04/27/2021

HyTech Racing BMS

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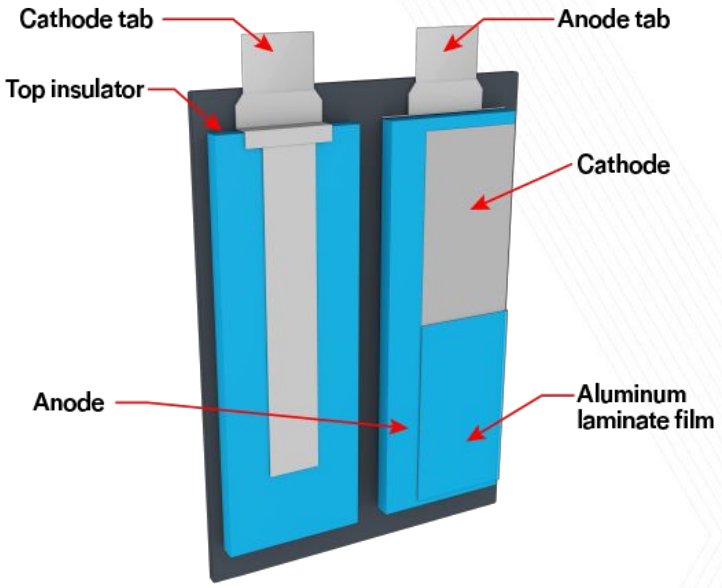
Summary

HyTech racing is interested in a custom battery management system for charging Lithium Cobalt Oxide pouch battery cells. This device is intended to speed up testing and prototyping in their workshop.

Building this system is the main focus of our project.

Problem Statement and Requirements

- User-friendly interface for charging Lithium Cobalt Oxide pouch battery cells
- Custom battery management system with an integrated data recording system
- Battery health estimation



Lithium Cobalt Oxide Pouch Cell

Requirements

- Charge at least 9 battery cells at a time (~38V and 10A)
- Voltage and current data for every battery cell must be recorded
- Cell balancing algorithm must be implemented
- Safe and easy to use

Engineering Constraints

Lithium Cobalt Oxide Battery Cell Characteristics

- Determines the nominal (3.7V) and maximum (4.2V) voltages
- Thermal characteristics

Safety Constraints

- Chosen material for device needs to be electrically insulated
- Ensure low likelihood for short circuits and human contact with energized components

Goals

Software:

- Start and stop battery charging sessions
- Data logging for voltage, current, and temperature of batteries
- State-of-health calculations for battery cells

Electronics:

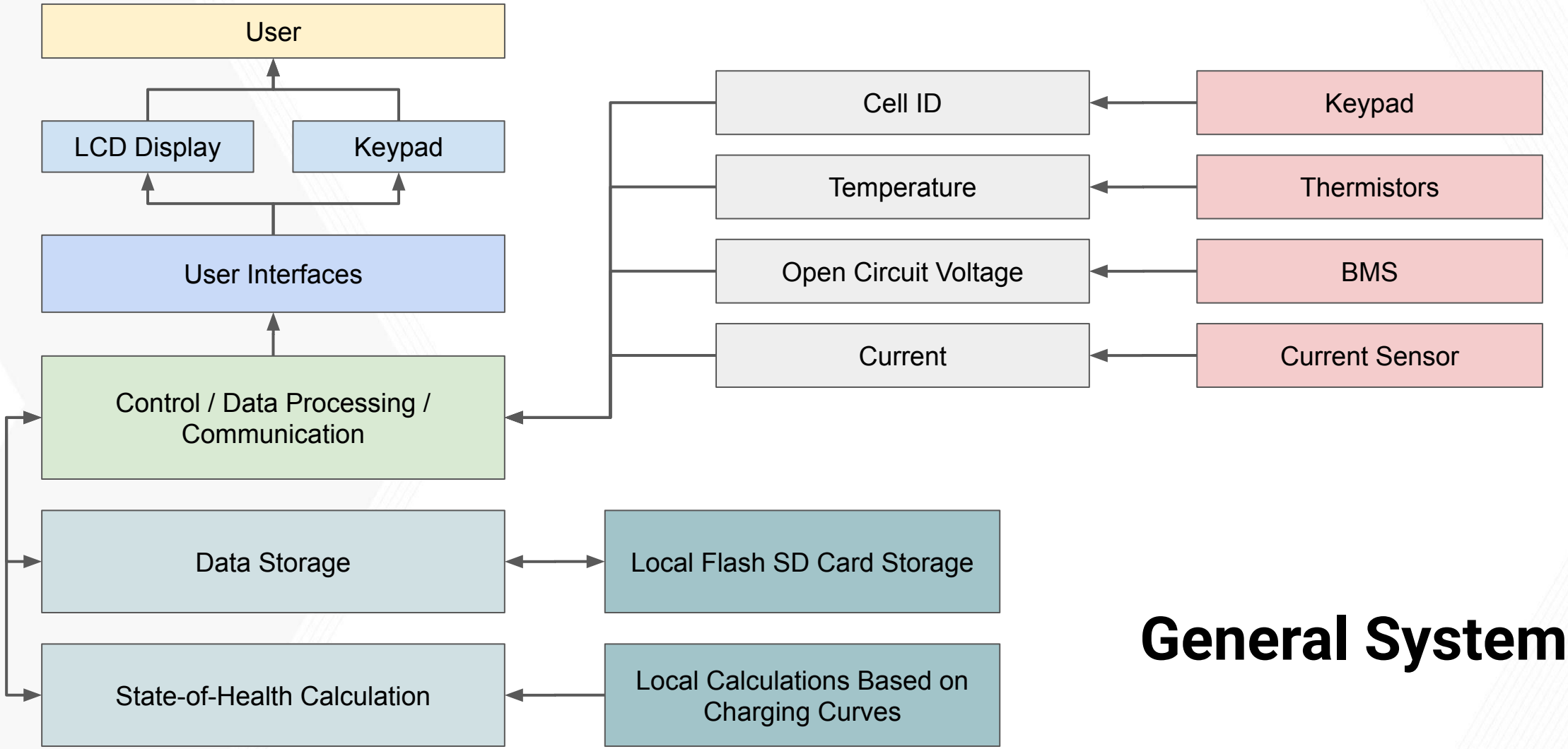
- Deliver the correct voltage and current levels to the battery cells
- Ensure battery cells remain stable

Physical device:

- Robust design, should be able to last at least five years under regular use
- Accommodates variance in cell dimensions
- Fairly insulated, does not transmit heat or warp from current

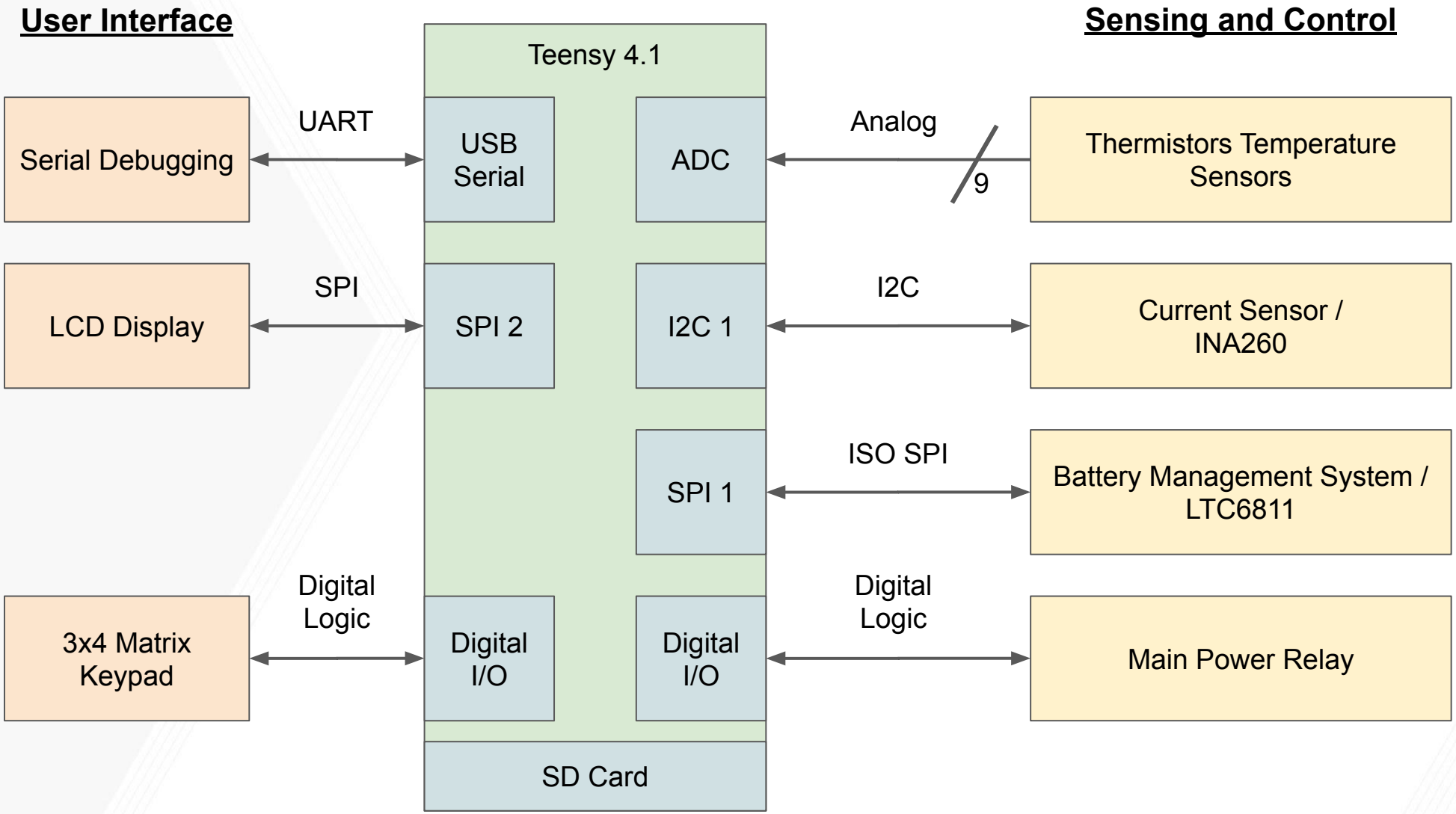
Project Demo

Solution Design



General System

Controller Board



Appendix

Thank You!

