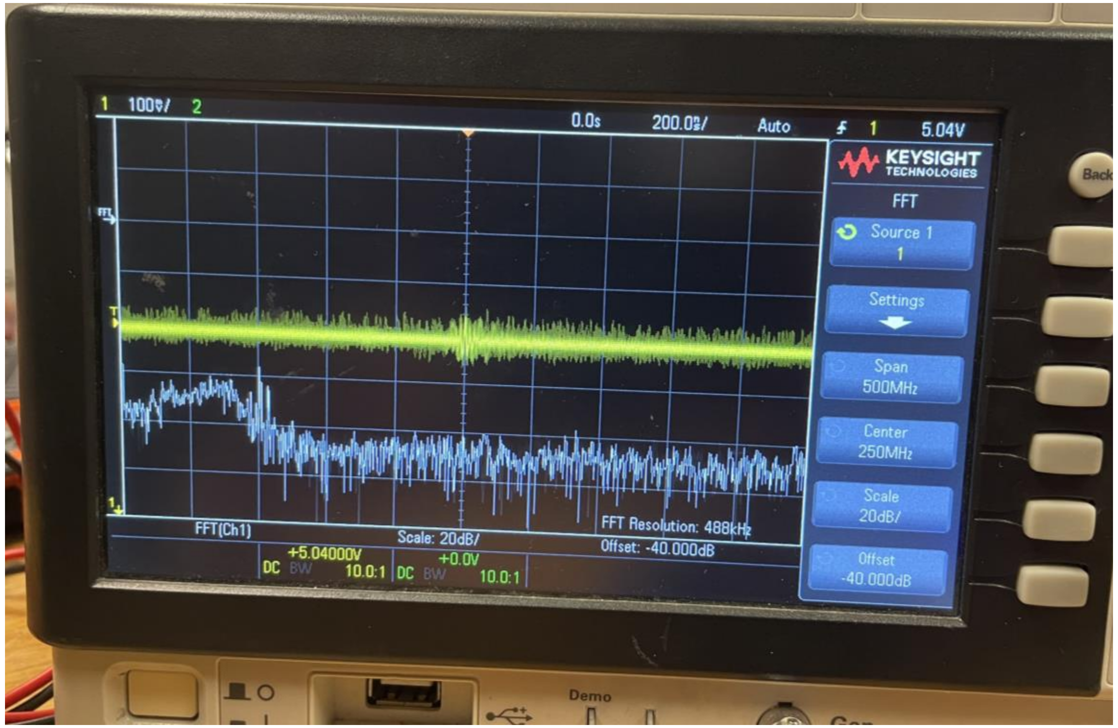
Power Subsystem

Power Subsystem Overview

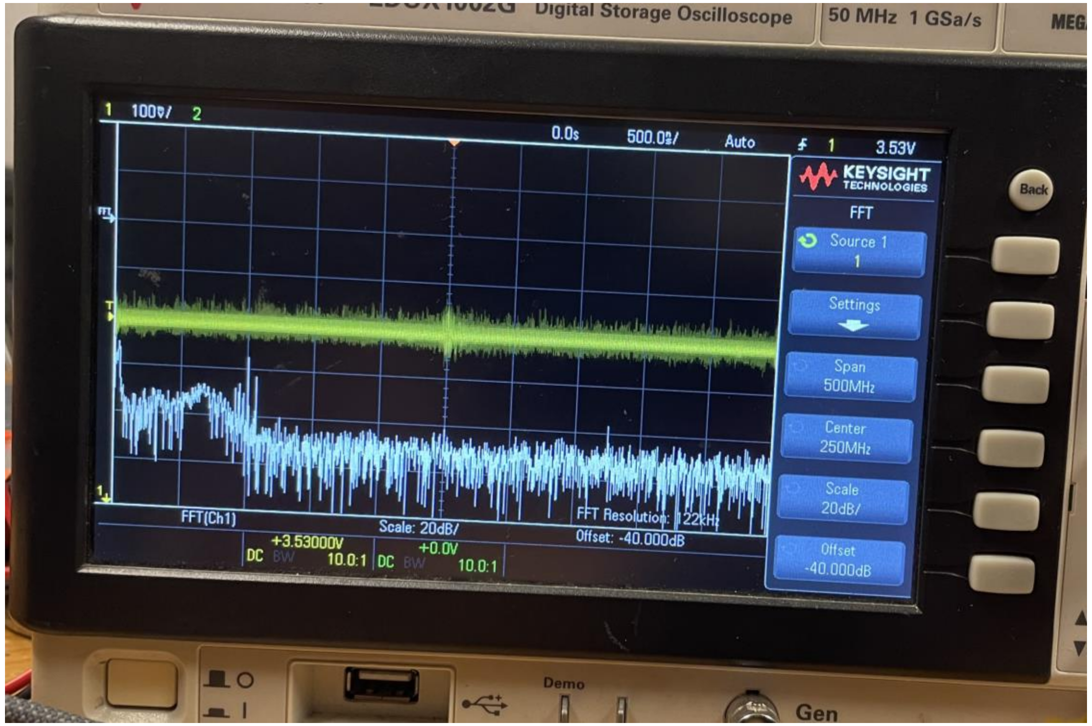
- Provide 3.3V to microcontroller
- Provide 5V to isoSPI interface chips
- Use buck converters because of higher efficiency compared to LDOs



