Senior Design Project Report

Battery Management and Communication System

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1. Overview

This project implements a complete Battery Management and Communication System (BMS) for a 10s1p lithium-ion battery pack using Molicel P42A cells. The design provides safe power management, precise measurement, and full isolation between high-voltage and host-computer domains. The system integrates hardware, firmware, and host-software components to support live monitoring, thermal control, and data acquisition.

2. Project Purpose and Objectives

- Ensure safe charging, discharging, and monitoring of a 10-cell lithium-ion battery pack.
- Provide full electrical isolation for data acquisition and communication with a host computer.
- Enable real-time measurement and visualization of voltage, current, and temperature.
- Implement fan control and protection mechanisms to maintain system reliability.
- Integrate flexible testing capability through both real and emulated battery pack modes.

3. System Architecture

The full system is divided into two major domains:

1. **Battery and Power Domain (High Voltage)** – includes battery pack, thermistors, fan, and system buses.
2. **Isolated Communication Domain** – includes STM32 microcontroller, isolated ADC, RTC, USB communication, and power conditioning.

3.1 Battery Pack Subsystem

- **Configuration:** 10s1p lithium-ion pack using Molicel P42A cells.
- **Nominal Voltage:** 36 V.
- **Nominal Capacity:** 4.2 Ah (151.2 Wh total energy).
- **Temperature Sensing:** NTC thermistors placed throughout the pack.
- **Fan Unit:** DC cooling fan powered from pack rail for thermal regulation.

3.2 Signal Processing and Conditioning

- NTC thermistor network provides analog temperature sensing via resistor dividers.
- Comparator circuits monitor critical voltage and temperature thresholds.
- Low-pass filters (LPF) smooth sensor data prior to ADC conversion.
- Comparator outputs drive a discrete N-channel MOSFET gate driver for load control.

3.3 System Bus

Two main buses interface between the high-voltage and isolated zones:

- **System Bus +** carries sensor and measurement signals.
- **System Bus −** provides return reference for analog signals.

4. Isolated Zone for Laptop/PC Communication

The isolated subsystem provides complete galvanic separation between the measurement circuitry and the host computer.

4.1 Power and Isolation Components

- **Isolated DC/DC Converter:** Generates isolated 5 V and 3.3 V rails (ISO_5V and ISO_3V3).
- **PTC Fuse:** Provides over-current protection for the isolated power supply.

4.2 Data Acquisition

- **Isolated ADC (8-channel):** Samples voltage and temperature data via SPI interface.
- **Low-Pass Filters:** Clean noisy analog inputs before ADC sampling.

4.3 Microcontroller Unit (MCU)

- **Device:** STM32 series microcontroller.
- **Interfaces:** SPI (for ADC), I^2C (for RTC), and UART (for PC communication).
- **Isolation:** All digital and analog signals pass through isolation barriers.
- **Tasks:**
  - Collect and timestamp ADC data.
  - Execute fan control algorithms.
  - Forward processed data via USB to host PC.

4.4 Real-Time Clock (RTC)

- Provides accurate timekeeping for data logging.
- Interfaces to MCU via I^2C.

4.5 USB Communication Interface

- **Interface:** USB-C to Laptop/PC.
- **Data Path:** STM32 MCU → USB Interface → PC Application.
- Enables live monitoring and control through a graphical desktop interface.

5. Electrical Protection and Safety

- PTC fuse protects isolated 5V line.
- Over-voltage and under-voltage comparators shut down MOSFETs in unsafe conditions.
- Isolation barriers prevent any high-voltage transients from reaching the PC.

6. Software and PC Interface

The system includes two software layers:

1. **Embedded Firmware:**
   - Handles sensor sampling, signal processing, and USB communication.
   - Implements fan control logic and safety interrupts.
2. **Host Computer GUI:**
   - Displays real-time voltage, current, and temperature data.
   - Allows user configuration of charging, discharging, and data logging.
   - Communicates via USB serial link with the STM32 MCU.

7. Key Components Summary

8. System Connectivity Summary

- Battery Pack → Comparator → LPF → Isolated ADC.
- Isolated ADC → STM32 MCU → USB-C → Host PC.
- Fan ↔ MCU (Analog control and digital enable line).

Component	Description / Function
Molicel P42A	21700 cell, 4.2 Ah, 3.6 V nominal per cell.
STM32 MCU	Core microcontroller handling ADC sampling, data logging, and fan control.
Isolated ADC	8-channel ADC sampling cell voltages and thermistor readings.
Isolated DC/DC Converter	Provides galvanic isolation and power regulation for measurement circuit.
PTC Fuse	Protects isolated 5V rail against over-current.
Comparators	Monitors battery parameters and controls MOSFET gate-driver signals.
LPF Networks	Filters sensor outputs for clean ADC conversion.
NTC Thermistors	Measure pack temperature for thermal management.
Fan	Provides active cooling controlled by MCU logic.

9. Symbol Legend

- $\rightarrow$ Single signal path.
- $= N \Rightarrow$ Harness containing N signal wires.
- $\leftrightarrow$ Bidirectional signal connection.
- $\approx\approx$ General signal path (no fixed direction).

10. Development Status and Next Steps

- Schematic design complete.
- Layout design initiated.
- Firmware in early development.
- CAD and block diagram revisions underway.
- Upcoming tasks include integration testing, Jetson AI model interfacing, and full system calibration.

11. Conclusion

This system delivers a modular, isolated, and safe approach to lithium-ion battery monitoring and communication. By separating the high-voltage sensing and host communication zones, it ensures protection and scalability for advanced applications such as AI-assisted battery health estimation on the Jetson platform.

End of Report