ECE 445

Spring 2025

Senior Design Project Proposal

Integrated Embedded Systems BMS/Battery

Team 51

Adi Nikumbh, Ritvik Kumar, Rishav Kumar

TA: Shengyan Liu

1. Introduction

1.1 Problem

One issue with the development of embedded systems systems for small companies is the issue of battery packs. Manufacturing of a battery pack can be dangerous, and can require the expensive development of a custom BMS system. There are currently few options for completely developed and integrated lightweight battery packs that also contain a high quality BMS system that has capabilities of cutting voltage off in the event of issues.

We propose a solution that uses a combination of temperature sensors and voltage sensors to develop a BMS system that can detect when our battery is in danger of thermal runaway and take action to prevent it. This system will be lightweight and inexpensive, making it suitable for use in a wide range of drones, robots and other applications. With the rapidly increasing use of drones and autonomous robots in a wide range of applications, from agriculture to logistics, the need for reliable and safe battery systems is more important than ever. Our solution will help to ensure that these systems are safe and reliable, reducing the risk of development and making embedded systems safer for everyone.

1.2 Solution

Our solution will be a prototype of a battery pack containing a battery management system (BMS). The system will use temperature sensors to monitor the temperature of the battery, and voltage sensors to monitor the voltage of the battery. These sensors will be hosted on a PCB daughterboard that will directly interface with each cell. The daughterboard will be connected to a mainboard that will be responsible for processing the data from the sensors and taking action to fault the BMS if an improper condition is detected. The fault conditions will include overvoltage, undervoltage, and over-temperature or under-temperature. If any of these conditions are detected, the BMS will take action to prevent thermal runaway, such as shutting down the battery output through a contactor, or initiating the cooling of our pack through fans. We plan to create a 50V max, 44.4V nominal, 12s1p system that can be used in a wide range of applications, from drones to embedded systems.

For our cells, we plan to use CosmX 13Ah pouch cells in a 12s1p configuration. This will give us 50V max and 44.4V nominal voltage. For our sensors, we will use either AD LTC6811 or LTC6813 chips on our sensing board. To communicate with these sensors, we will use either the AD LTC6820 or the AD LTC6830. For our chip, we will use an STM32H7 in an LQFP package in a smaller size.

1.3 Visual Aid

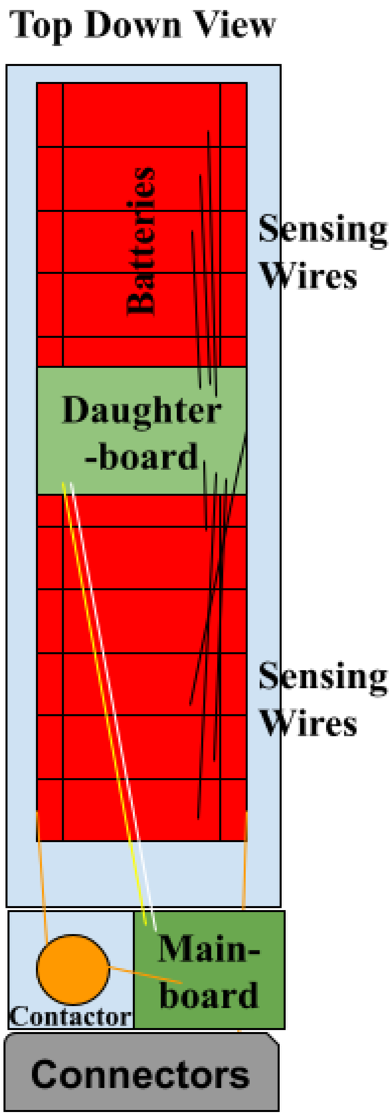

Figure 1: Visual aid depicting minimal solution for BMS Mainboard (Controller), Daughterboard (Sensor), and Battery Pack.

1.4 High-Level Requirements

1. The BMS shall communicate with a “ground station” utilizing a serial interface to transmit updates and battery data for monitoring and SOH/SOC tracking every 100 ms.
2. The BMS shall be able to maintain cell voltages in the pack to within 100 mV via balancing.

3. The BMS shall monitor the temperature and voltage of cells in the pack and shall take immediate corrective actions when any fault conditions (overvoltage, undervoltage, under temperature, or over temperature) are detected according to the datasheet.