Buck Converter Performance



Output of 5V Buck Converter

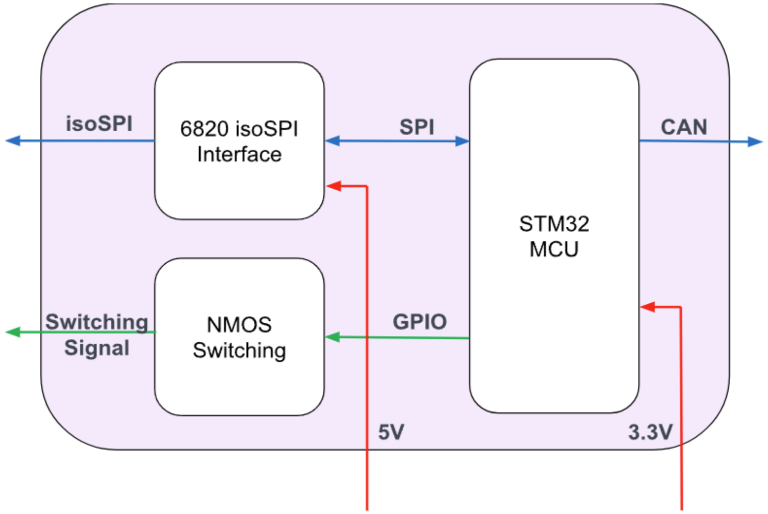


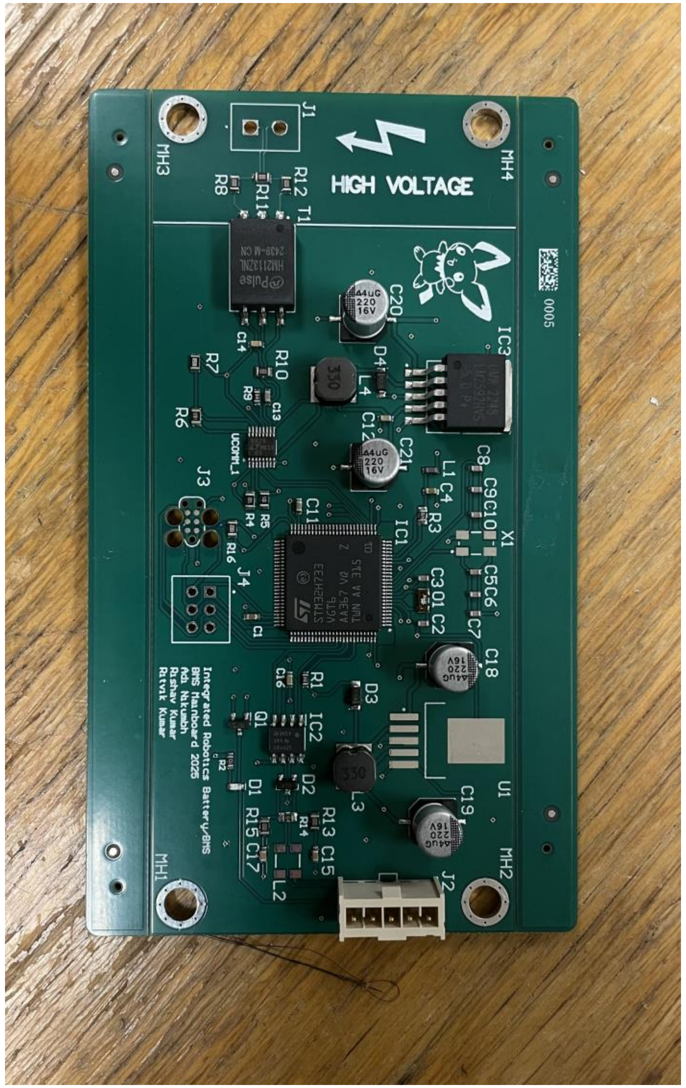
Output of 3.3V Buck Converter

Mainboard (Controller) Subsystem

Controller Subsystem Overview

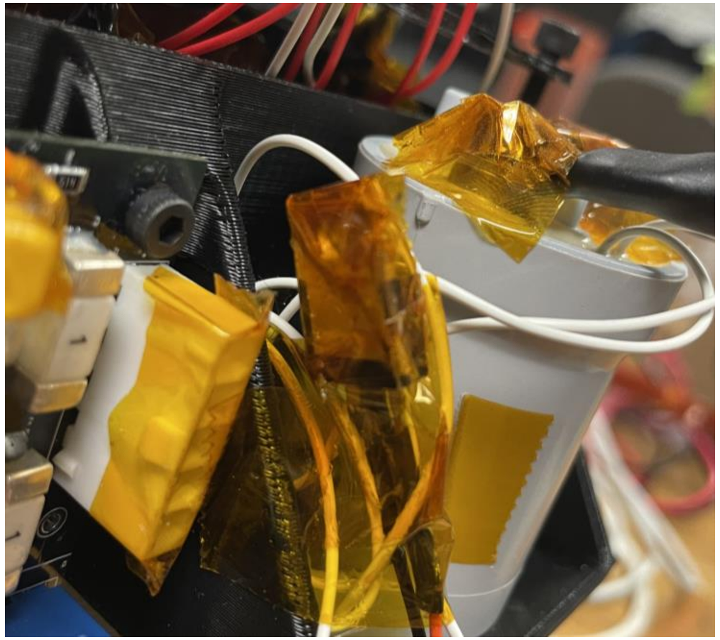
- Identify faults in the battery pack
- **Fault Handling:** Send a signal to the contactor to disconnect the battery if a fault occurs
- **Communication:** Send commands over SPI to daughterboard to discharge cells
- **Ground Station Interface:** Send and receive messages over CAN bus to external systems