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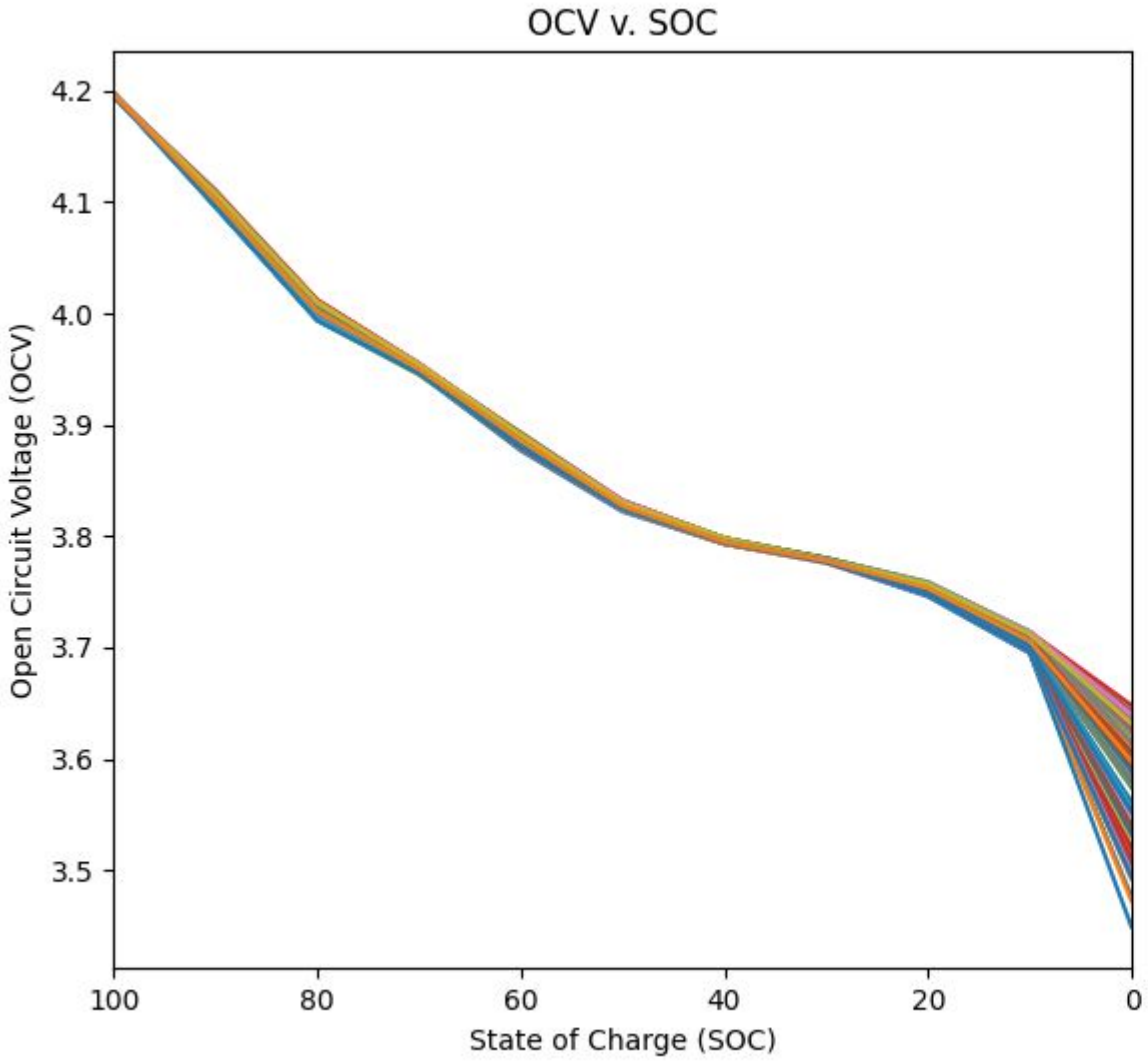
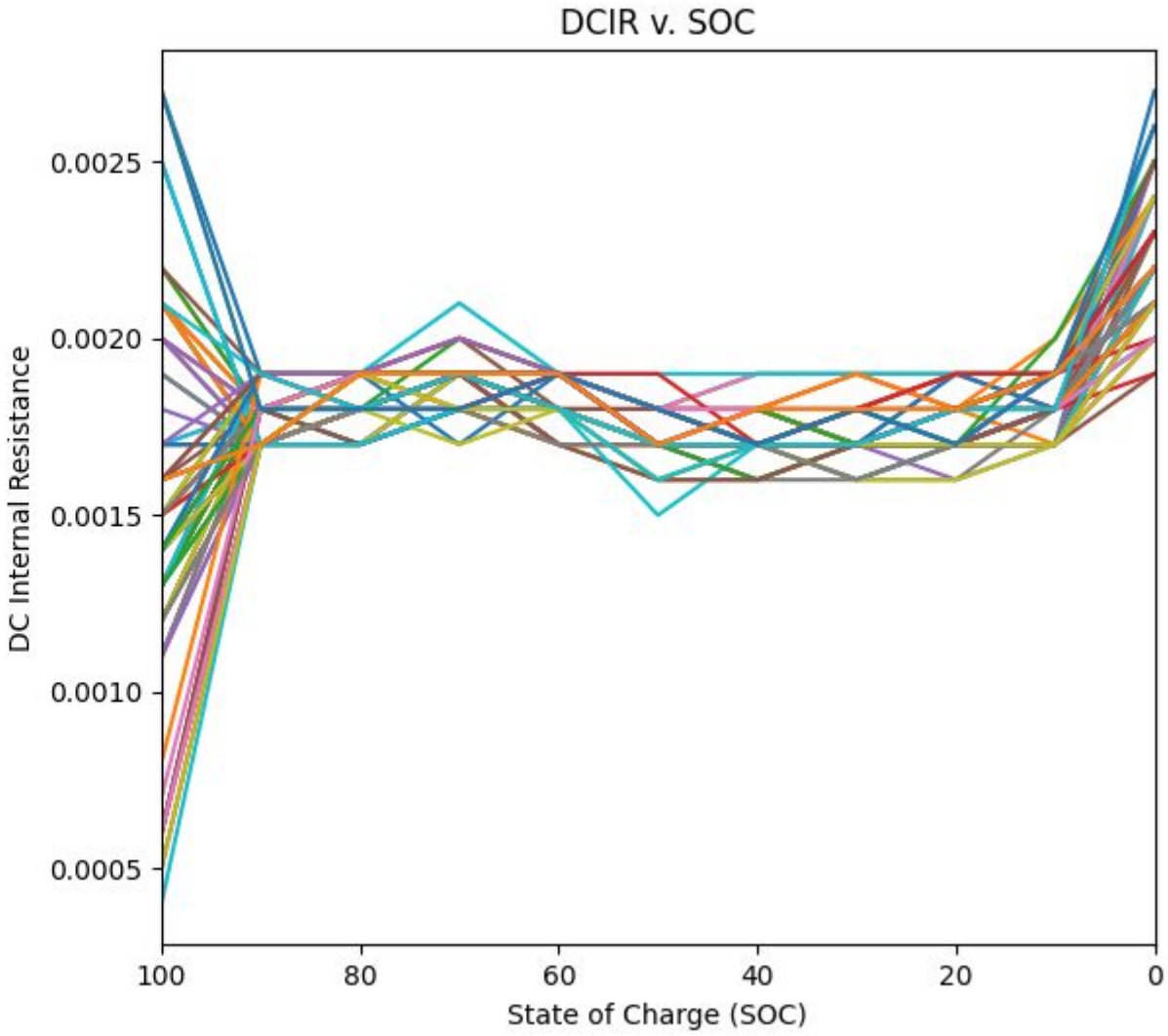
State-of-Charge Curves





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Updated Customer Requirements

Category	Customer Requirements
1) Function	a) Charge 9 LiCoO2 pouch battery cells with a nominal capacity of 18Ah
	b) Record and store current and voltage data for every cell
	c) Must be compatible with Melasta SLPBA580183 battery cells
2) Electrical Characteristics	a) Charging current of 9-10A (0.5C rate)
	b) Must have a cell balancing algorithm
	c) Powered from a regular electrical wall outlet
3) Mechanical Characteristics	a) Minimal risk of environmental damage to batteries (ex. water)
	b) Modular design (adaptable to changes in dimensions or geometry)
	c) Relatively lightweight and easy to transport
	d) Keep battery cells below 45 degrees celsius
4) Safety	a) Must be easy and safe for someone trained to operate the device
5) Reliability	a) The device must be able to withstand regular use for 2-3 years

Engineering Design Specifications

- ~38V and ~10A needed to charge nine battery cells in series at 0.5C
  - max voltage of one battery cell is around 4.2V
- Safe battery temperature range is between 10-45 degrees Celsius
- Required I/O includes a temperature sensor, current sensor, local data storage, a keypad for user input, and a screen for user output
- Physical stress on battery cell tabs need to be considered

