The LiPo Crew
Dataforth Battery Charger

Team Design Document

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Jonathan Ciulla - jc3598@nau.edu
Luis Camargo - lc833@nau.edu
Jace Jenkins - jcj248@nau.edu
Elray Santiago - eks226@nau.edu

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1. Introduction

Dataforth Corporation, a world leader in designing, manufacturing, and marketing analog signal conditioning, data acquisition, and data communication product solutions and was established in 1984. Their products provide industry-leading protection from the degrading effects associated with signal noise experienced mainly in industrial applications. Their analog signal conditioners feature enhanced modularity for ease of use with a variety of; current, position, strain, temperature, and voltage measuring devices. With the ever-increasing need for sensor density in the automotive, commercial, and industrial applications, the inherent demand for accuracy is met by their 8B series isolated analog signal conditioners that have an accuracy rating ±0.05% to ±0.50%. Dataforth is looking to showcase its product applications as a response to the increasing demands of the industry.

Mr. John Lehman, Vice President of Product Development for Dataforth Corporation, has reached out to the LiPo Crew to develop a safe and efficient multi-cell LiPo battery charger with support for user-defined fault conditions. The battery charger is centered around a Texas Instruments MSP430 microcontroller, which will be responsible for varying charging algorithms, given the battery chemistry. The MSP430 family of microcontrollers utilizes a 16-Bit Reduced Instruction Set Computer (RISC) architecture which provides an efficient, robust, and versatile platform capable of driving a multitude of sensors while simultaneously performing routine computational functions. These features, coupled with Dataforth's signal conditioning hardware, will prove to be the most effective route while preserving the signal integrity of the sensors.

Intending to develop an exemplary product considering cost, efficiency, and size, it is paramount that the LiPo Crew design incorporates Dataforth products to showcase their specialization and scalability in data acquisition and signal conditioning hardware. The LiPo Crew battery charger will accentuate the features stated above while also displaying the versatility of their signal conditioners in a low energy application (LEA). Our design focuses on the manufacturability along with scalability for small LEAs to large high energy applications (HEA). Proper safety measures will be incorporated to include, but not limited to; fuses and voltage regulators to ensure modularity is rendered in the safest possible circuit design.

It is our goal to design, prototype, and manufacture a product that embodies the Dataforth mission in setting new standards of product quality, performance, and customer service.
The LiPo Crew has completed the following steps: identifying the problem, defined working criteria, goals conducted market research and analyzed subsystem prototypes. The qualitative and quantitative analysis conducted thus far has produced potential solutions that will be further explored in the coming weeks. The team's determination and current momentum will continue to propel the design process through extensive model development and stringent evaluation over the winter break.

2. Previous Work

The LiPo Crew conducted individual preliminary research to better understand both the available technologies and approaches others had taken towards similar goals as our own. Through this research, our team acquired valuable information and possible processes we could later employ in our design. The subject matter outlined in this section covers battery management systems and their functionality along with various safety features. The analysis of prior work relevant to our design aided in our team's understanding of how to formulate a streamlined approach toward our BMS decision making process.

The first article of interest is [9] where the author had designed a battery charger for a Photovoltaic (PV) system that utilized both the MSP430F1232 microcontroller and a MAX3485 chip for communication between the various circuit elements. The motivation behind this project was how traditional PV systems charge battery cells directly and lack the circuitry for both over current and short-circuit protection. The lack of a telemetry subsystem in a PV system negatively impacts the efficiency of the solar panels. Also, a battery charging system without an overvoltage and discharge protection function is unsafe for the user and environment alike as well as degrading the battery. The MSP430F1232 was used due to its ultra-low-power mixed-signal processing capabilities as stated in [9]. The MSP430F1232 hosts eight channels for a 10-bit analog to digital converter with an integrated reference voltage making it an ideal choice for up to an eight-cell battery. The over-current and short-circuit protection aspect of their project was achieved through triggering interrupts of the MSP430 to start the protection circuitry. The system response time according to [9] was 6µS using the interrupt approach. For the charge and discharge protection, the article referenced the use of comparing the charge of the battery versus the reference voltage preset value via a comparator. The MSP430 would determine the appropriate action according to the voltage reading. These two approaches proved to be suitable for their application and aid in the extension of the battery's lifespan through implementing proactive circuitry and interrupts.

The next article studied the balancing system of a BMS that is broken up into three separate levels to combat the wastefulness attributed to the contemporary approach of balancing circuitry. The first level of the hierarchical BMS as stated in [10] constitutes the circuitry connected to each cell of the battery. This circuitry measures the temperature and voltage of each cell while transmitting that data to the second level. The second level is the module controllers which process the incoming data from the individual cells and relay this information to the pack management unit [10]. The pack management unit is the third level that is responsible for promoting the pack management unit to execute certain actions in the case of various triggers.

The findings in [10] were that with the implementation of solid-state relays, their overall power consumption decreased substantially compared to that of traditional coil relays. With a decrease in overall power consumption, the switches negatively impacted the dimensions of the project making it an unlikely candidate for smaller applications. Another aspect in [10], discusses how they used their active balancing to reduce the loss of power when compared to passive balancing. Another factor brought to light in [10] is the need for redundancy to allow for undisrupted data flow from the sensors, further ensuring the accuracy of the measurements received. The three-tier hierarchical approach displayed its robustness and efficiency over the traditional cell balancing approaches making it a viable option for our project.