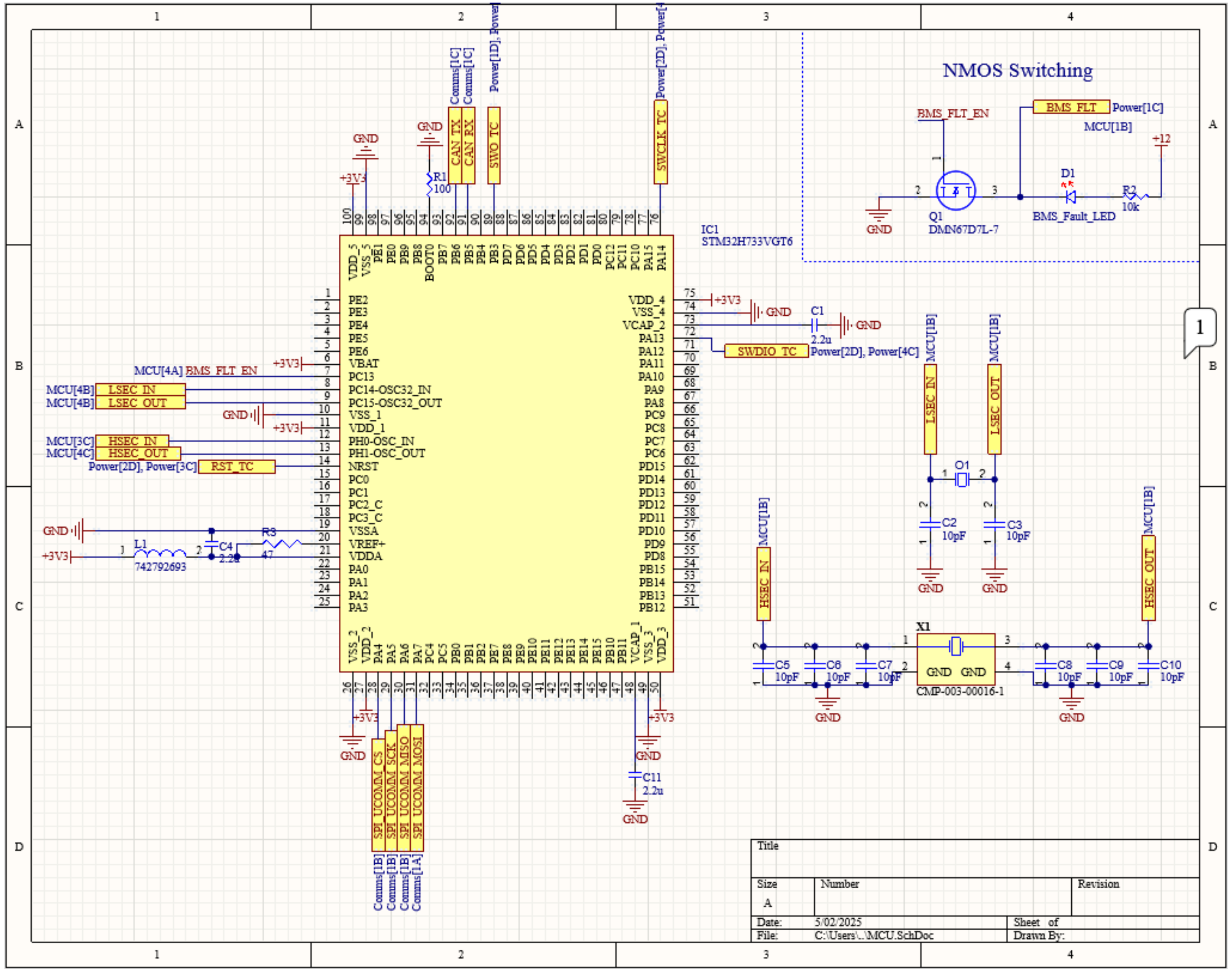




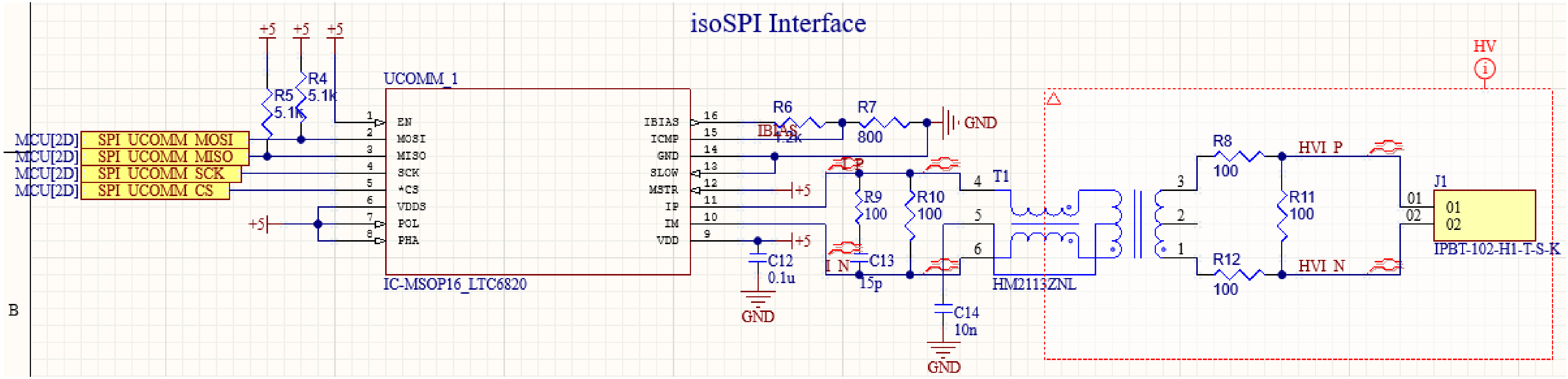
Controller PCB Schematic

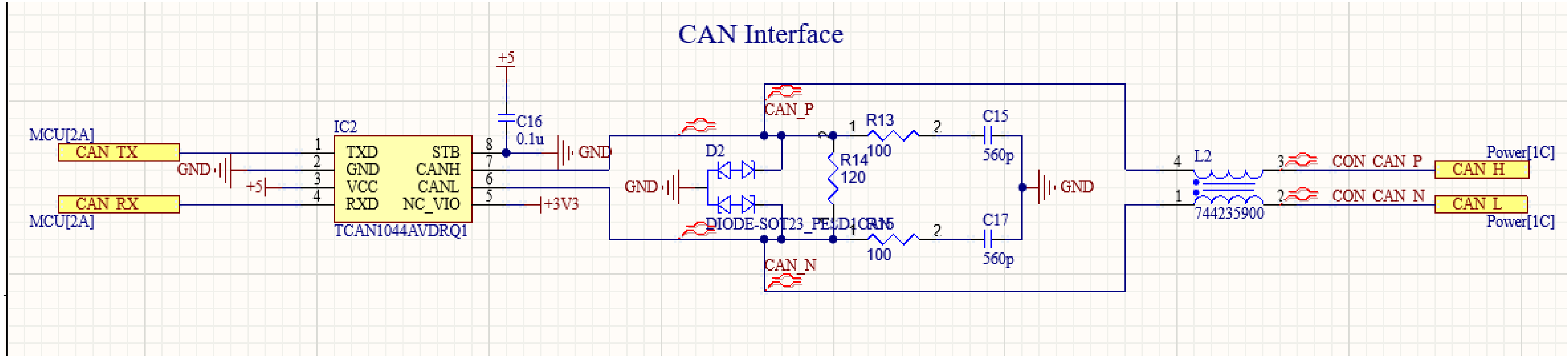
- STM32 MCU
  - 3X FD-CAN interfaces
  - 2X SPI interfaces
- NMOS Switching for the BMS fault signal



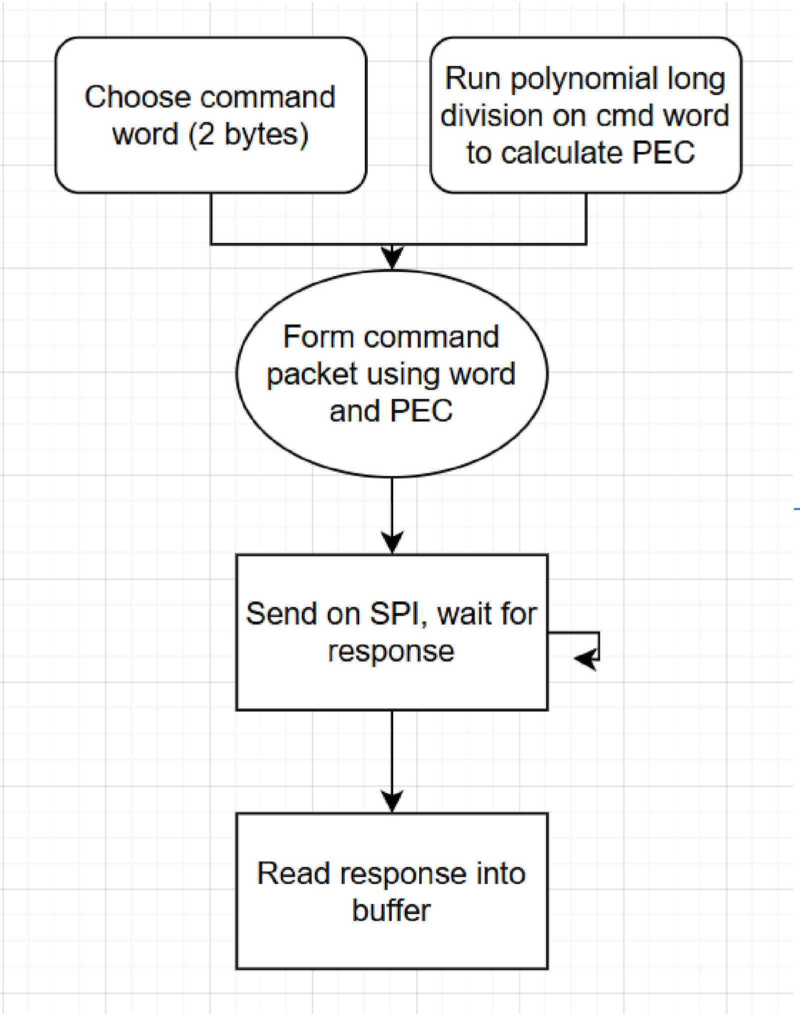


Communication Interfaces





Software Integration for Communication Protocols




```
loop forever:
  // Wakeup sequence
  set CS pin low
  wait 2 ms
  set CS pin high
  wait 2 ms

  // ADCV command (Start cell voltage conversion)
  create command_buffer[4]
  command_buffer[0:1] = ADCV command bytes
  calculate PEC for first 2 bytes
  append PEC bytes to command_buffer
  send command_buffer via SPI

  // SNAP command (Capture cell voltages)
  reset command_buffer
  command_buffer[0:1] = SNAP command bytes
  calculate and append PEC
  send command_buffer via SPI

  // RDCVF command (Read captured voltages)
  reset command_buffer
  command_buffer[0:1] = RDCVF command bytes
  calculate and append PEC
  send command_buffer via SPI
  wait 2 ms
  receive SPI response into read_buffer

  // UNSNAP command
  reset command_buffer
  command_buffer[0:1] = UNSNAP command bytes
  calculate and append PEC
  send command_buffer via SPI

  // Process voltage readings
  for i in 0 to 7:
      combine byte pairs from read_buffer (little-endian)
      convert to voltage: raw_value × 0.0001 volts
      store in voltages array

  // Over-voltage check
  if voltages[0] > 6.4 V:
      turn on FAULT_LED
  else:
      turn off FAULT_LED

  // Resistance calculation
  fixed_resistance = 3.25 Ω
  supply_voltage = 3.3 V
  read ADC_value from sensor
  calculate variable_resistance using ADC_value, fixed_resistance, and supply_voltage
```