2. Design

2.1 Block Diagram

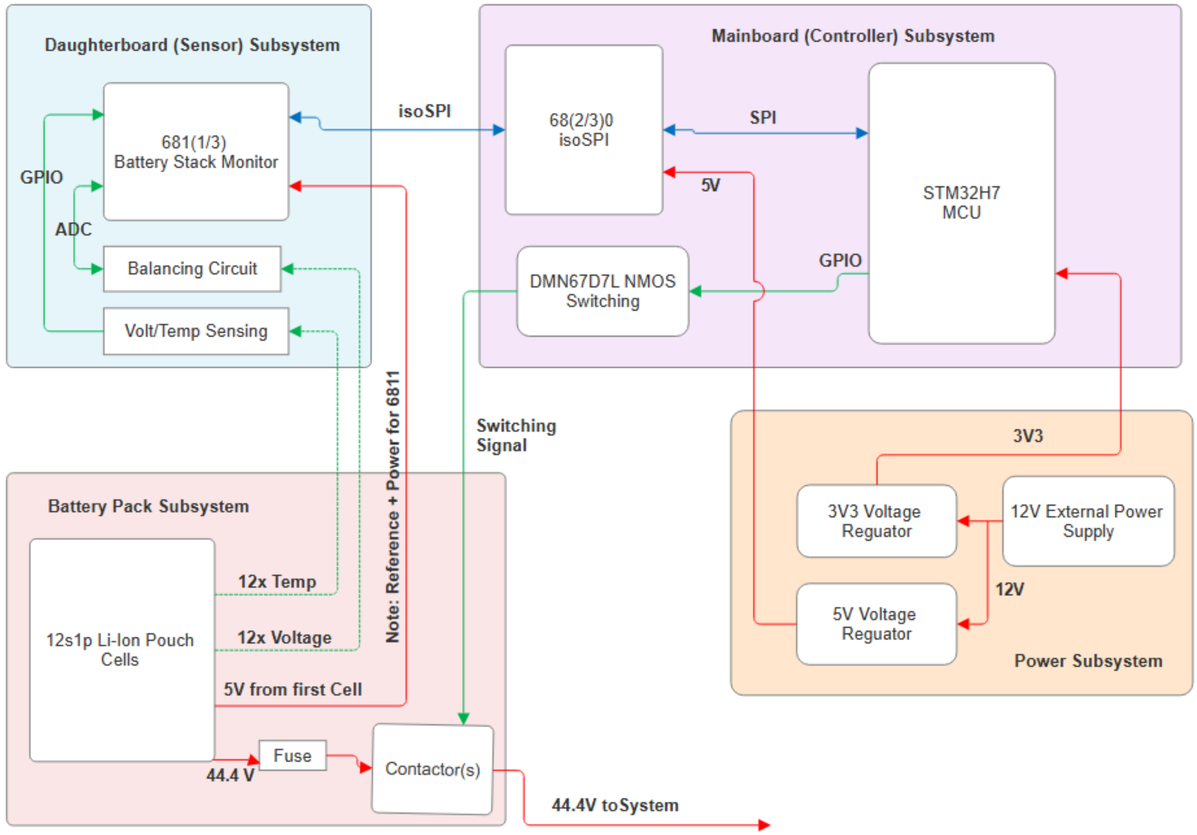

Figure 2: Block Diagram for Integrated embedded systems BMS/Battery

2.2 Electronics Subsystems Overviews and Requirements

2.2.1. Battery Pack Subsystem

Description, Purpose, and Interactions:

The battery pack subsystem will be a 12s1p lithium ion battery pack. We will use high capacity CosmX pouch cells with a nominal voltage of 3.7V. We have chosen pouch cells due to being able to manufacture our pack without needing to spot weld. The cells will be connected in series to create a 44.4V nominal battery pack, with a capacity of 13Ah.

The battery pack will be housed in a lightweight and durable enclosure, with provisions for mounting the BMS and other components. The cells will be bolted together with low resistance bolts, and the pack will be designed to be easily disassembled for maintenance and repair. The pack will also include provisions for cooling, such as vents or heat sinks, to help prevent thermal runaway.

The battery pack will be fused, and it will only supply voltage to the system (the contactor closes) when no faults are detected. It will supply voltage and temperature sense, 5V power, and a reference to the daughterboard (sensor) subsystem. The contactor in the battery pack subsystem will be connected to the mainboard (controller) subsystem.

Requirements:

1. The battery pack shall supply 44.4V nominal voltage (max 50V) to the system when no fault conditions are present.
2. The cells shall be rigidly connected to each other and mounted to the enclosure with protection against vibrations and requisite electrical isolation and safety.

2.2.2. Mainboard (Controller) Subsystem

Description, Purpose, and Interactions:

The mainboard will be a PCB that will host the microcontroller (MCU), isoSPI communications interface (either the AD LTC6820 or AD LTC6830), and other components. The mainboard will be responsible for processing the data from the daughterboard, and taking action to fault the BMS if an improper condition is detected. The mainboard will use a STM32H7 in an LQFP package in a smaller size microcontroller to process the data from the daughterboard, and will use MOSFETs to control the battery output (through the contactor). The mainboard will also include provisions for connecting to the daughterboard, such as headers or connectors.

The MCU will communicate with the daughterboard (sensor) subsystem using isoSPI. It will run the algorithm for cell balancing, as well as for checking the numerous fault conditions. It will take 3V3 input from the power subsystem.

Requirements:

1. The subsystem shall have a stable connection to the daughterboard (sensors) subsystem.
2. The subsystem shall correctly determine faults in the battery pack and appropriately turn on/off the contactor(s) in the battery pack.
3. The subsystem should send commands over SPI to the LTC chips in order to be able to discharge the cells.