The information obtained in reading the research done on dynamic equalization for lithium battery management systems by students at the Changchun Institute of Technology in China has proven crucial to the team's understanding of the potential efficiency gains associated with incorporating a stand-alone BMS in our design. The focus and goal of engineers working on a battery management system (BMS) are to find out how to extend the life and capacity of batteries by utilizing a more efficient charging system. The authors listed four distinct requirements for a lithium BMS to be functionally efficient. The requirements are battery state of charge (SOC) estimation, real-time dynamic monitoring, the balance of the monomer in the battery pack, and battery fault protection. The SOC estimation, real-time dynamic monitoring, and battery fault protection are necessary to prevent overcharge and over-discharge, while the balance of the monomer in the battery pack is important for achieving reliable battery management [25]. They also provided a general diagram for a dynamic equalization BMS that contains the main control module along with an equalization module for each battery pack that uses a controller area network (CAN) bus for communication [25]. The authors argue that this type of BMS can be used to properly manage the battery monomer and increase the charge power and battery life of LiPo batteries. Two experiments, one charging with equalization and one without, were conducted and the results concluded that equalization did have its advantages [25]. Verifying their argument, they were able to raise the monomer voltage with equalization and decrease the charging time and minimize charging current [25].

A potential manufacturer for our BMS chip is Microchip, a globally recognized company that produces and sells a variety of products for any engineering project. Through their website under the link entitled "Battery Charge Management and Controllers [19]," several documents can be found on various chips that perform well under different circumstances per battery management system. Also, there is a long list of documents that provide data sheets on different battery management systems and their configuration, process, and results. One of the particularly interesting chips was the MCP73812 Single Cell, Li-ion/Li-Polymer charge Management Controller [19]. For a cheap price of only, $0.39 this chip includes thermal regulation, a 4.2V regulated voltage output, a +/1% voltage regulation accuracy, and a resistor programmable charge current that can go up to 500mA. Furthermore, this chip also has reverse discharge protection which is useful in case of any critical errors that may harm the users in the charger that are configured wrong [19]. Although this chip is only limited to a 1S LiPo integration we could potentially scale up the process to incorporate a 6S LiPo or use this chip as a standard when searching for a chip(s) that can give our team better performance for less [19].

As our team continued research, it became apparent that the issue of logging and tracking each cell of a battery pack could pose to be a hindrance in our use of a BMS chip. A requirement of design states that we must be able to charge a minimum of a six-cells LiPo battery. This complicated our team's initial design because it required the battery management system to keep track of individual battery temperatures, voltage, current, while also balancing the cells and maintain knowledge of which stage they are in[2]. No two things are the same, and when it comes to charging these high energy batteries, minuscule differences in maximum voltage can be the difference between a safe charge and catastrophic failure. When multiple cell LiPo Batteries are used, they are not used at the same rate, for example, one standard that applies to all LiPo batteries is that each cell provides a 4.2V output. That is not always the case, they vary by minuscule voltages +-0.05 but these variations could have disastrous effects if not taken care of appropriately. The BMS aims to consider those variations to charge multi-cell batteries at the same time. The way this is achieved is with battery balancing techniques that can keep track of the rate at which each cell is charged and cut off at providing overvoltage and under-voltage protection.

The following research paper titled "Search for Optimal Pulse Charging Parameters for Li-Ion Polymer Batteries Using Taguchi Orthogonal Arrays [17]," used a different approach in terms of managing overall system stability and safety. Following pulse charging, which "is an effective technique to decrease charge time and improve battery charge and energy efficiencies [17]," which is great for any type of battery especially when it comes to our everyday electronics including our smartphones, tablets, and laptops. However, without proper monitoring, fast charging can eventually damage the battery causing a parasitic effect of power consumption. Therefore, with the implementation of optimized parameters via the Taguchi OA method, regulation and higher efficiency become easier to manage [17]. The Taguchi OA is a method used to optimize the parameters for a series of control factors within the battery through means of a limited number of experiments to test the sensitivity of the outputs while also giving each parameter an equal chance to perform [17]. Integrating a pulse charging technique with Taguchi OA will allow for consistent charge capabilities to maintain the Li-ion, and therefore their LiPo, batteries efficiency, and lifespan.

Extending on the notion of improved battery power, capacitance, and life expectancy, battery management systems must be set up for varying battery chemistries. LiPo (Lithium

Polymer) Batteries are becoming increasingly popular and need precise management of the speed at which they are charged to maintain their life expectancy [3]. They are charged using the three-stage charger which divides the charging into three stages: the pre-charge, constant current, and constant voltage. The pre-charge stage is not so important but necessary to understand so that we know what the maximum current a battery can be efficiently charged at which is half C (Capacity)[3] and that is what the battery will initially charge at. The constant current stage does just that, regardless of the stage of charging the battery is in, it will remain at a constant current of half C. As the current increases in this stage, the voltage of the battery steadily increases until it reaches the threshold of the battery, usually about 4.1 or 4.2 volts[3]. Once the threshold voltage is reached it transitions into the third stage where it switches to constant voltage and the current starts to gradually decrease until the current reaches zero. Once the supply current reaches zero signifies the battery has reached maximum capacitance. A current sensor would then relay that a flag had been set, and trigger an interrupt to begin a trickle charge to the battery. This safety feature minimizes the irreversible effects of overcharging any type of battery.

The user's safety is of the utmost importance in our design given the sensitivity during the charging and discharging of the LiPo battery packs. This would entail the use of over/under current and voltage detection, along with a suite of other safety features programmed into the BMS. This reflects directly in our emphasis on different variations and features employed by modern BMS chips. In completing our preliminary research, our team has identified essential features required for a design of such magnitude. This knowledge will guide our design synthesis and govern circuit topology ensuring a safe and reliable product.