Daughterboard (Sensor) Subsystem

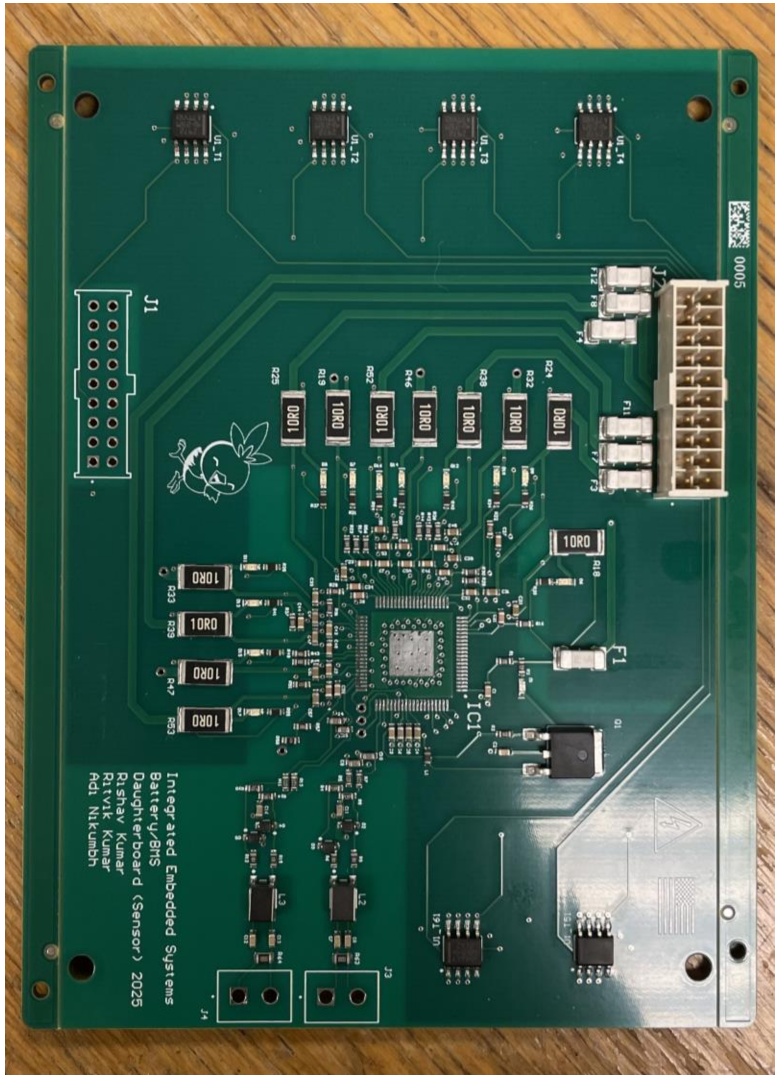
Daughterboard (Sensor) Subsystem Overview

Functions:

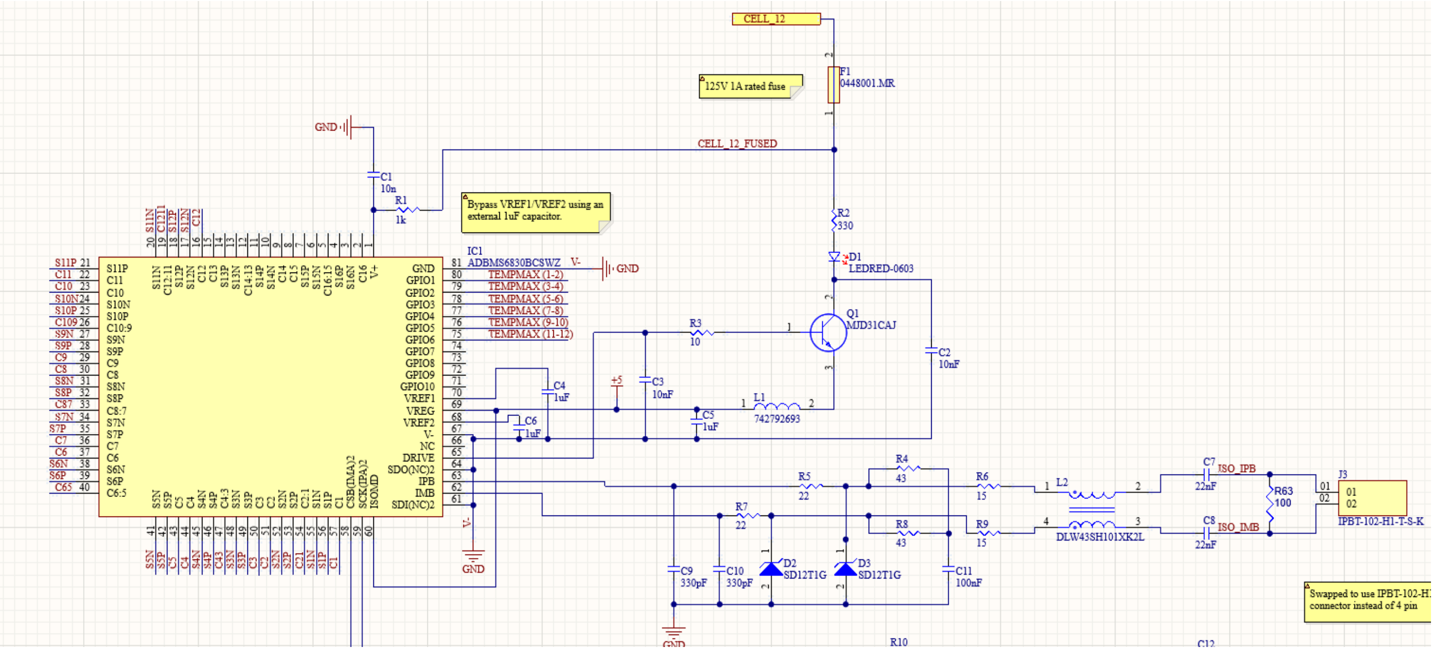
- Temperature Sensing
- Voltage Sensing
- Balancing