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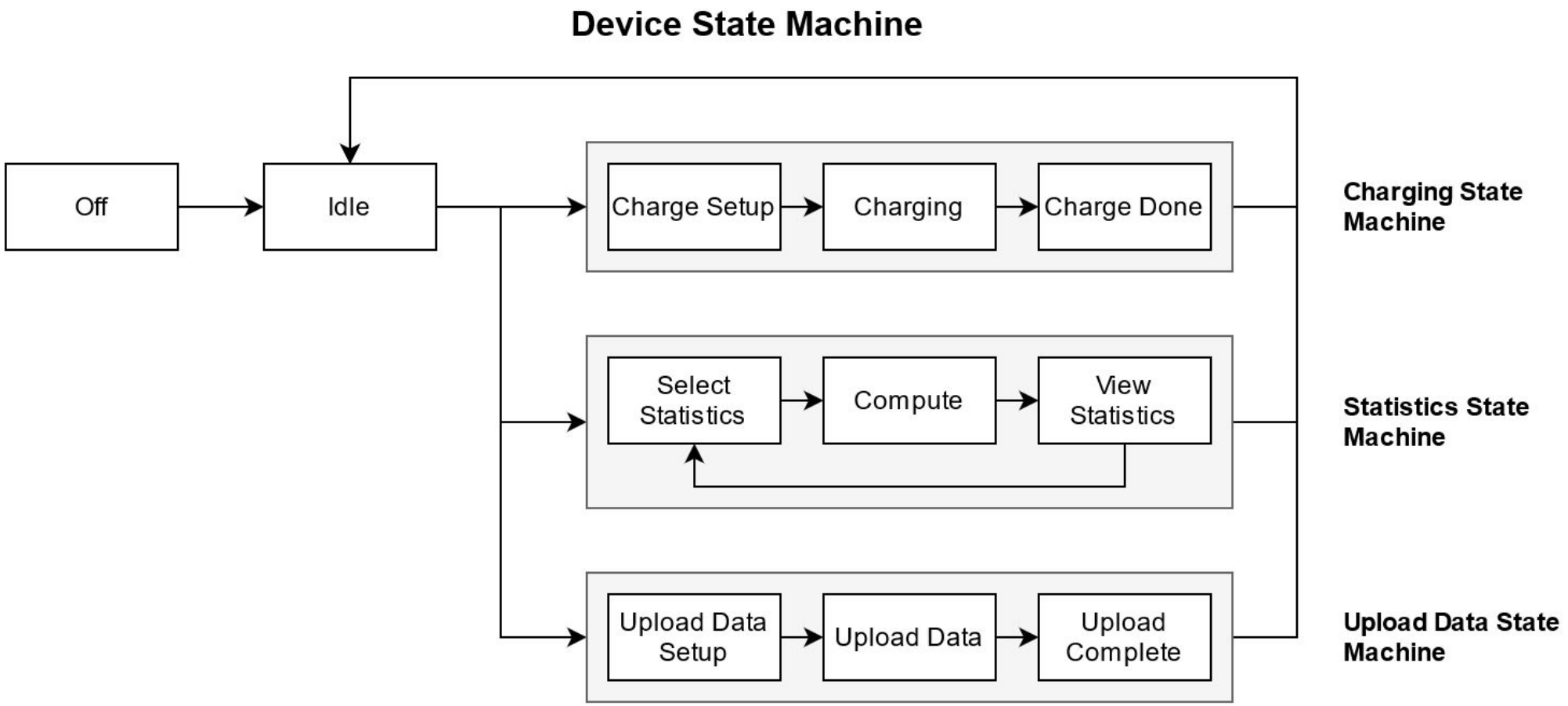
Concept and Component Selection

- Clamping mechanism chosen to secure battery terminals to the charger (discussed more later on)
- **Teensy 4.1 Microcontroller**
  - HyTech already uses the Teensy 4.1
  - Integrated SD card reader (used for data logging)
- **LTC6811 Battery Stack Monitor**
  - LTC6811-2 already implemented by HyTech
  - Used for cell voltage measurement and cell balancing
- **Power Supply** (BK Precision 9104)
  - HyTech already has this power supply unit
- Thermistors for measuring individual cell temperatures
- Keypad and LCD screen for user input/output

Embedded System Design - Updates

- Current parts we have / are prototyping with
  - LCD screen
  - Teesny
- Parts arriving soon (~Friday)
  - Current sensor
  - Thermistor
  - Keypad
- Working on writing and testing code for state machine and LCD screen (needs to be pushed to repo)
- A little behind schedule but the pace we are right now will line up with when the PCBs arrive

Embedded System Design - State Machine



Electrical and PCB Design - Cell Charger BMS

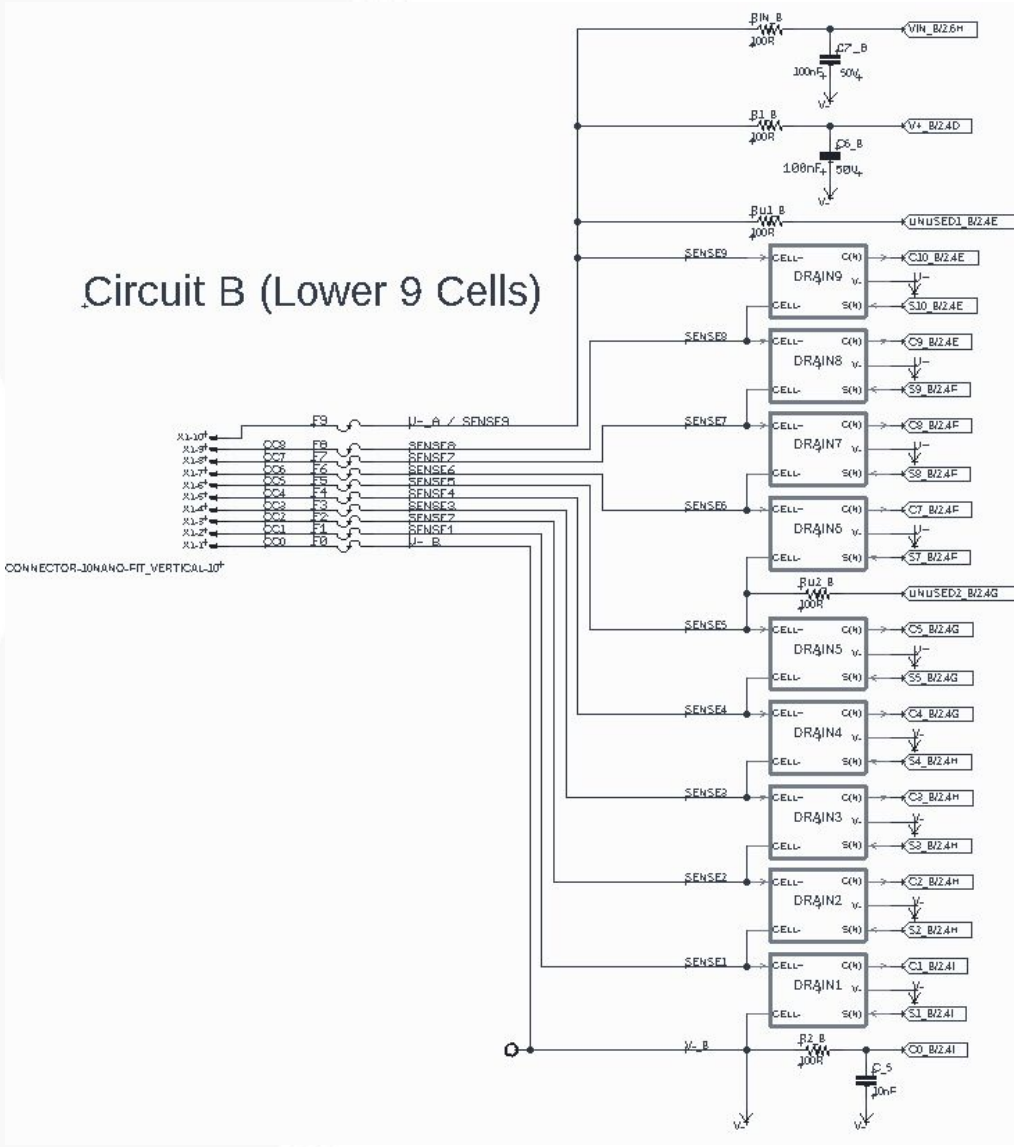
Purpose of Cell Charger BMS Board:

- Includes:
  - LTC6811-2 Multicell Battery Stack Monitor Chip (measures voltages)
  - Fuses
  - Battery connections
- Adapted from HyTech’s previously existing BMS circuit

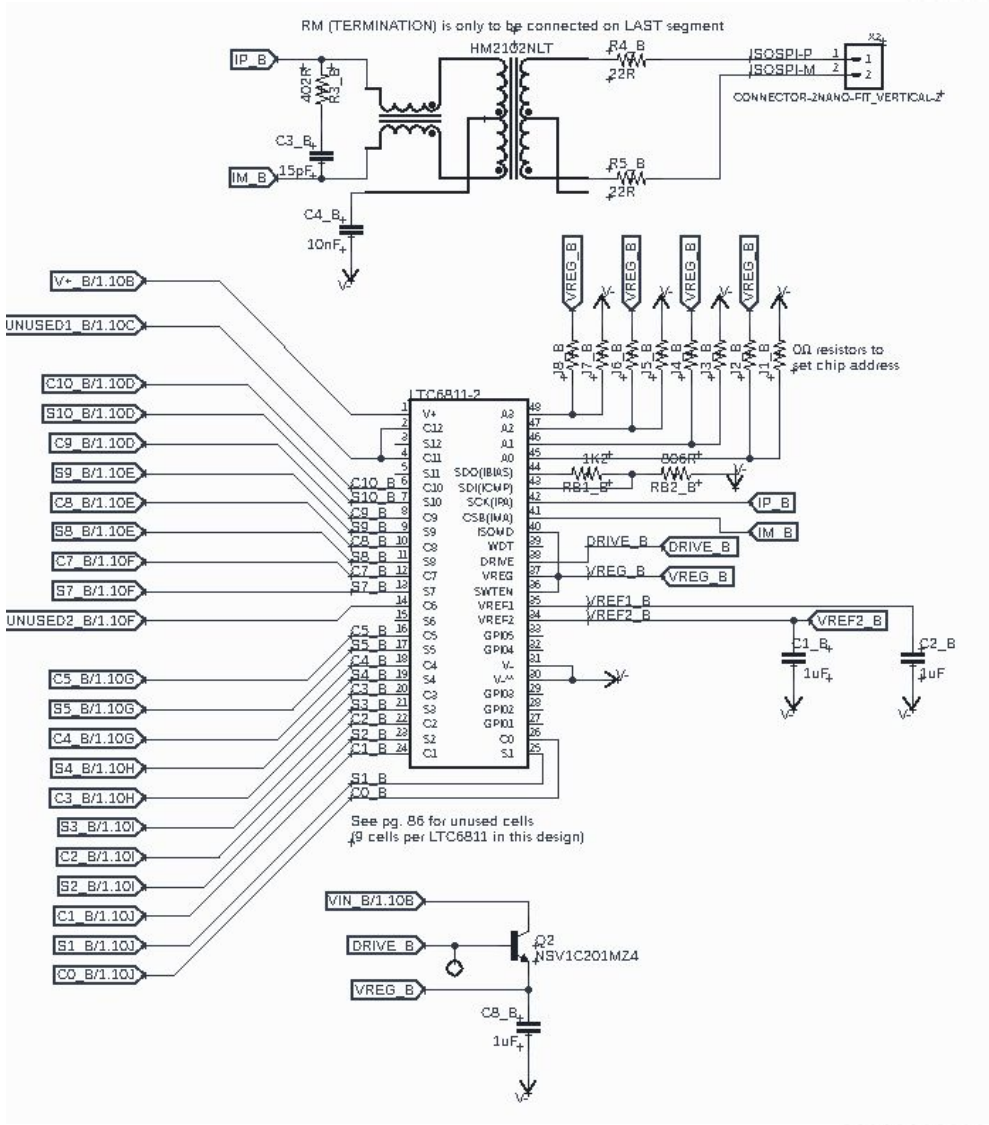
Electrical and PCB Design - Cell Charger BMS