3. Prototypes

The LiPo Crew conducted four individual prototypes focused on the risk reduction of the overall project. The prototypes delved into the following subfunctions: LCD interface and fault detection assigned to Elray Santiago, cell disconnect and state of charge indicator assigned to Jonathan Ciulla, battery cell temperature readings assigned to Jace Jenkins, and finally constant current and constant voltage supply assigned to Luis Camargo. Each prototype was decided based on our level 1 and level 2 system architecture following the figures below in section 4. Overall, our prototypes focused on the main components of a simple battery charger to create a strong fundamental understanding of how a basic battery charger will function.

The LCD interface was chosen to be prototyped to mitigate any unforeseen hindrances that could arise further down our design process. The LCD interface prototype held significance considering it will be used to allow the user to set up the notification system, scroll through the battery chargers' different features, to choose the appropriate settings for charging, and to see the overall status of the system. To realize this prototype, Elray Santiago used an Arduino microcontroller paired with a: buzzer, LED, thermistor, LCD, and a voltage divider to read the voltage of the connected AA 1.5V battery as seen in figure C in appendix A. The flowchart labeled as figure D in appendix A, associated with the program depicts the program functionality.

Overall, the prototype worked successfully with one minor hiccup that eventually worked due to a small connection error. The LCD displayed the voltage of the Duracell battery it was connected to as well as the time that has elapsed and the temperature of the room. When it disconnected from the battery, the LCD showed that a battery was disconnected and set off the buzzer alarm as well as a red LED. Also, if the temperature got too hot then the LCD will let the user know. Finally, if the system was connected to a battery that is larger than the 1.5V then it will ask the user to change battery type. In the end, the results were as expected. By completing this prototype, our team learned a great deal about how battery connectivity works and how to accurately read the output of the battery through the sensor to voltage conversions. Our team will leverage Elray's findings during our full system integration to reduce any unexpected connectivity issues.

The cell disconnect and state of charge indicator were chosen with the intention of a better understanding of how to achieve an analog input signal coupled with proper fault condition triggers. This prototype aided in our team's ability to recognize a possible algorithm for the Texas Instruments MSP430 to move forward with. This prototype came to fruition through the use of a Texas Instruments MSP430FR6989 Development board connected to a buzzer for audible fault condition notification along with three different reference voltages to simulate various stages of charging. A breakdown of the program can be seen in figure E of appendix A.

The three input voltages were 1.6V from a AA battery, 2.2V from a buck-boost converter, and 3.1V from two AA batteries connected in series. If the input voltage was zero to simulate a cell disconnect, the red LED would toggle every half second in tandem with the buzzer. For an input voltage from 1mV to 1.75V, the red LED would be enabled and the buzzer disabled as seen in figure B.3. The next condition was for an input voltage ranging from 1.755V to 3V, both the green and red LEDs would be enabled with the buzzer disabled seen in figure B.1. The final condition was for an input voltage greater than 3V, the green LED would be enabled seen in figure B.2.

The demonstration was successful, considering all elements of the prototype functioned as programmed. With the algorithm, our team is well equipped to proceed with full system integration. The biggest challenge faced was mapping the hexadecimal values to their respective analog input voltage value. This was overcome by establishing the upper limits of the analog input for the MSP430FR6989 and dividing that value by the 4096 considering the analog to digital converter used had a resolution of 12-bits.

The third prototype focussed on the battery cell temperature readings which is an integral part of safety assurance. Lithium Polymer (LiPo) batteries can be hazardous if they are not managed properly, so to ensure the user is safe we must have an accurate temperature reading of the battery at all times. If the battery reaches a high enough temperature during charging or discharging it can cause irreversible damage to our product, or even worse, cause harm to the user. Correct temperature input from the battery is crucial to the success of our project given that it provides the deterministic behavior of the system.

The battery cell temperature reading prototype incorporates the LiPo battery and the battery management system blocks of our system architecture. This prototyping reduces risk by attempting to find a solution for one of our most important inputs that the battery management system will be receiving. The difficulty incurred by this prototype was due to the unfamiliarity with the analog input for the MSP430FR6989. Running into these software and hardware problems early on is important because we will have a much better idea of how much time to allocate in the future for a viable solution.

The result of the battery cell temperature reading prototype was not as successful as we had intended. Nonetheless, the demonstration was of a functional software program that took input from external hardware. The results consisted of a properly working Arduino code that took an analog voltage input from a thermistor sensor and converted that to a temperature in Fahrenheit for display. The temperature value was also used for setting a condition that manipulated an LED to signal an unwanted temperature. The results were functional, but not considered a full success because the goal of the prototype was to program the MSP430FR6989 instead of the Arduino. Originally the program was written in Code Composer, but due to unforeseen complications, the program was unable to compile. To meet the time constraint of the demonstration date, the code was successfully translated to the Arduino Code. The transferability of the program and circuitry was seamless allowing for the foundation required for later implementation onto the MSP430FR6989.

The final prototype was based on the requirement for constant current and constant voltage for the charging block of the system. The purpose of this prototype was to understand how to control the current and voltage delivered to individual battery cells. This would allow our team to use a digital potentiometer to either amplify or reduce the voltage and current as needed. For this prototype, a program was set up to increase and decrease the resistance in the potentiometer for demonstration purposes as seen in figure A. This prototype will supplement the final system design regarding proper charging algorithms.