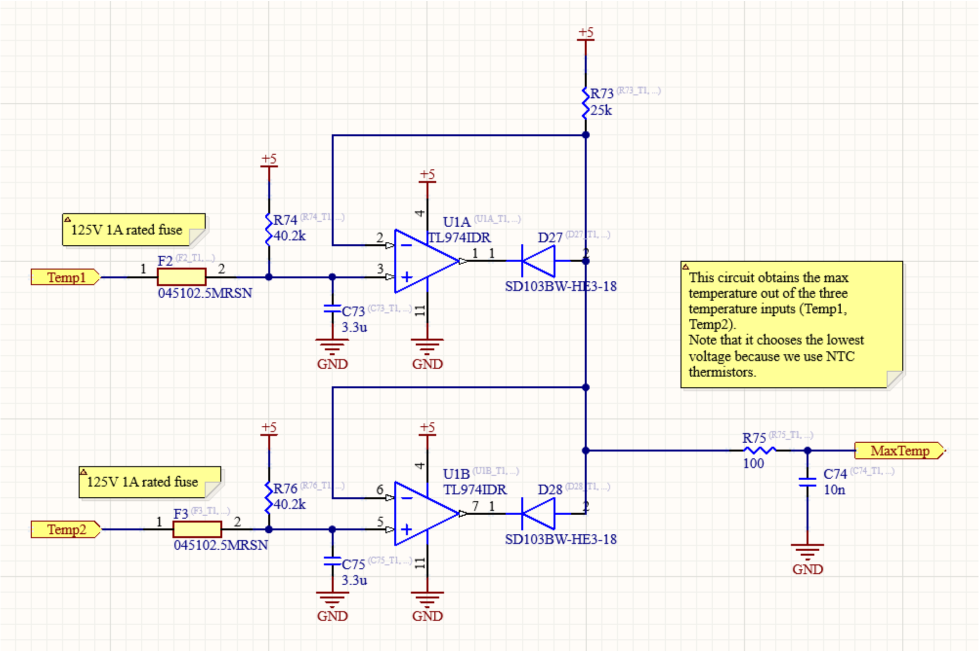
Requirements:

- **Temperature and Voltage:** within ±1% and within ±20mV respectively
- Provide real-time updates for pack monitoring.



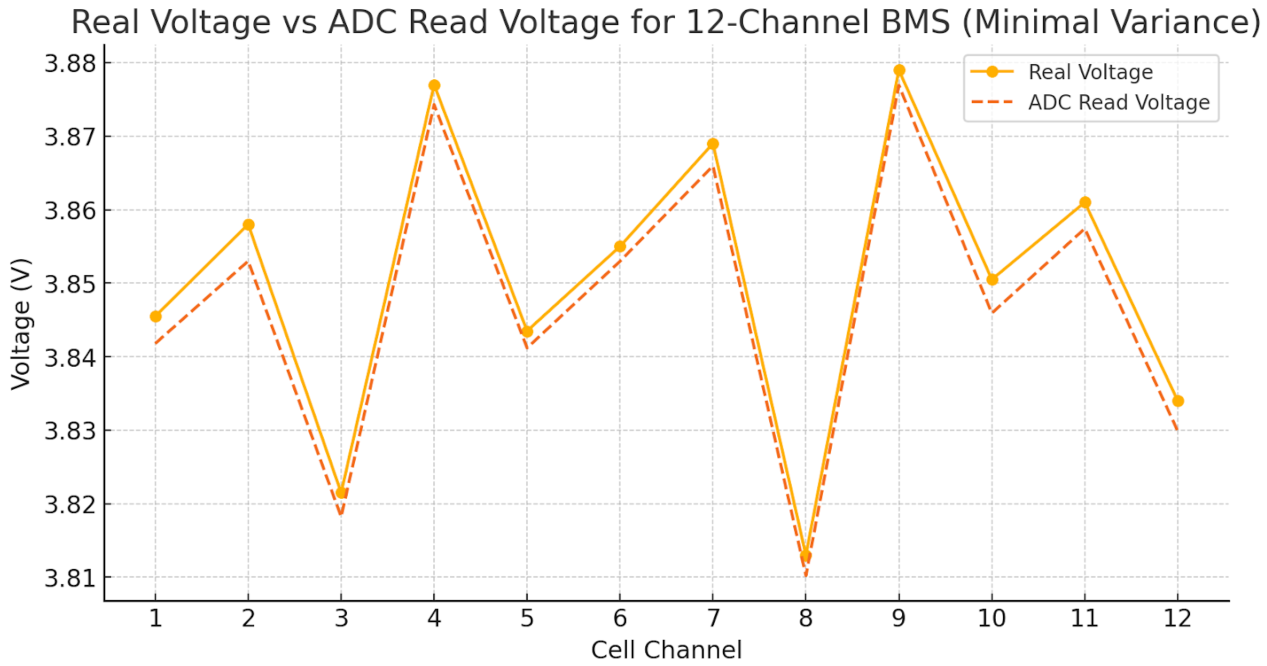
Daughterboard (Sensor) PCB Schematic





- **LTC6811 12 Channel Multicell Battery Monitor**
- **Circuit to detect lowest voltage (highest temperature) due to limited analog inputs on 6811**