Design Change	Justification/Reasoning
Include the appropriate number of battery cells	Our design specification only requires the charger to be equipped for 9 cells, whereas HyTech's previous BMS circuit was designed for 18 cells.
Remove thermistors from existing design	Temperatures now measured on separate controller board
Change the contact method of the board to the battery cells	Spring pad contacts swapped out for 10-pin connector

Electrical and PCB Design - Cell Charger BMS



Cell Connections, Drains, and Fuses



LTC 6811-2 Multicell Battery Stack Monitor Chip

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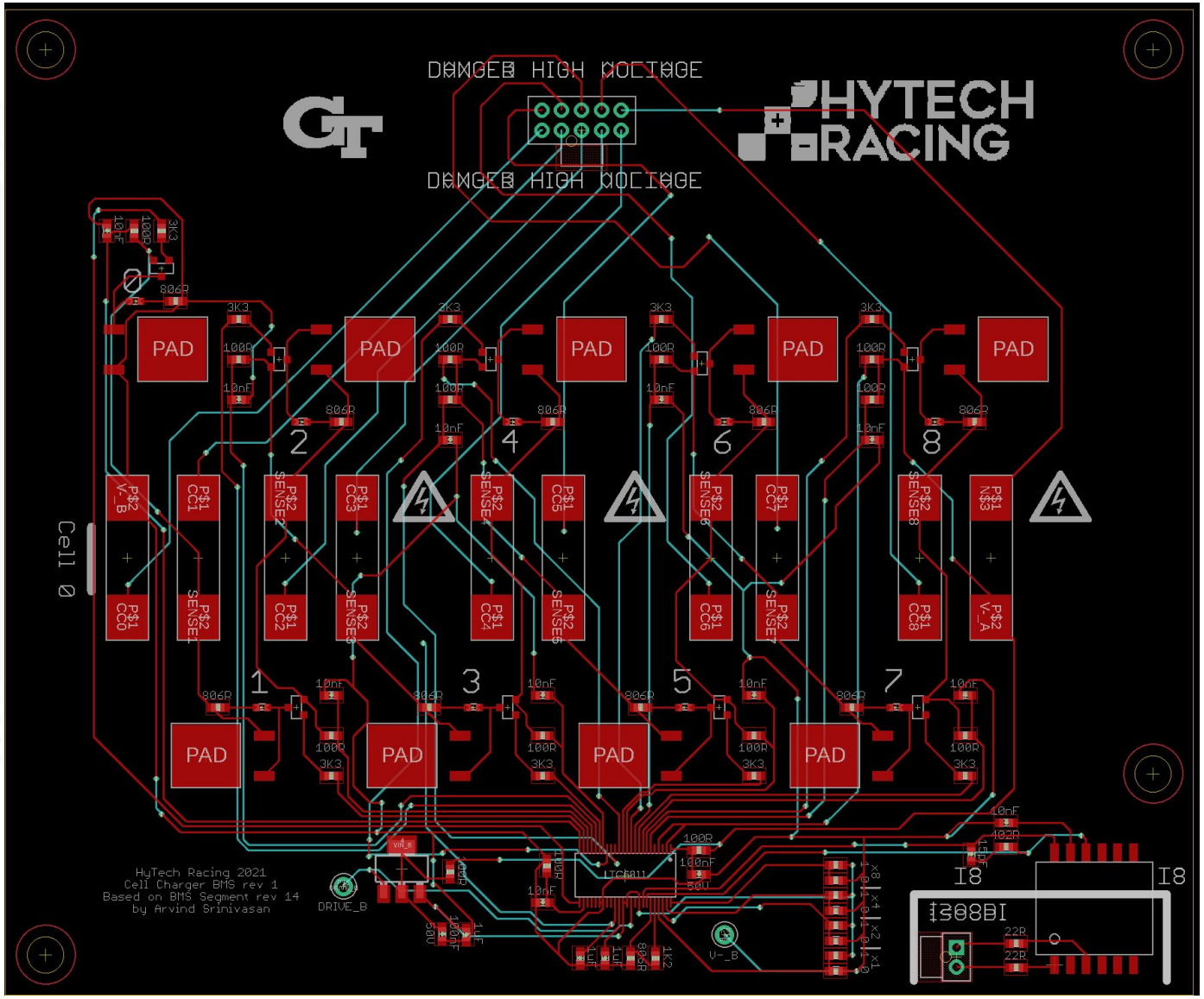
Electrical and PCB Design - Cell Charger BMS

10-pin connector

Fuses

Multicell Battery Stack Monitor Chip



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Electrical and PCB Design - Controller Board

Purpose of Controller Board:

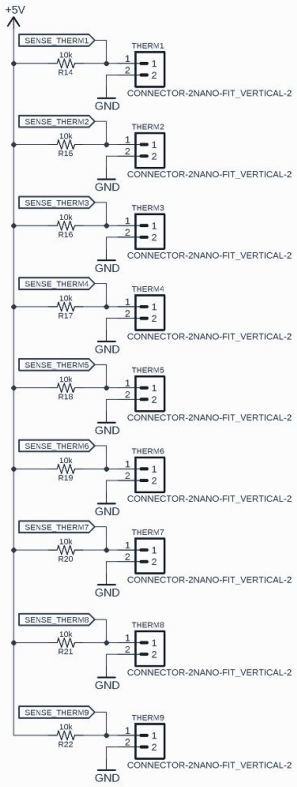
- Measures charging current
- Communicates with BMS via isoSPI
- Monitors cell temperatures
- Implements user interface with a keypad and a screen

Electrical and PCB Design - Controller Board

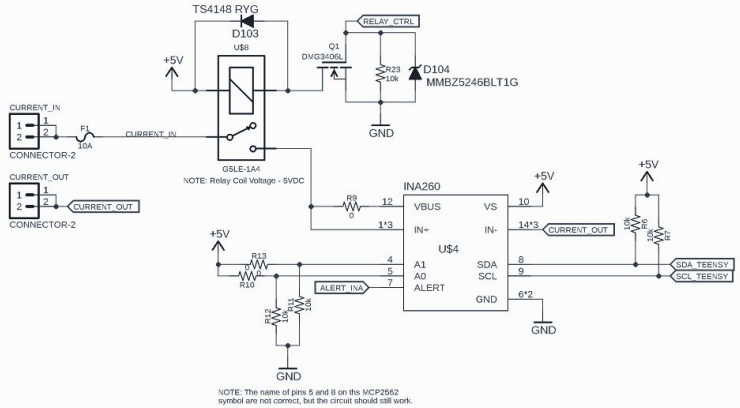
Feature	Implementation
Fusing	10A replaceable mini-blade fuse
Current switching	Omron G5LE-1A4 SPST Relay with 5VDC coil voltage
Current sensing	TI INA260 current sensor in TSSOP-16 package
Microcontroller	Teensy 4.1 microcontroller is compatible with Arduino toolchain, includes a powerful Cortex-M7 (600 MHz), integrated SD card slot, SPI, I2C, and CAN ports.
isoSPI communication	LTC6820 isolated communications interface with HM2102NLT transformer
CAN communication	MCP2551 CAN transceiver connected to the Teensy allows for use of programmable power supplies or future module additions.
User interface	3x4 Matrix keypad coupled with 240x320 TFT display
Cell temperature sensing	Nine 2-pin Molex Nano-fit connectors allow for use of 10 KOhm thermistors such as Vishay NTCALUG02A103F. The thermistors are connected in a voltage divider configuration.
Board power	The controller board is powered with a 12V power supply through a 2-pin Molex Mini-Fit Jr. connector. 12V is converted down to 5V using Murata OKI-78R-5 voltage regulator. The 3.3V rail is supplied by the Teensy 4.1 on-board regulator.

Electrical and PCB Design - Controller Board

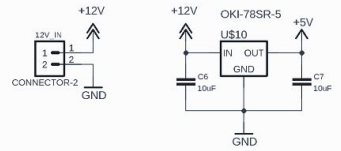
Thermistor connections



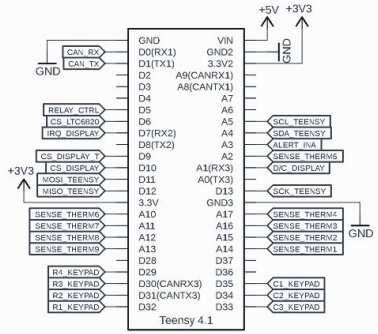
Current sensing and main relay



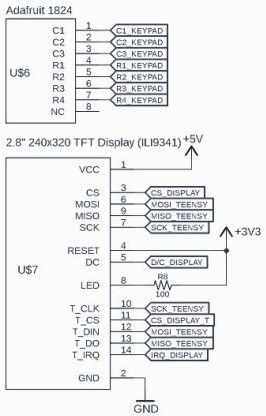
Board power



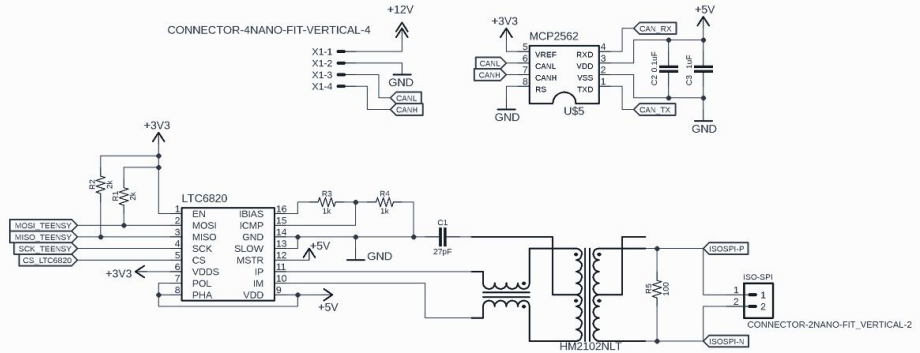
Microcontroller



User interface



isoSPI and CAN communications



Engineer: Leonid Pozdneev	Document Name: Cell Charger Controller rev1
HYTECH RACING	Description: Shematic for HyTech Racing battery cell charger controller board.
	Date: 3/26/2021 8:00 PM | Sheet: 1/1