The prototype was completed by using a potentiometer attached to a buck-boost converter to control the duty ratio, which is then connected to the Arduino UNO via MISO (Master In Slave Out) seen below in Figure A (in appendix). First, the physical potentiometer had to be desoldered which controlled the current and voltage output of the buck-boost converter and connected each one to their buck-boost wiper terminal on the digital potentiometer. In testing, adjustments to the variable power supply powering anywhere from 12 Volts to 24 Volts with one Amps to the buck-boost converter, and using the wiper as a voltage divider achieved an output voltage of ~4.1V to ~7.4V. Unfortunately, this success did not translate to the constant current portion of the prototype. There were many issues with varying current due to the quality of the buck-boost converter. With further inspection, it had appeared that a component on the buck-boost converter had overloaded causing the entire converter to work improperly.

Through this prototyping process, Luis had conducted research that led to the realization to use a pulse width modulation (PWM) for a more efficient and cheaper way to control the current. The prototype has been deemed a success due to the knowledge gained. For example, the digital potentiometer comes in multiple resolutions. The one used in this prototype had a resolution of 7-bit capable of 127 steps, for our final design we will move to an 8-bit to achieve higher precision with the output. voltage Another is the output range experienced during the demonstration, it was not the range that is desired for charging individual cells, but it demonstrates that we can control the output with code and using the appropriate flags and conditions, we can lower, raise, or cut the voltage off.

With the completion of our four individual prototypes, the LiPo Crew feels prepared to either integrate or refine the prototypes into our final design. The experience of defining high-risk areas of our design while also prototyping them, allowed for our team to thoroughly understand the inner working of our respective prototype subsystems. With the combined efforts of our team, we will continue to prototype other systems to mitigate overall system risks.

4. Design

The purpose of this project is to design a multi-cell battery charger that is compatible with multiple battery chemistries, including LiPo battery packs. In order to achieve this, our team has conducted a functional analysis of the four fundamental subsystems required in our design for the battery charger. The subsystems include the power delivery system, LCD/User input module, MSP430 interconnections, and the battery management system. To achieve a harmonious system design that incorporates and follows requirements and specifications, our team had to first establish the ancillary components within each subsystem. From here, the LiPo Crew continued to route the interlinking connections between components while validating all communication and power requirements that need to be met. This can be seen in figure 4.1 which depicts the breakdown of the power delivery system. The voltage requirement for the MSP430FR6989 is rated at 3 Volts while the BMS that our team had chosen, the Texas Instruments BQ78350 requires 2.5 Volts input. The last major component of this design is the LCD which will require a 5 Volt input.

The purpose of this function is to visualize the applicable connections of each subsystem to better understand any interdependency requirements. Some of the revelations made while performing this functional decomposition include the BMS not being capable of sensing the current and temperature from every individual cell and the prior notion that the MSP430FR6989 would be capable of driving multiple sensors. In terms of scalability, our design would have to incorporate a mux to accommodate the various required sensors. Finally, the power delivery system might need additional filtering dependent on its output voltage ripple. These revelations were beneficial to our team's overall system design in that they allow for a reevaluation of our initial, second-level designs. Translating to an enriched system built upon an efficient second-level design.

4.1 High-Level System Architecture

To ensure the LiPo Crew satisfies all of the requirements and specifications set forth by our client, Dataforth, we created a high-level system overview depicted in figure 4.1. This visual representation of our multi-cell battery charger provides a functional decomposition of the fundamental components within our design. The four main components consist of: a power supply to rectify the incoming 115VAC voltage, the Texas Instruments MSP430 to provide the charging algorithm, the battery management system to interface with the thermocouples and voltage sensors, and the LCD/user input peripherals. These systems are the lifeblood of the battery charger to provide a safe and efficient charger that allows user-defined fault conditions.