Voltage and Temperature Sensing Validation

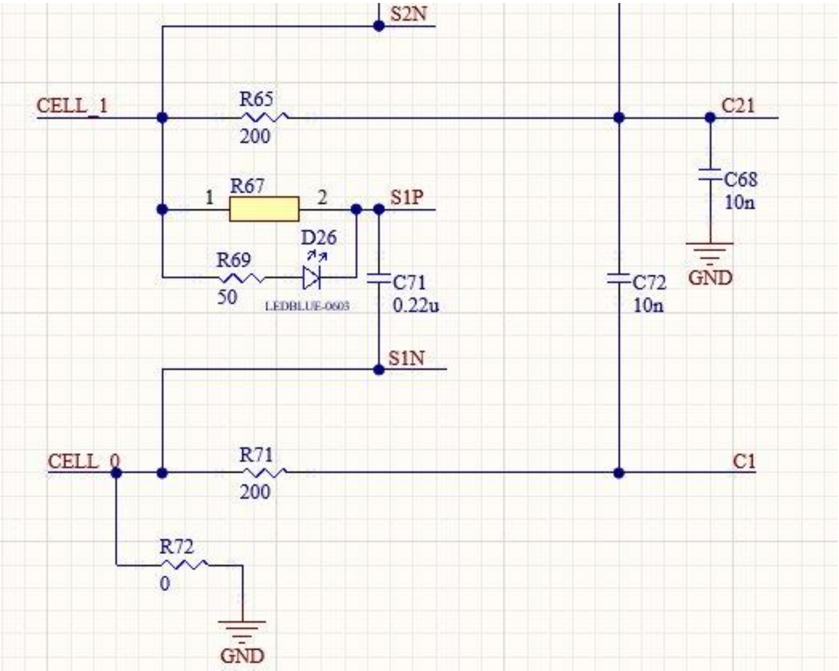


Testing Data for ADCs at different ‘cell voltages’

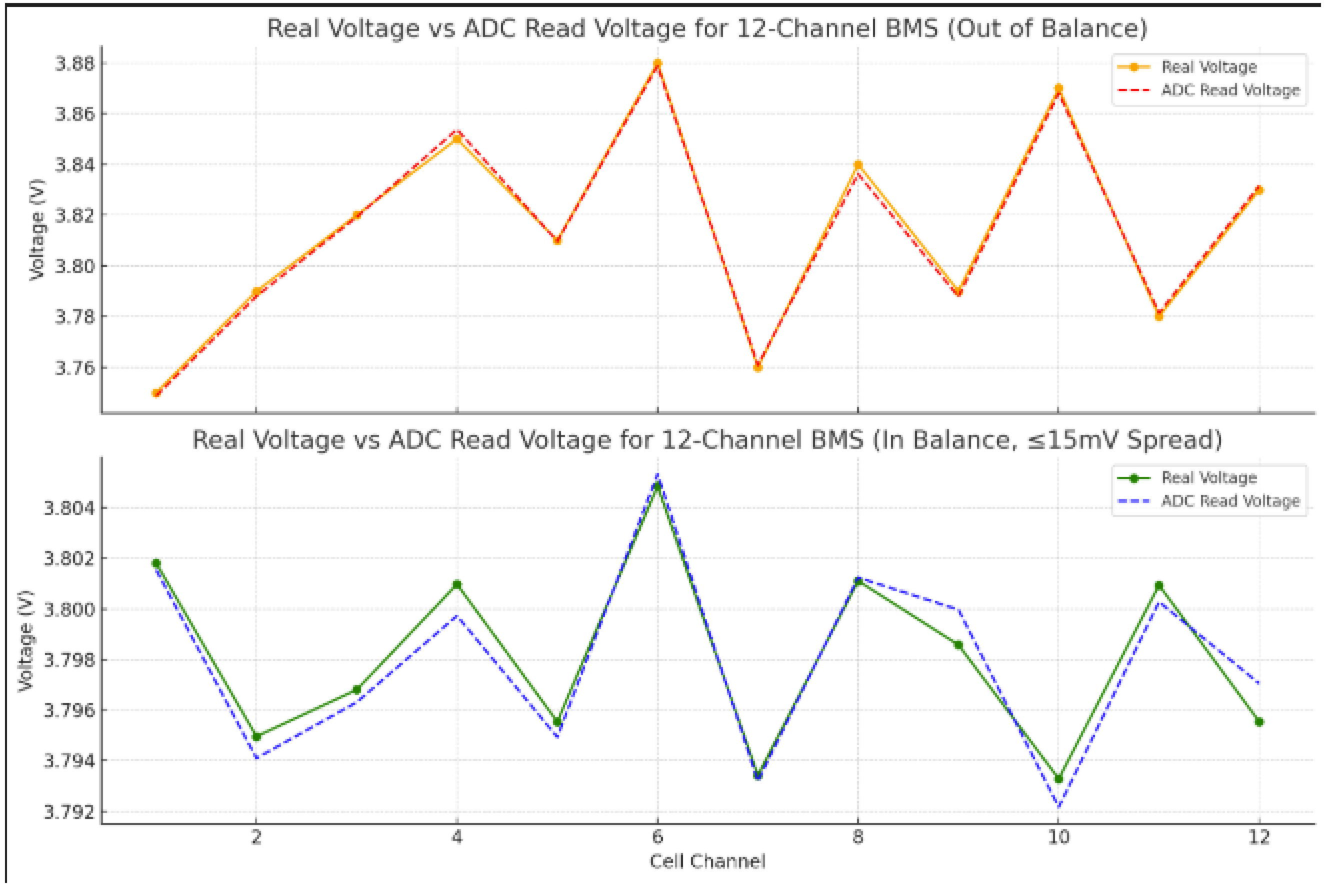
Note: It was difficult to measure temperature with an IR gun due to reflective cell tabs