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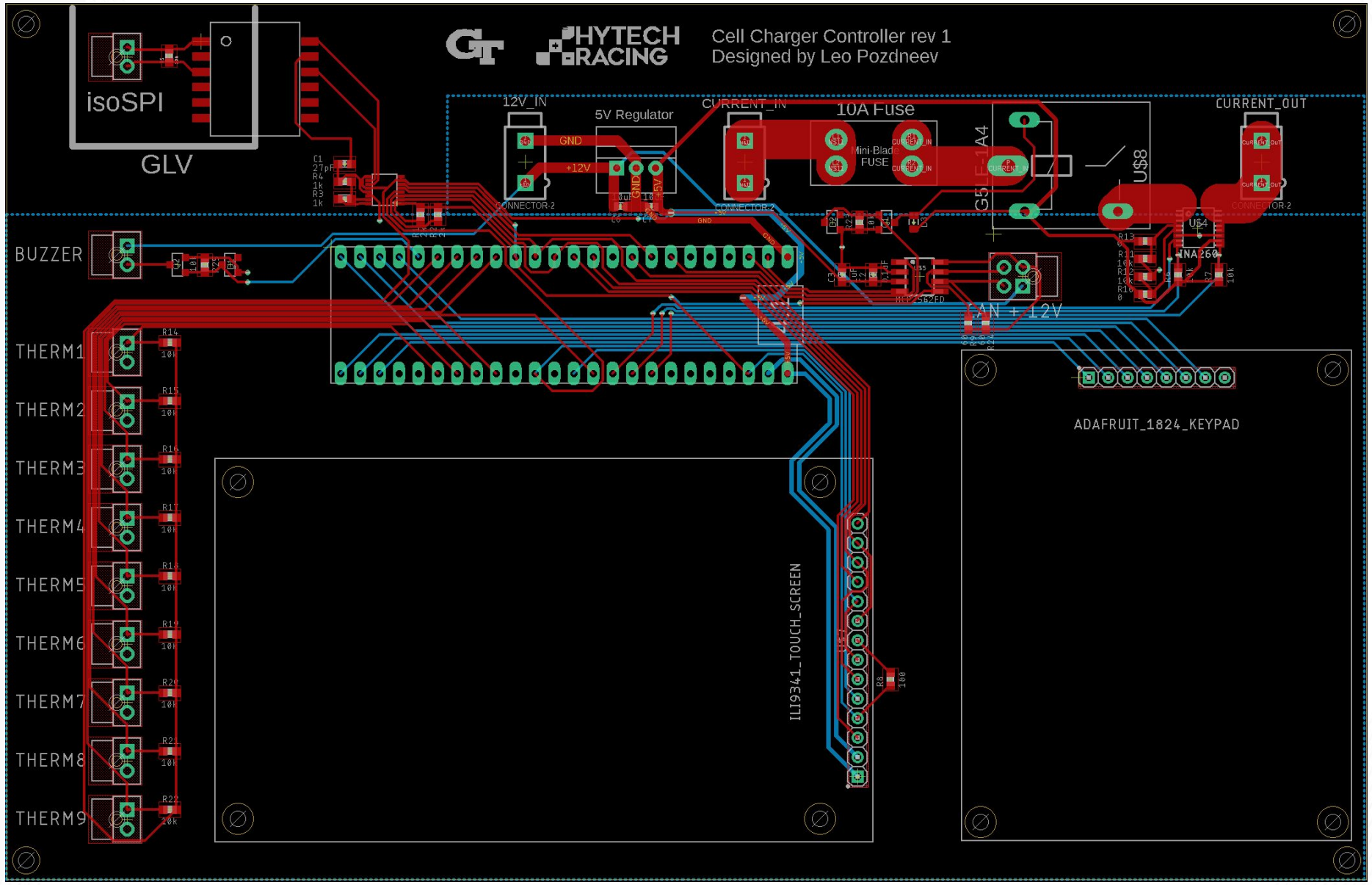
Electrical and PCB Design - Controller Board



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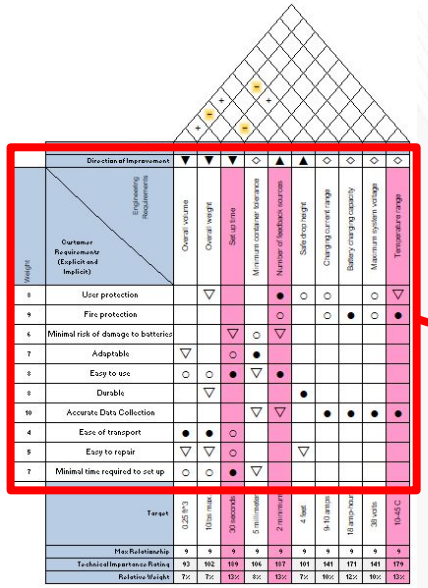
Mechanical Design (House of Quality-Correlation)



Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

	Column #	1	2	3	4	5	6	7	8	9	10
	Direction of Improvement	▼	▼	▼	◇	▲	▲	◇	◇	◇	◇
Weight	Customer Requirements (Explicit and Implicit) \ Engineering Requirements	Overall volume	Overall weight	Set up time	Minimum container tolerance	Number of feedback sources	Safe drop height	Charging current range	Battery charging capacity	Maximum system voltage	Temperature range
8	User protection		▽			●	○	○		○	▽
9	Fire protection					○		○	●	○	●
6	Minimal risk of damage to batteries			▽	○	▽					
7	Adaptable	▽		○	●						
8	Easy to use	○	○	●	▽	●					
8	Durable		▽				●				
10	Accurate Data Collection				▽	▽		●	●	●	●
4	Ease of transport	●	●	○							
5	Easy to repair	▽	▽	○			▽				
7	Minimal time required to set up	○	○	●	▽						

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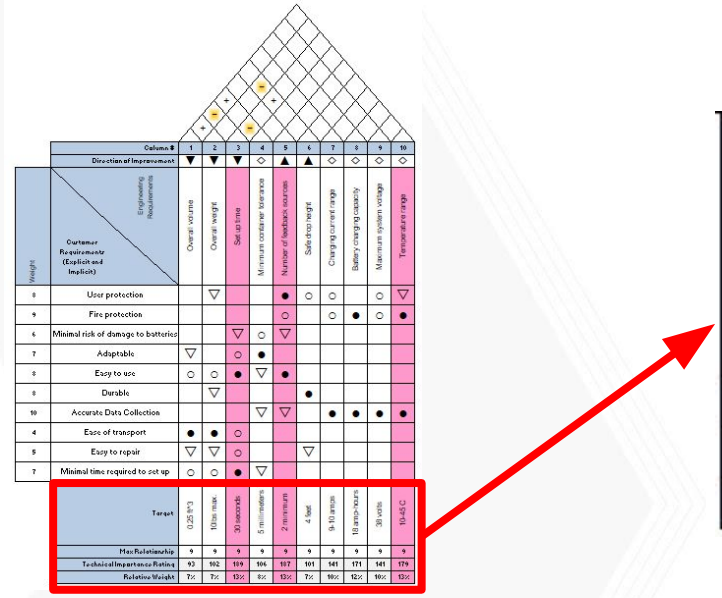
Mechanical Design (House of Quality-Targets)



Target	0.25 ft^3	10lbs max.	30 seconds	5 millimeters	2 minimum	4 feet	9-10 amps	18 amp-hours	38 volts	10-45 C
Max Relationship	9	9	9	9	9	9	9	9	9	9
Technical Importance Rating	93	102	189	106	187	101	141	171	141	179
Relative Weight	7%	7%	13%	8%	13%	7%	10%	12%	10%	13%

- Results indicate the engineering requirements with the highest priority is set-up time, number of feedback sources, and the cell temperature range.
- Last four requirements are highly prioritized as they are specified ranges by HyTech Racing

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Mechanical Design (Spec Sheet)

Specification	Want(W) / Demand(D)	Requirement	Responsibility	Validation
Physical Device				
Overall Volume	W	< 0.25 ft^3	Mechanical	CAD
Overall Weight	W	<= 10 lbs	Mechanical	Sum of overall material and weighing of assembled device
Safe Drop Height	D	4 ft (average table height)	Mechanical	Impact testing of dummy components (FEA if there is time)
Storage Capacity	D	9 batteries	Mechanical	CAD
Container Tolerances	D	> 5 mm	Mechanical	CAD
Battery/Electrical Characteristics				
Electrical Input	D	Wall outlet	Electrical	Power supply specifications
Charging Current Range	D	9-10 A	Electrical	BMS design
Battery Charging Capacity	D	18 A h	Electrical	BMS design
Battery Operating Temperature	D	10-45C	ME and EE	Cell temperature sensors and insulative material
Maximum System Voltage	D	38 V	Electrical	BMS design
Usability				
Set Up Time	W	< 30 s	Mechanical	Timed trial runs of setup
Number of Feedback Sources	D	at least 2 (one audio and one visual)	Electrical	Combination of user interface and sensor feedback