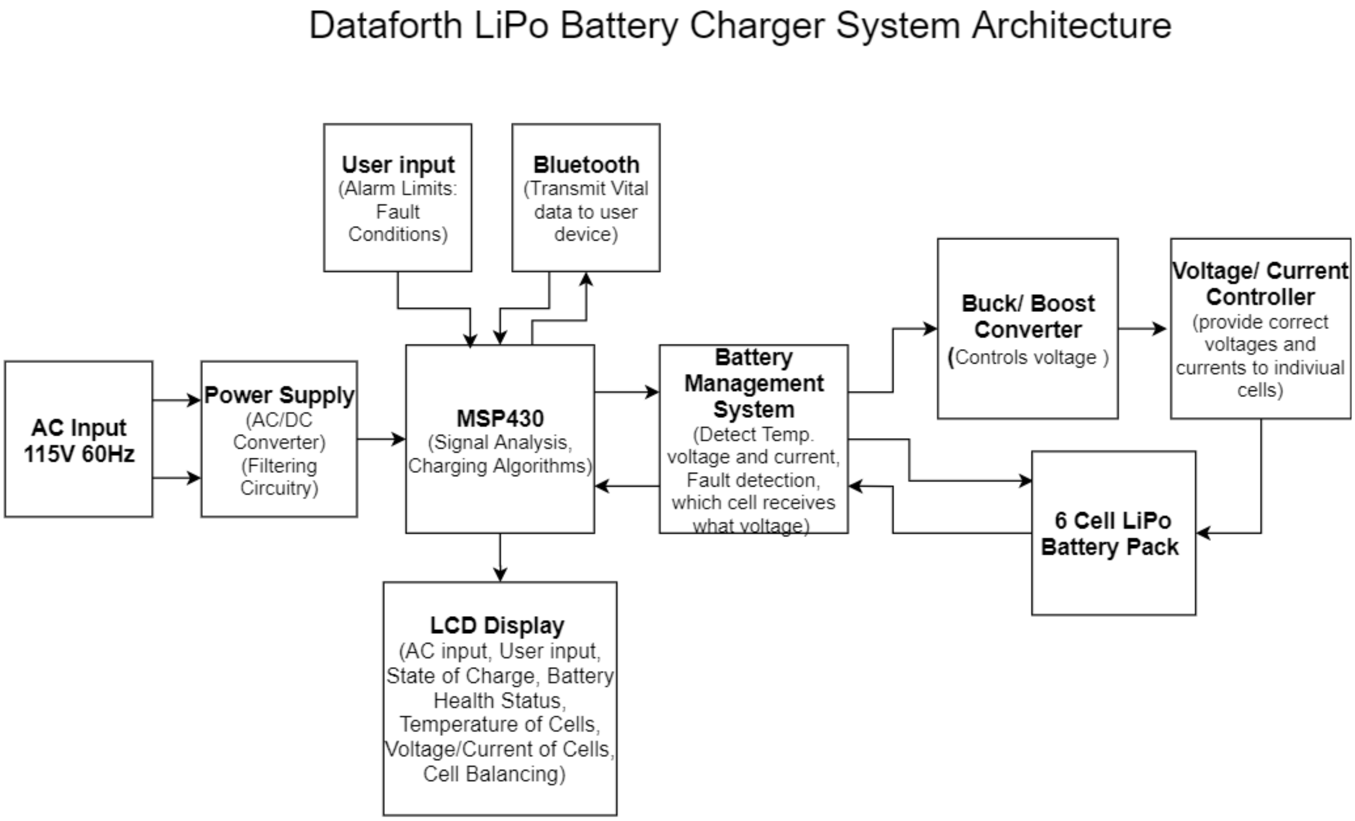


Figure 4.1 Dataforth LiPo Battery Charger System Architecture

4.2 Design: Power Delivery System

The power delivery system in figure 4.2 carries a significant amount of importance concerning system stability and user safety. The power delivery system incorporates a step-down transformer feeding into an electromagnetic interference (EMI) filter to diminish any unwanted high-frequency current. The full-bridge rectifier will allow the AC voltage to be converted into a DC voltage because, at any given time, two diodes will be conducting in a forward bias while the other two will be in reversed bias. The output from the full-bridge diode rectifier will then feed into a voltage regulator which will regulate the output voltage increasing system stability and ensuring less voltage ripple from the three buck converters.

The MSP430FR6989 requires an input voltage of 3V which will be supplemented via a 3V rail buck converter. The MSP430 will then provide 3V output to both the red and green LEDs along with the buzzer The battery management system will require an input of 2.5V while the LCD will be attached to the 5V rail. This second level provides an in-depth view as to how all of the major components receive their power.