Cell Balancing – Circuit

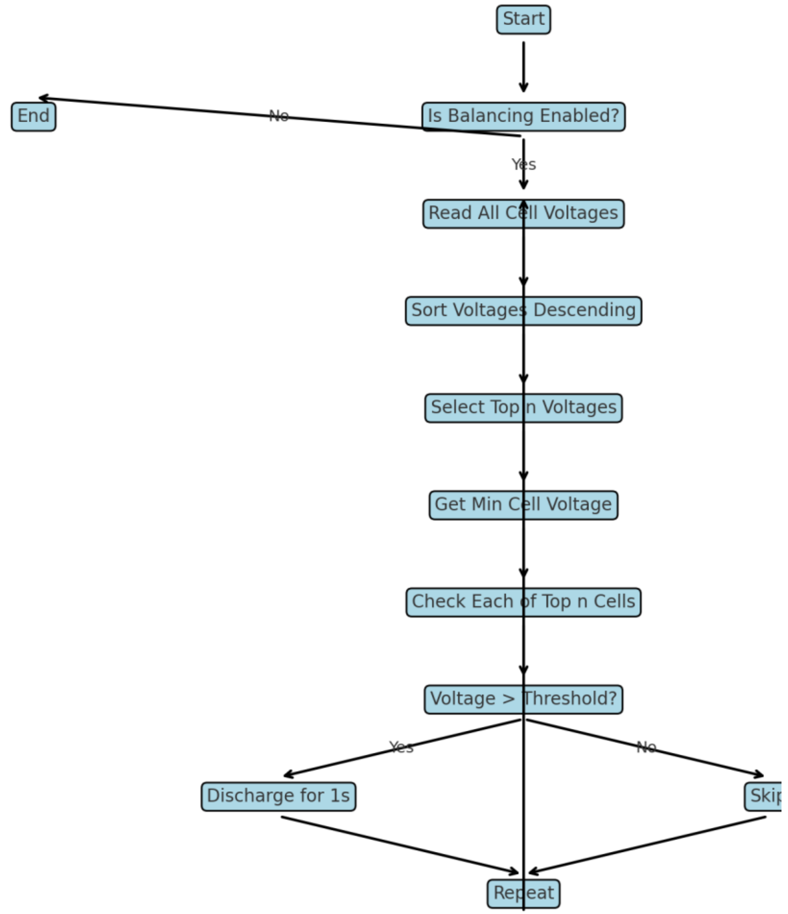
- Passive balancing to remove imbalances in individual cell voltages in pack
- Discharges up to 6 at a time based on delta to lowest cell voltage

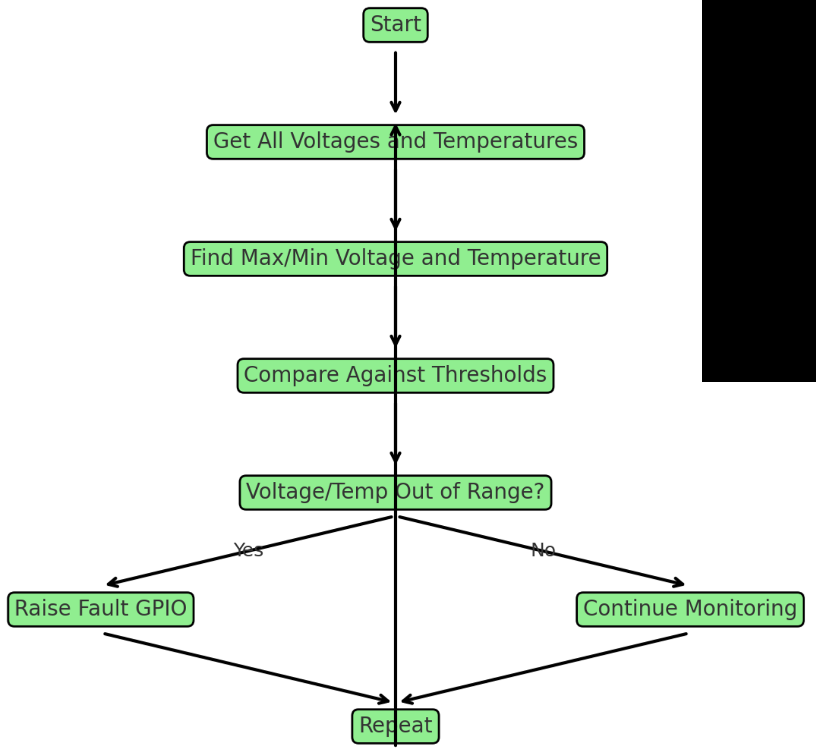


Cell Balancing – Before vs After



Software Integration for Cell Balancing and Fault Detection



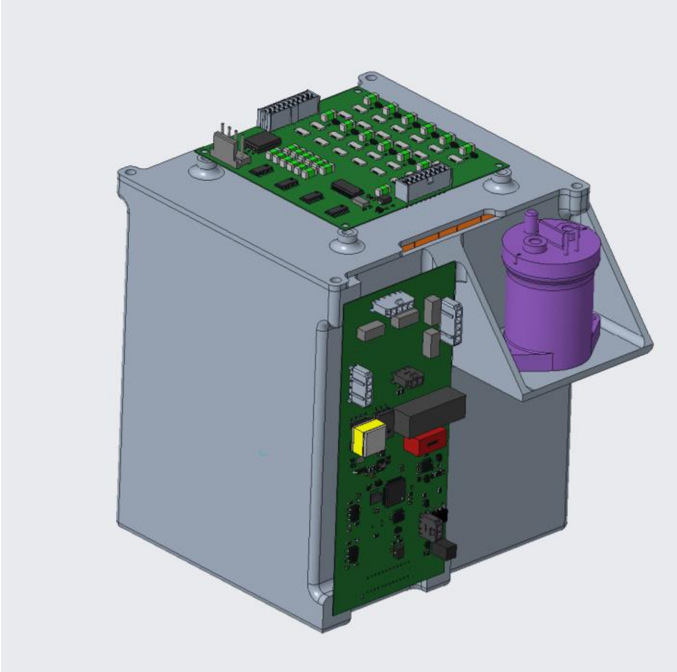


Basic Flowchart of BMS Software Execution

Project Results

Successes:

- Able to get working prototype
- Integrated sensing electronics with self-manufactured pack



Conclusion

What We Learned:

- Battery safety and balancing
- Communication protocols (isoSPI, CAN)

What We Would Change:

- Update chips to increase scalability

What are the Next Steps:

- Improved software interface
- Current monitoring
- More efficient balancing

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