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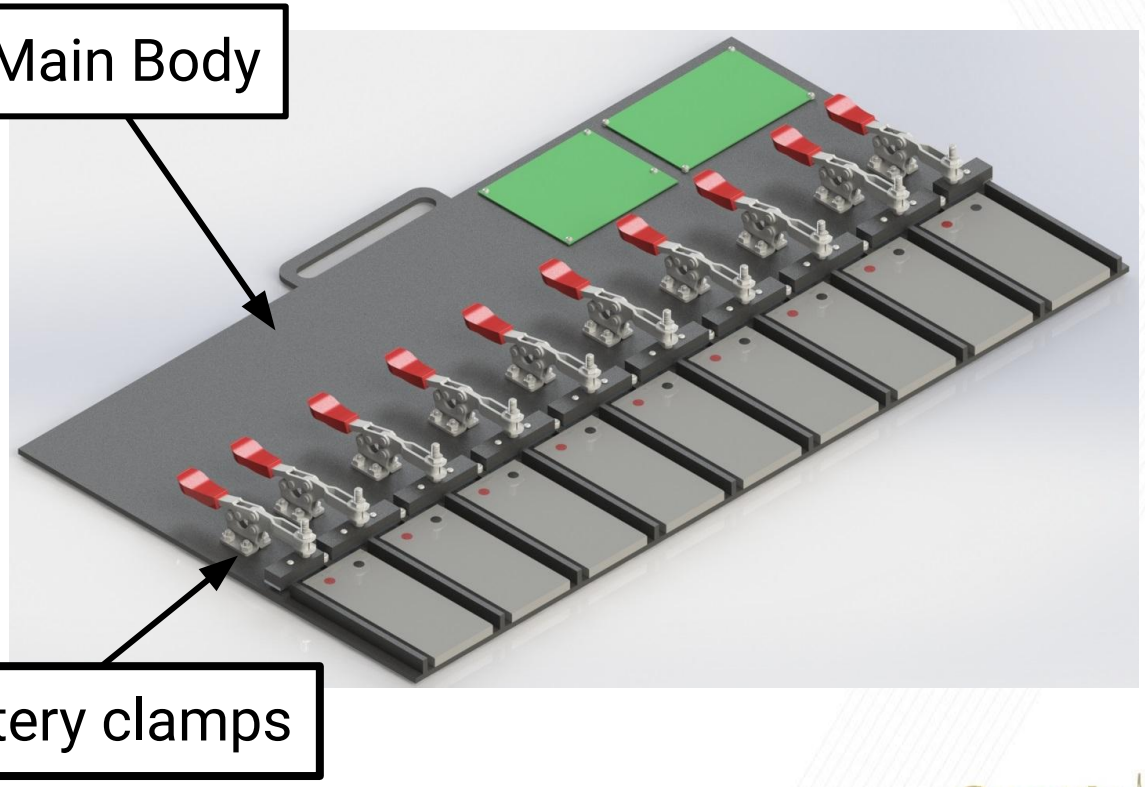
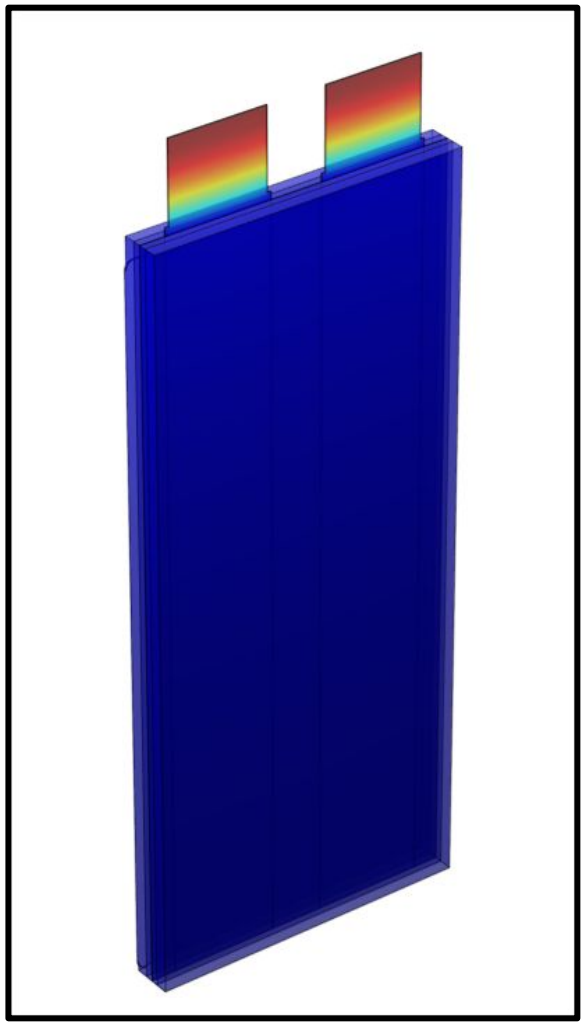
Mechanical Design (CAD)

- Overall objective: Ensure device is capable of interfacing with batteries while accounting for potential variance in battery dimensions
- Composed of three main regions:
  - Main body: mounting board for electronics and each of the other sub-components
  - Battery clamps: toggle-able lever clamps with metal contact pieces for interfacing with cell tabs
  - Electronics mounting: contains mounting points for BMS and controller board

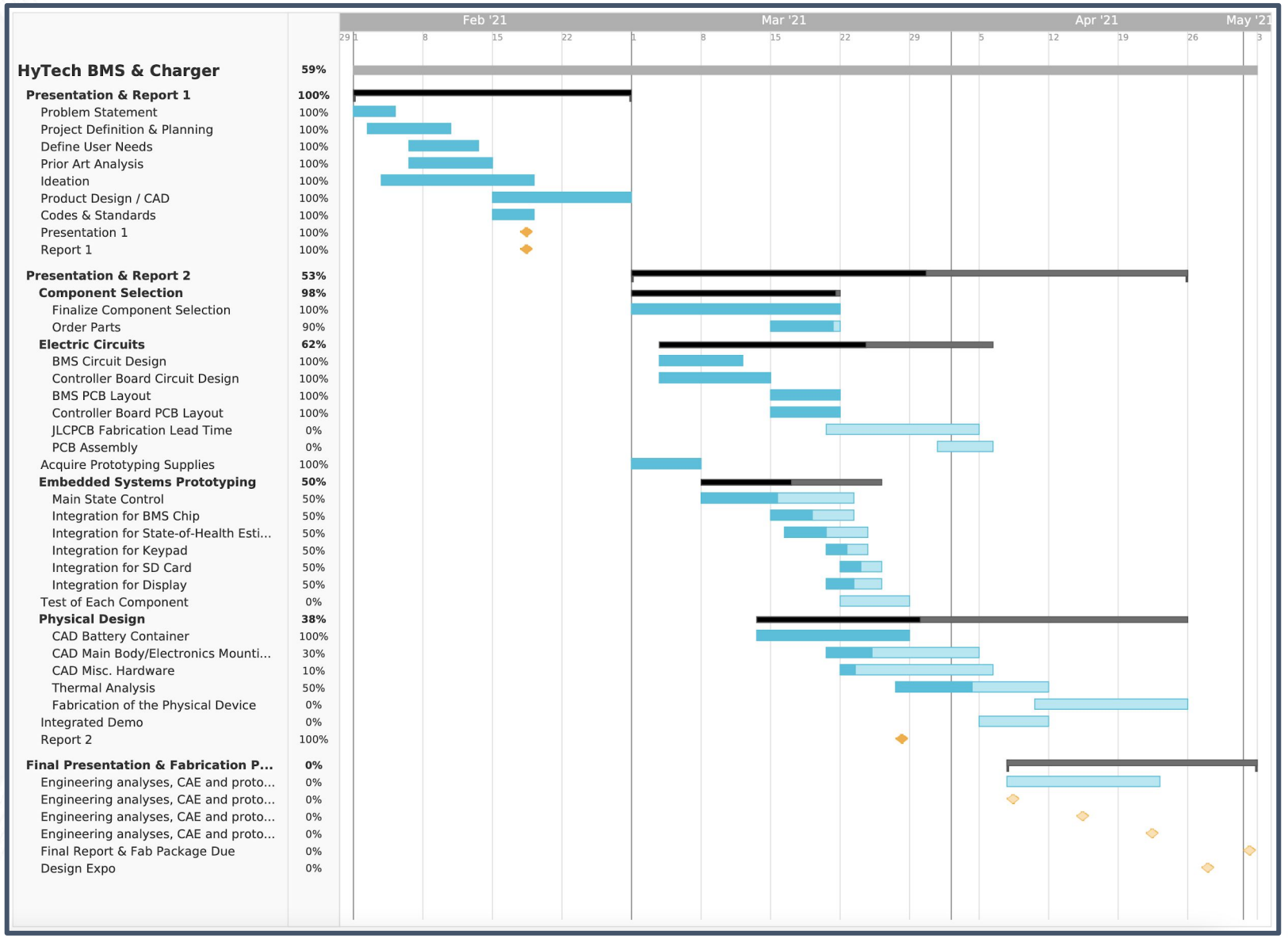


Thermal Analysis

- Temperature rise of the battery cells should not pose risk to the performance of container
- Material used mostly accounts for concerns
- Attempted to create simulation that models electrochemistry and heat transfer



Schedule (Gantt Chart)



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Future Work

- Finish prototyping embedded systems
- Solder PCBs
- Integrate electrical components
- Detailed CAD
- Fabricate the physical structure
- Assemble and test the final product

Introduction / Background

- HyTech racing is interested in a custom battery management system, a data recording system, and a user interface for charging Lithium Cobalt Oxide pouch battery cells
- The end goal is efficient battery charging and health estimation

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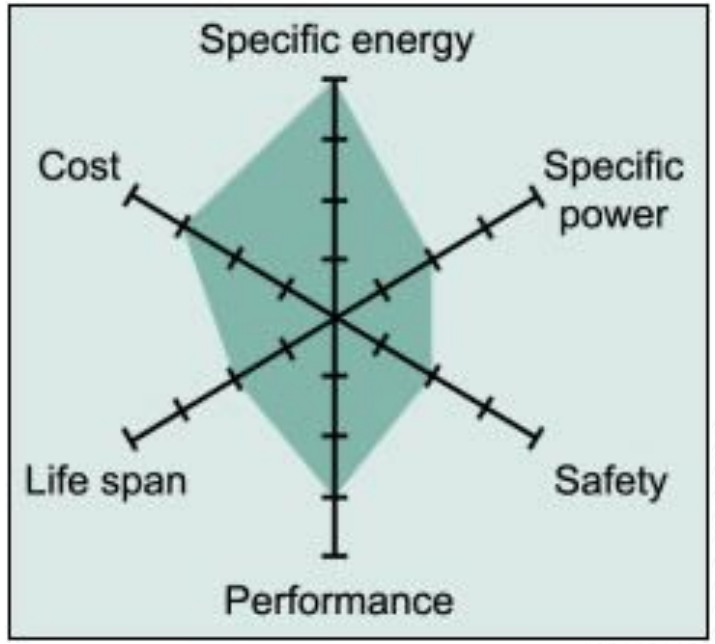
- Lithium Cobalt Oxide batteries are used because of their high specific energy but are limited by short lifespans