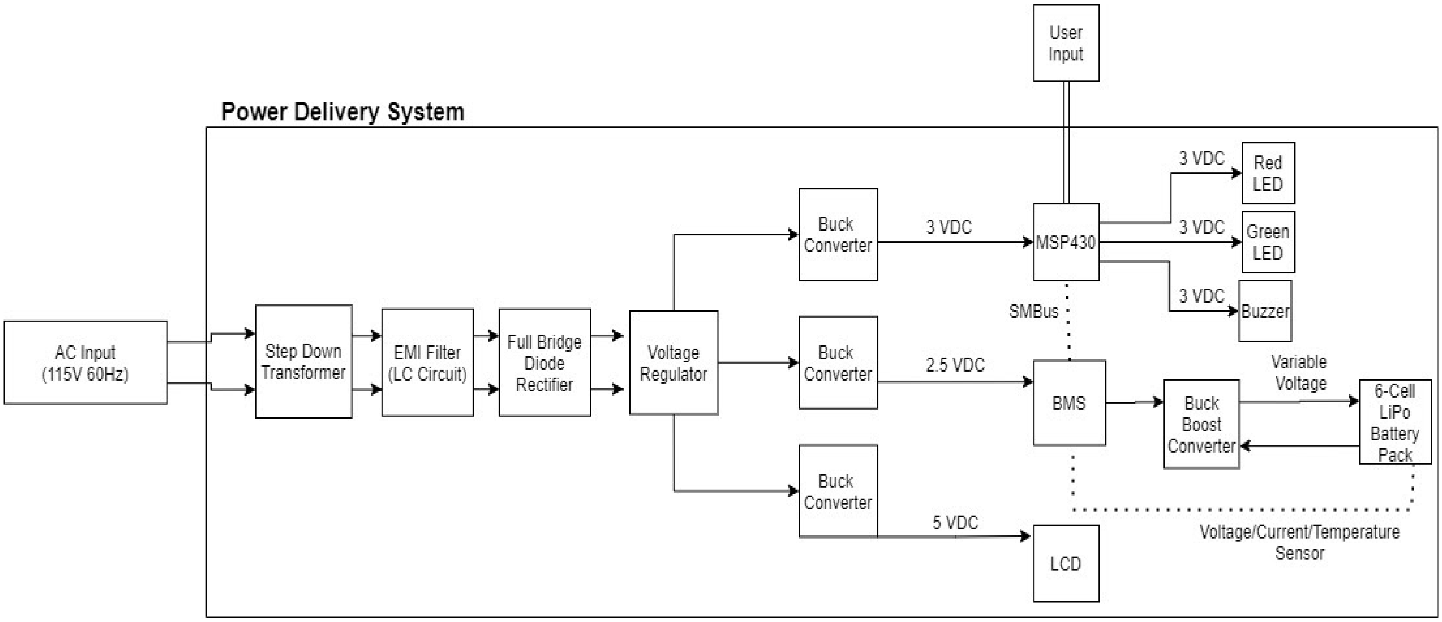


Figure 4.2 Power Delivery System

4.3 Design: LCD/User Input

The LCD/user input is one of the most critical components in our system design due to its ability to provide a visual representation of the overall system performance. Also, the user input systems will be implemented through the use of either a rotary encoder or multiple push buttons. The LCD in conjunction with the user input will guarantee compatible battery chemistries are selected through a user-friendly interface. This interface will allow the user to monitor all parameters of the connected battery to ensure the battery charger is safe and reliable. In addition, if for any reason one of the following should occur the fault conditions will trigger and prompt the user with necessary actions to debug the error: the wrong battery is selected, the battery is not connected properly/not at all, or if the temperature is above the threshold pre-set per battery chemistry.

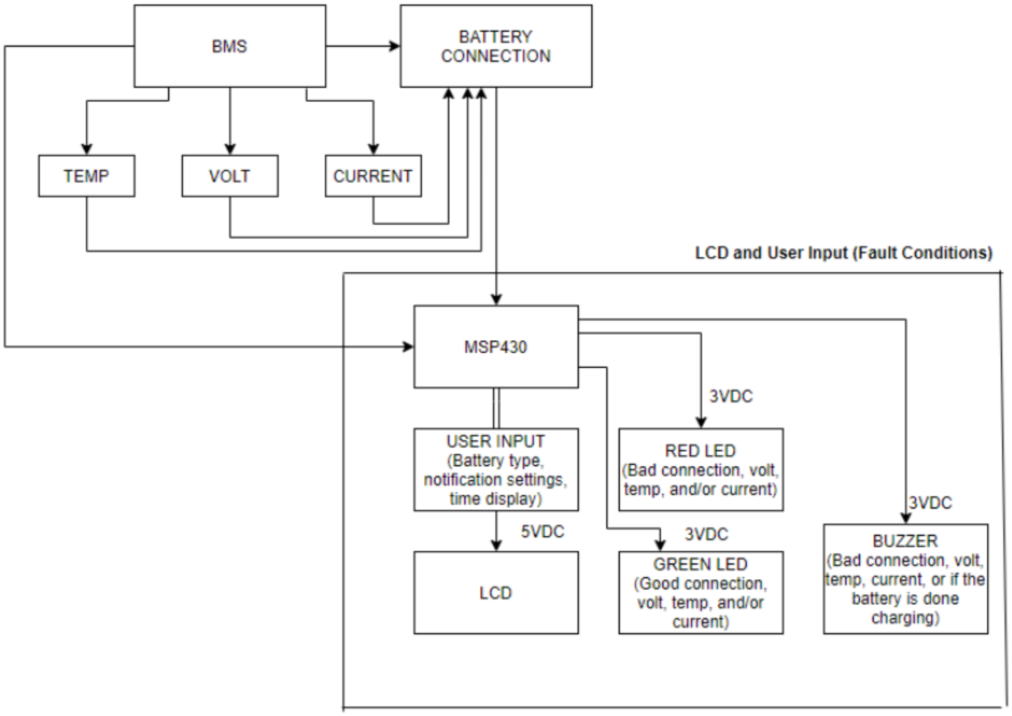


Figure 4.3 MSP430 LCD/ UserInput

4.4 Design: MSP430 Interconnections

The MSP430 is the computational powerhouse of the system supplying simultaneous analog to digital conversions for temperature and voltage readings. This is imparted by the requirement for several voltage readings for the individual cells. The MSP430 will communicate with the BMS via System Management Bus (SMBus) and the LCD via preprogrammed display ports and will ultimately provide the appropriate voltage and current to the battery pack, through the buck-boost converter. The temperature sensors will also feed into one of Dataforth's signal conditioning units to ensure signal integrity. With precision being instrumental in achieving a successful battery charger, it is of the greatest importance that our team employ none other than one of Dataforth's signal conditioning units. In doing so, our design will showcase the ability and versatility of the component in an Automotive Roadshow.