2.2.2. Daughterboard (Sensor) Subsystem

Description, Purpose, and Interactions:

This subsystem will be a PCB that will host the temperature and voltage sensors. The daughterboard will be connected to the mainboard via a two wire isoSPI interface, which will allow for easy communication between the two boards. The daughterboard will be responsible for monitoring the temperature and voltage of each cell in the battery pack (i.e., 12 voltage and 12 temperature sense lines), and sending this data to the mainboard for processing. The daughterboard will use Analog Devices LTC (either AD LTC6811 or LTC6813) chips to monitor the voltage of each cell, and will use thermistors to monitor the temperature of each cell. The daughterboard will also include provisions for connecting to the mainboard, such as headers or connectors.

The daughterboard will be powered by the first cell in the battery pack and receive a reference voltage from there as well. It will have circuitry to balance (and/or discharge) the cells based on readings from the sensors.

Requirements:

1. Read temperatures within 1°C and read voltages within 20mV.
2. Communicate to the MCU over isoSPI to provide constant updates for pack monitoring.
3. Provide stable connection to battery pack to read voltages and temperatures.

2.2.2. Power Subsystem

Description, Purpose, and Interactions:

This subsystem will receive a 12V input from an external power supply and modulate the voltage to 3.3V and 5V to power the STM32 microcontroller and isoSPI interface chips. We will use a buck converter from 12V to 3.3V and 5V because they are more efficient than LDOs (dissipate less power and heat into the board), though if stability of provided voltage is an issue, we might switch to low-noise LDOs.

Requirements:.

1. Provide stable 3.3V and 5V to microcontroller and isoSPI interface chips.

2.2 Tolerance Analysis

The most important tolerances for our design include the voltage sense tolerances, and the circuits for temperature sensing. The 6811 IC has a total advertised tolerance of 1.2mV, which we likely foresee could be affected by noise in the system or through the isoSPI line [1]. The 6813 offers a similar level of tolerance, but slightly higher, around 2.3mV [2]. One important thing we also may want to prioritize over simply the overall tolerance of the voltage sensor is the timing of the system. We want to be able to measure the voltages at a high speed, for which both of the IC's will be more than capable for. The 6811 and 6813 both boast a total measurement speed of 290us [1][2]. As for temperature, NTC thermistors have a temperature tolerance of around 2%, which we believe is suitable [3].

3. Ethics and Safety

The main safety concerns for the project are lithium-ion batteries. Since lithium ion batteries are unregulated energy sources, they are capable of discharging large amounts of amperage if shorted over a low resistance connection. If we short our batteries over something like an allen key or piece of wire, we could see upwards of a hundred amps output across just a few volts between the tabs of our cells. Thus, it is of utmost importance that we maintain the best safety standards. We will use things such as insulated tape that has dielectric strength well beyond the voltage of our system, and use connectors and plugs that are up to code as well. We will be extremely careful to make sure that nothing touches the battery leads, and not to short them. If we have any issues with the battery and it becomes unsafe, we will contact DRS and dispose of our cells in a safe manner [5]. However, our system has a nominal voltage of under 50V, so we will not have to follow high voltage standards as stringently.

In terms of ethical issues, there is the issue of the usage of our project in unethical applications. Since our design is general purpose and marketed towards industry, it is possible that a usecase could be found in the military complex, as there are many usecases where a high quality battery could be used; for instance, autonomous vehicles and/or drones. To follow the IEEE Code of Ethics – which states, "to hold paramount the safety, health, and welfare of the public" – we will avoid ethical breaches by making sure that our designs stay private and are only seen by people we trust [6].

4. References

[1] Analog Devices, "12 Channel Multicell Battery Monitor with Daisy Chain Interface," LTC6811-1/LTC6811-2 datasheet, Aug. 2017 [Rev. C]. https://www.analog.com/media/en/technical-documentation/data-sheets/ltc6811-1-6811-2.pdf.

[2] Analog Devices, "18-Cell Battery Stack Monitor with Daisy Chain Interface," LTC6813-1 datasheet, Nov. 2020 [Rev. B]. https://www.analog.com/media/en/technical-documentation/data-sheets/ltc6813-1.pdf.

[3] "NTCALUG54A103G351A | DigiKey Electronics," *DigiKey Electronics*, 2025. https://www.digikey.com/en/products/detail/vishay-beyschlag-draloric-bc-components/NTCALUG54A103G351A/10379532?s=N4IgTCBcDaIHIBUDCBBAMgVQOIFYAsKAjAAwDMWpOhKIAugL5A [Accessed Feb. 11, 2025].

[4] "STM32H7 - Arm Cortex-M7 and Cortex-M4 MCUs (480 MHz) - STMicroelectronics," *www.st.com*. https://www.st.com/en/microcontrollers-microprocessors/stm32h7-series.html.

[5] "Division of Research Safety | Illinois," *drs.illinois.edu*. https://drs.illinois.edu/Page/SafetyLibrary/BatterySafety

[6] IEEE, "IEEE Code of Ethics," *ieee.org*, Jun. 2020. https://www.ieee.org/about/corporate/governance/p7-8.html