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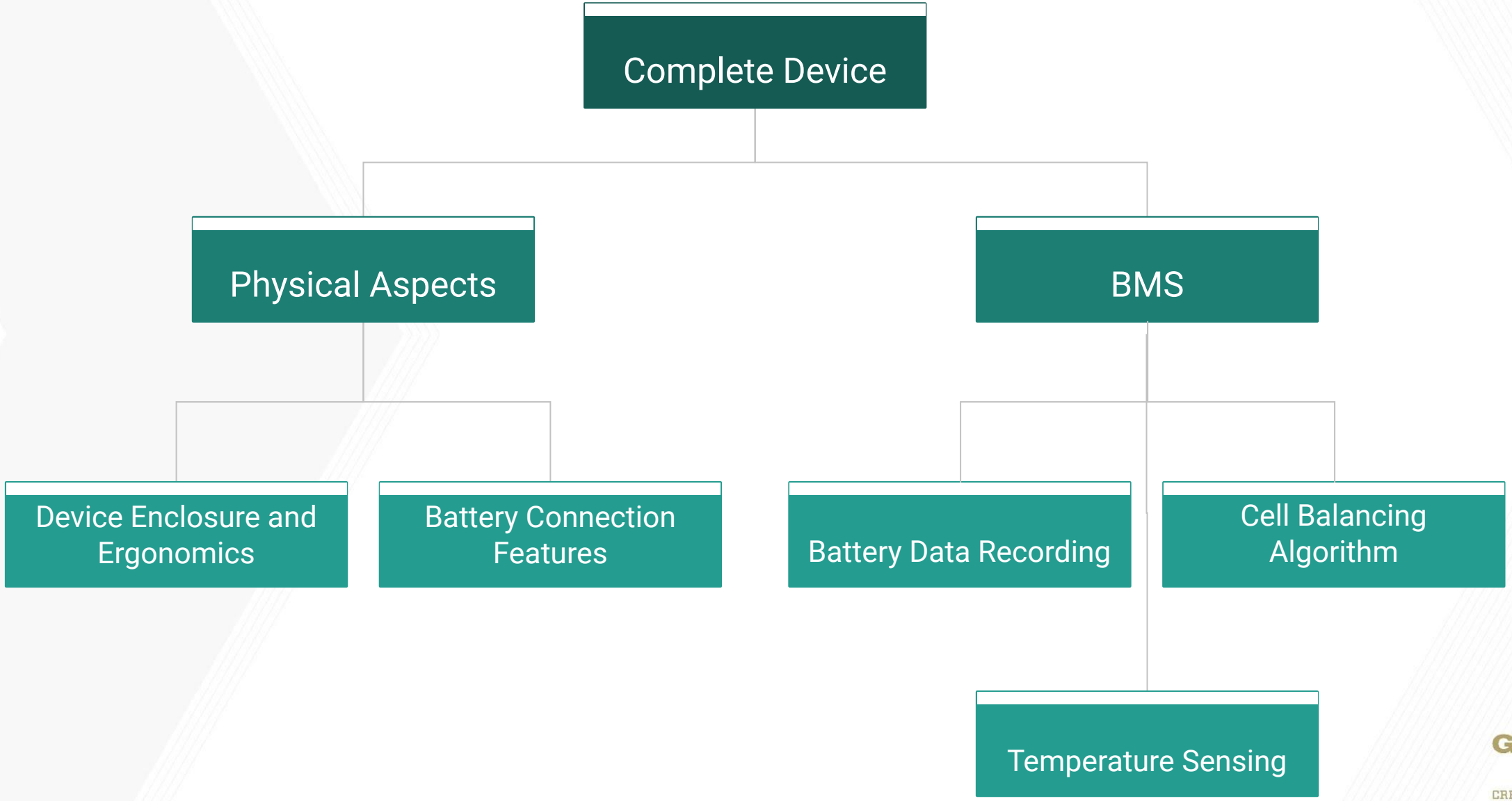
Categories of Prior Art



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Existing Products / Prior Art / Applicable Patents

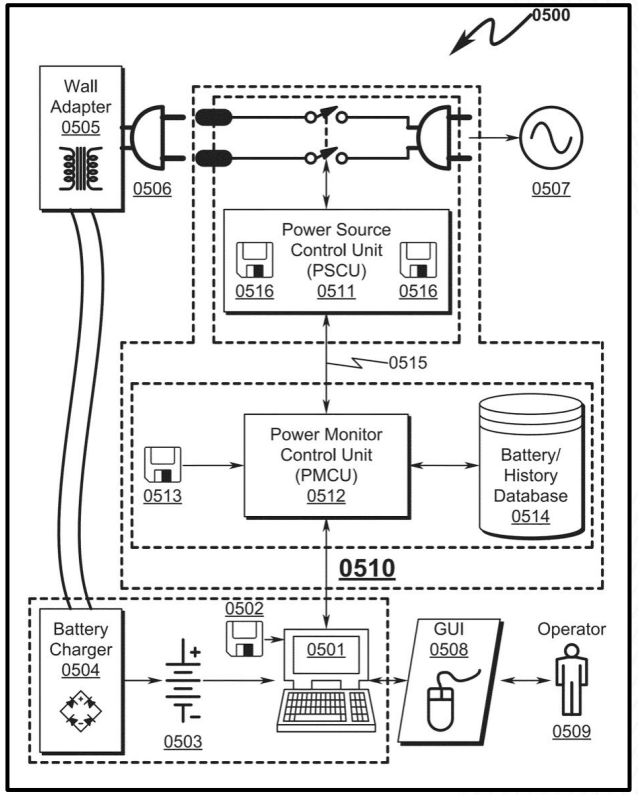
HyTech Racing:

- Already have a pre-existing BMS design utilizes LTC6804 Multicell Battery Monitors with voltage logging using a Tensey 3.2 microcontoller
- This design has already been thoroughly tested
- More functionality is still to desired (logging storage, temperature monitoring, mechanical design)

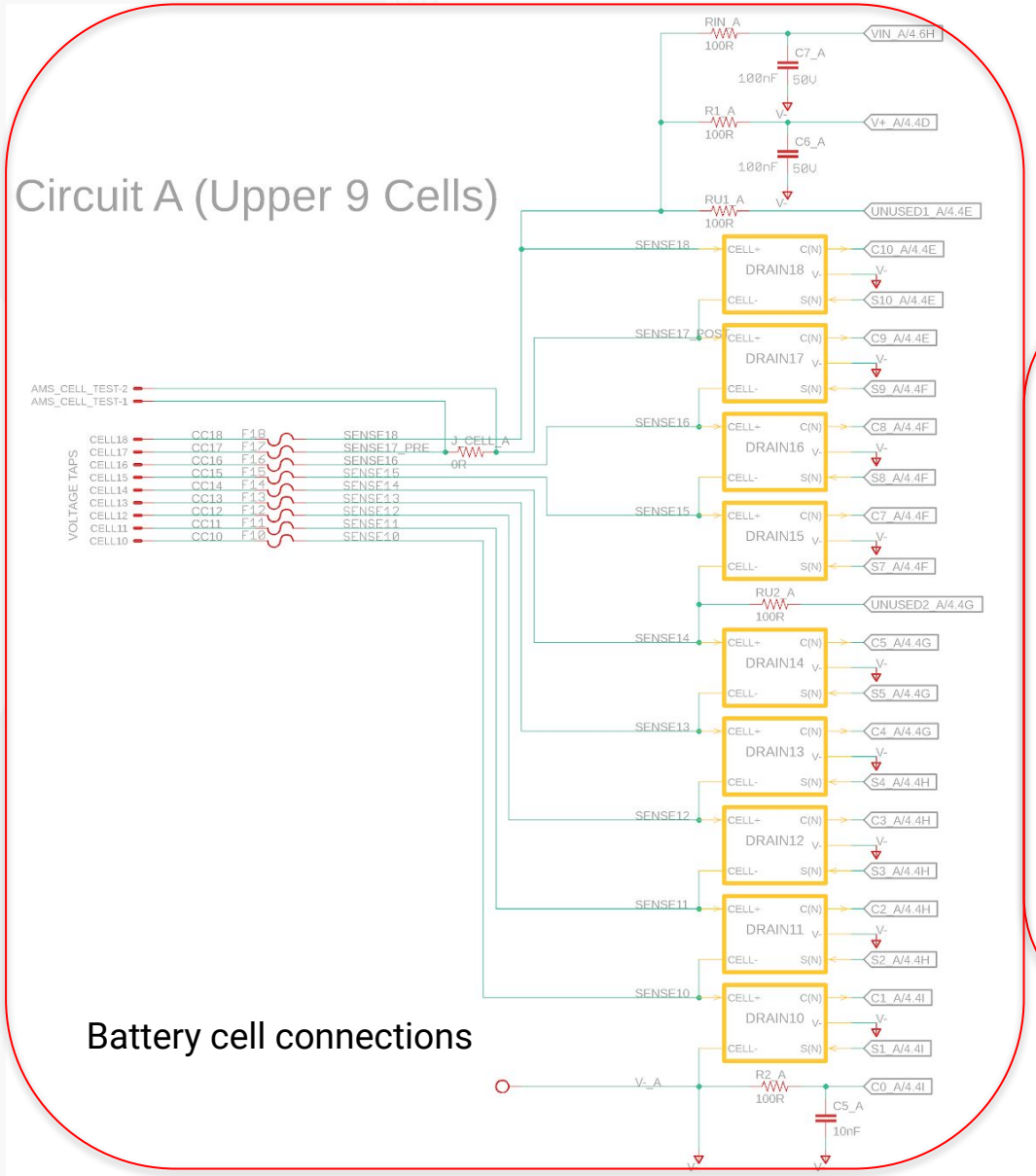
Orion BMS

- Was used previously by HyTech
- Has many great features and is field programmable
- Orion BMS in the end was not a desirable solution for HyTech
- Large size and weight
- A lot of features that were not needed