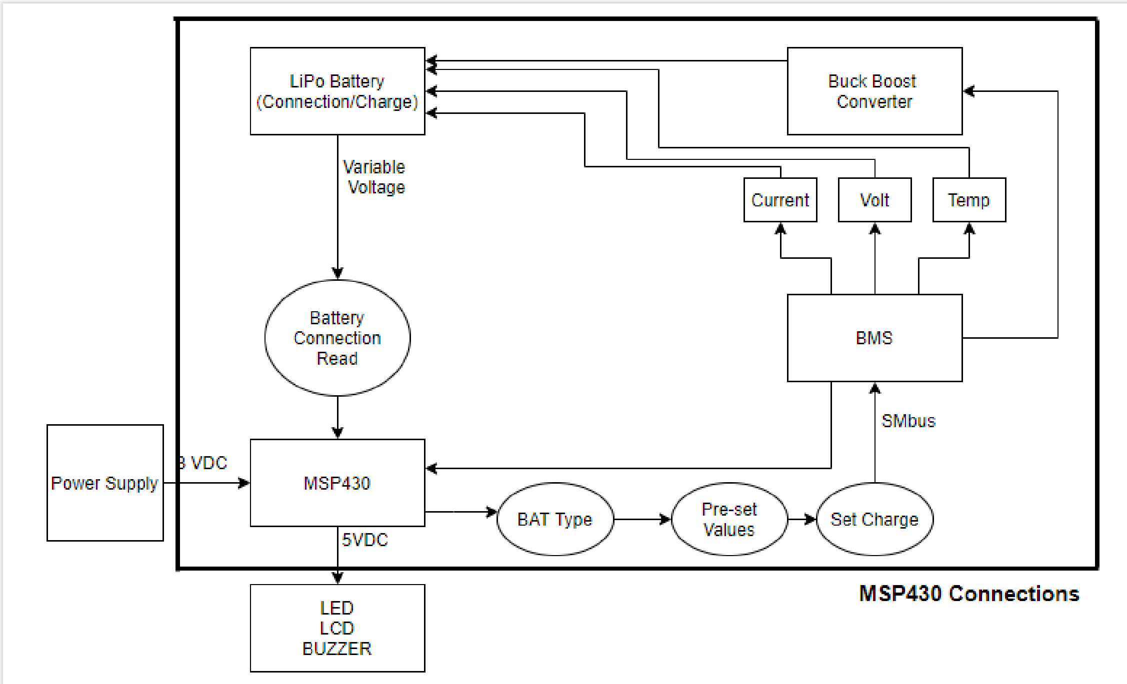


Figure 4.5. MSP430 Interconnections (Charging Algorithm)

4.5 Design: Battery Management System

The battery management system (BMS) will be responsible for fault condition triggers and relaying the information to the MSP430. The fault conditions controlled by the BMS will include: over/under current, voltage and temperature, short circuit protection, cell imbalance detection, and open thermocouple detection. The BMS also boasts user-defined charge control features which include variable charge voltage, reports the constant voltage required for constant current charging as well as the voltage required for constant current charging. These features will prove to be key in reaching our goal of developing the safest, affordable, and efficient battery charging system capable of competing with modern commercially available chargers.