Patents

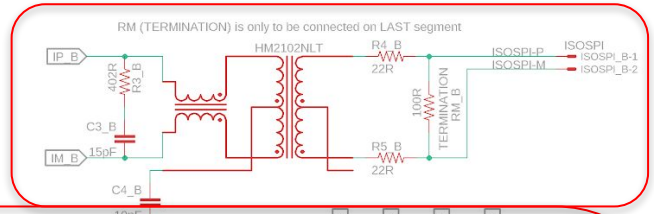


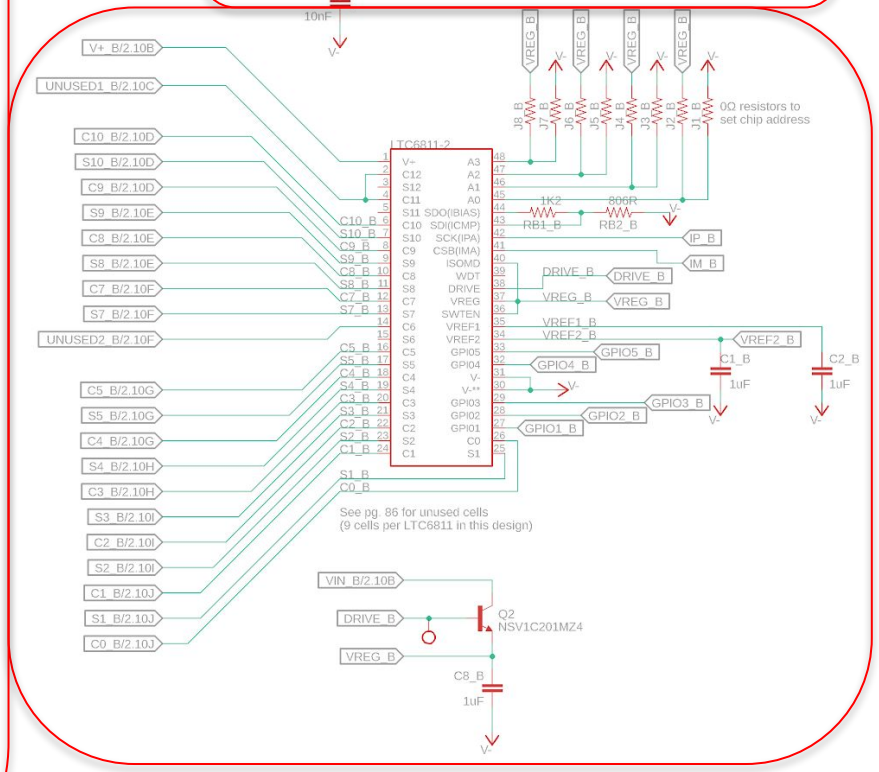
Prior Art: HyTech BMS Design



Battery cell connections

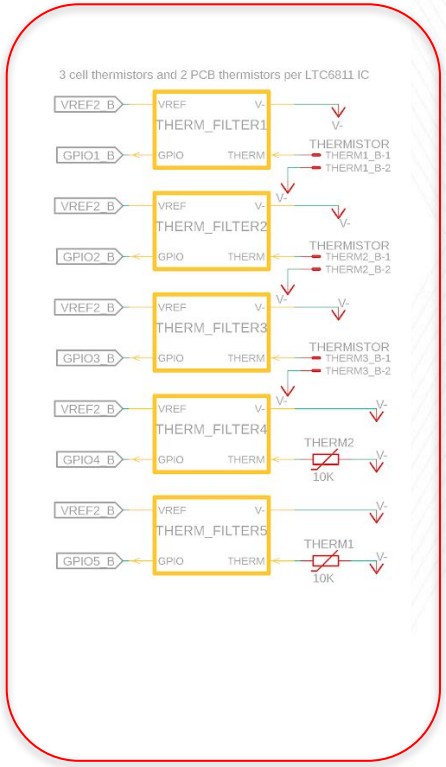
isoSPI transformer





BMS chip (LTC6811) connections

Thermistor connections



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Prior Art: HyTech BMS Design

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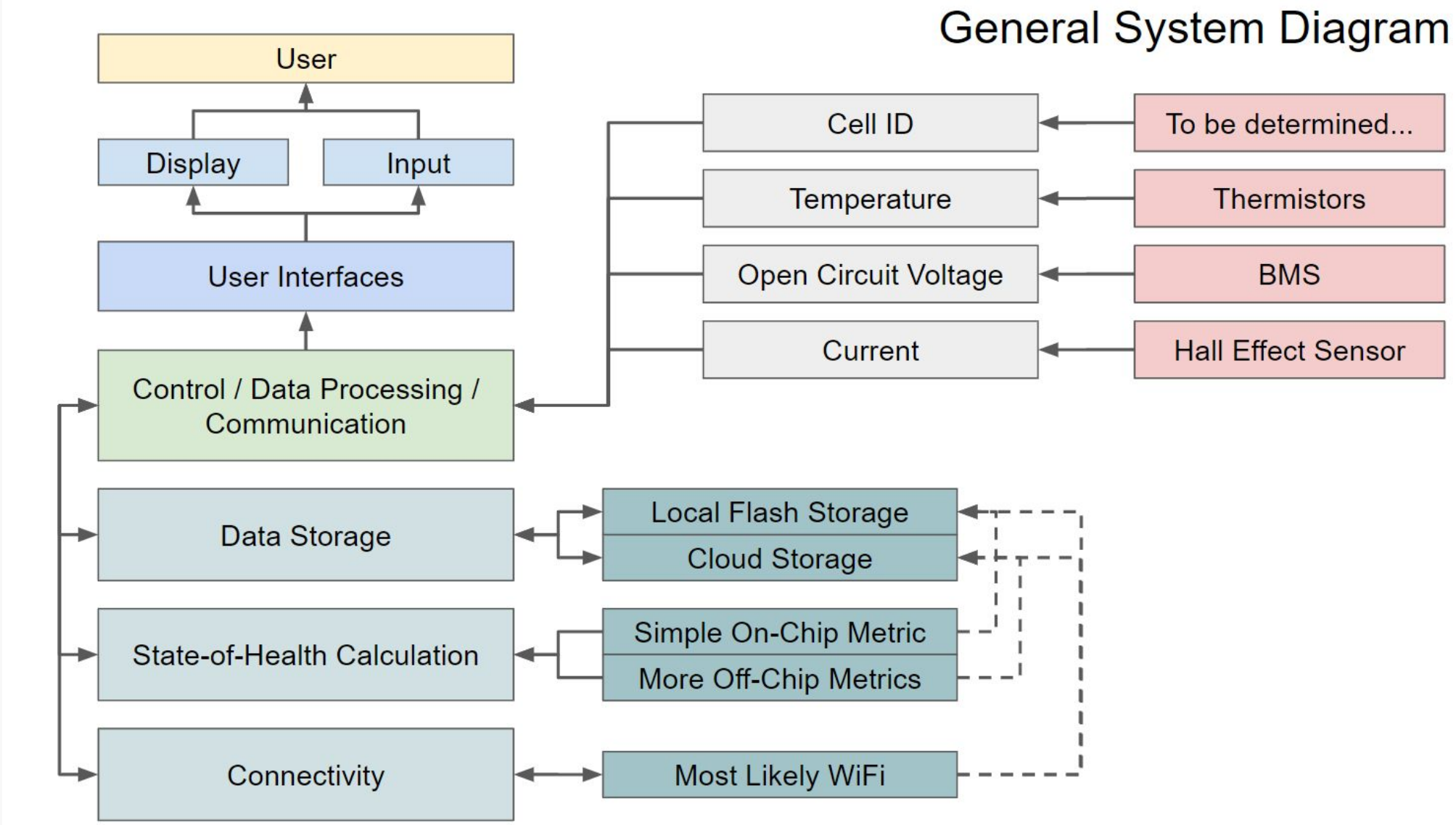
Customer Requirements / Design Specifications

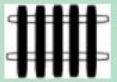
- **Function**
  - Charge 9 LiCoO2 Battery Cells with nominal capacity of 18Ah
  - Record and store current and voltage data for every cell
  - Must be compatible with Melasta SLPBA580183 battery cells
- **Electrical Characteristics**
  - Charging current of 9A (0.5C)
  - Must have a cell balancing algorithm
  - Powered from a regular electrical wall outlet
- **Safety**
  - Must be easy and safe to use

Design Concept Ideation: General System Diagram



Design Concept Ideation

Morphological Chart:

	Solutions			
Sub-Functions	1	2	3	4
Multi-Cell(9) Charging	 Velcro Straps/Net	 Elastic Band	 2-Part Slots	 Single-Part Slots (loose tolerances)
record voltage and current data	 Cloud		 flash storage	
Power Supply	 Off the shelf		 Original Design	
Temperature Management	 heat sink	 fan	 liquid cooling	 radiator
User Friendly Interface	 computer connection	 LCD	 Touch Screen	
Cell Tracking ID	 NFC	 RFID	 barcode	 QR

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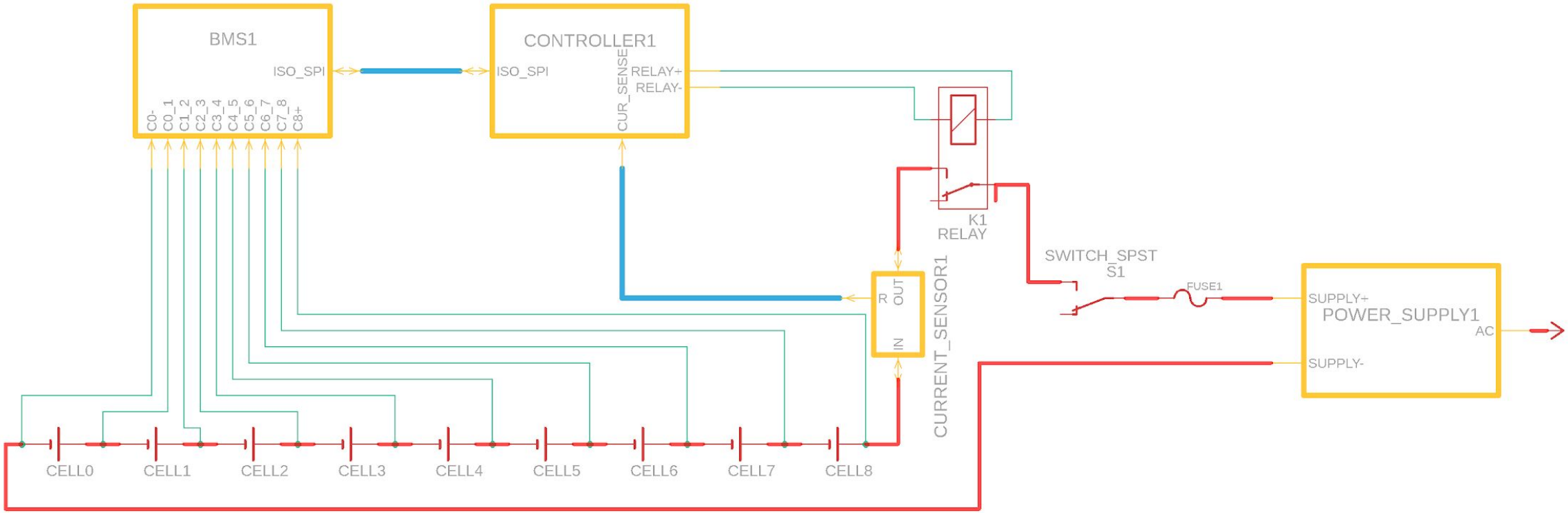
Design Concept Ideation: Electrical System Diagram



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