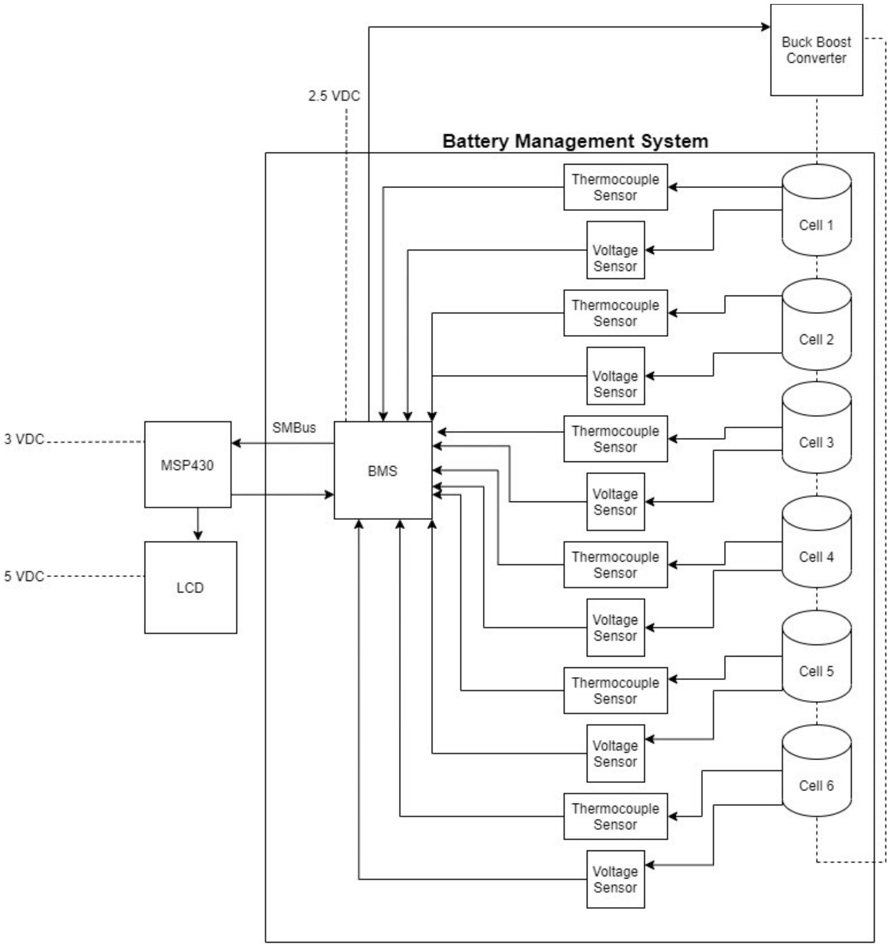


Figure 4.6 Battery Management System

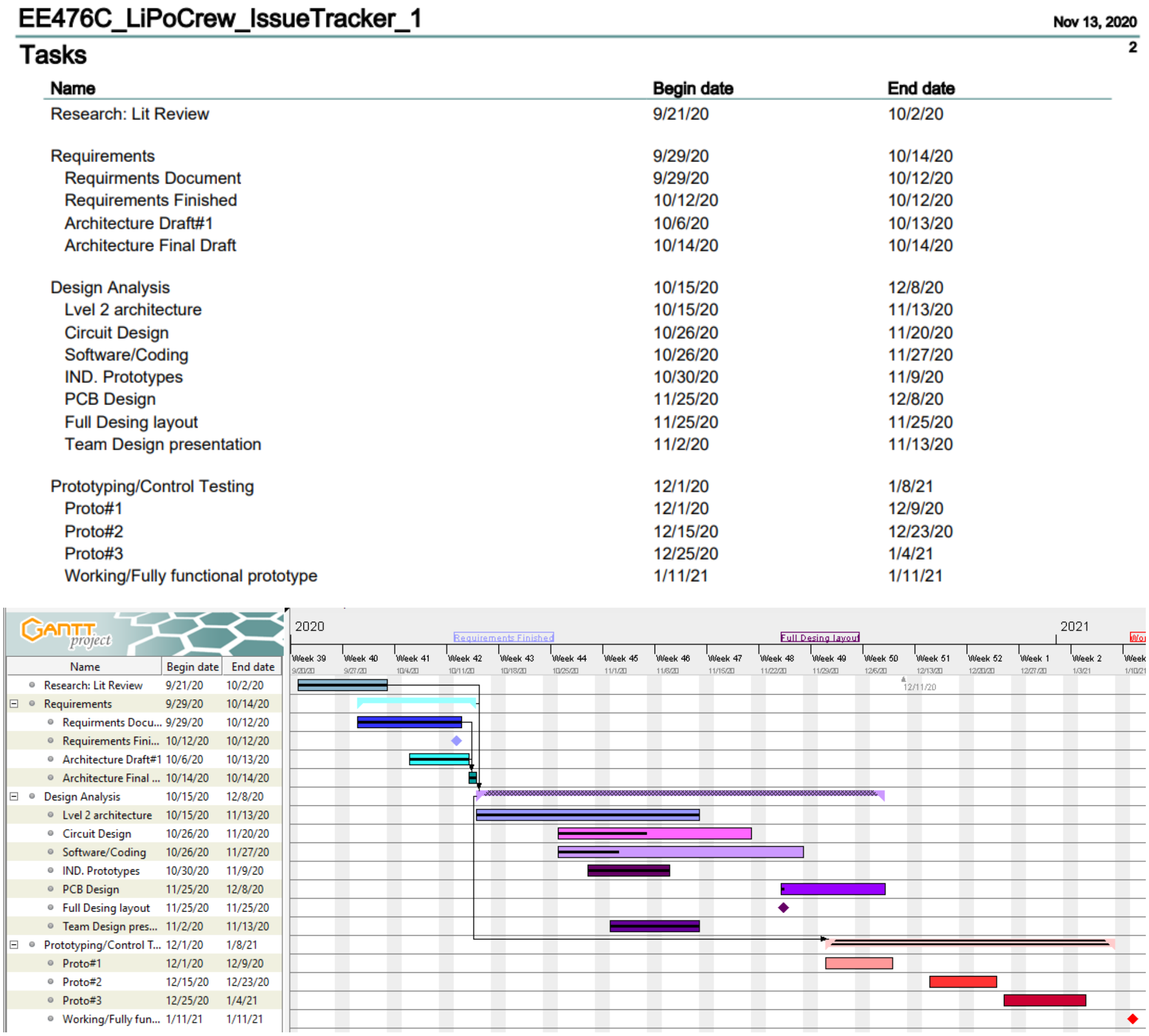
5. Plan Forward

Our team plans on maximizing our time over the coming winter break by translating our current productivity levels into completing full system simulations and prototyping. Through research and prototypes, we have attained the confidence required to move forward with variations of our full system design. These variants will incorporate our prototype findings and streamline our team's design process. The hurdles ahead will facilitate the innovativeness required in deriving a charger capable of competing with the commercially available chargers of the market.

One of the variants will incorporate a BMS chip to perform the charging algorithms determined by the connected battery's chemistry. Although the user will have the capability to manually input the chemistry, the BMS will verify the correctness of the chosen chemistry and either approve or reject the user's input. The BMS will also allow for the user to define which fault conditions are enabled along with its parameters. To manage the possible risk factor associated with such great control over the system, our team plans on integrating a series of checks and balances. These checks and balances will come in the form of hardware coupled with software to compare the input parameters against known charging tolerance levels of the selected battery chemistry. The solution of checks and balances remains unsynthesized at our current phase of the design. Over the coming weeks, our team plans on further investigating the validity of this projected option.

The second system design will negate the use of a BMS chip and focus on augmenting the capabilities of our design. This will be completed by mirroring the functions of a BMS within a Texas Instruments MSP430FR6989 microcontroller. Although our team has not performed any formal power and timing analysis on this design, the self-contained aspect of the layout for a single chip promotes power efficiency and reduced timings. Careful consideration and proper identification of potential hazards are critical to ensure data dependencies remain independent of one another. By employing high throughput computing algorithms to reduce possible stresses that the Arithmetic Logic Unit (ALU) may incur during normal operating conditions. Our solutions will provide the system stability, allowing for future expansion on our design for both low and high-energy applications alike.

To complete our full system simulations and prototypes, our team has allocated time over the winter break to facilitate such an endeavor. As seen below in figure 5.1, our team has set forth a stringent timeline to comply with the UGrads symposium at the end of April 2021. The narrow window provided by the coming winter break will allow for a conducive environment in which the LiPo Crew will solely focus on the task at hand. We will continue to hold weekly meetings with our client to provide status updates, as well as team meetings to discuss the course of our design.



EE476C_LiPoCrew_IssueTracker_1 Nov 13, 2020

Tasks 2

Name	Begin date	End date
Research: Lit Review	9/21/20	10/2/20
Requirements	9/29/20	10/14/20
Requirments Document	9/29/20	10/12/20
Requirements Finished	10/12/20	10/12/20
Architecture Draft#1	10/6/20	10/13/20
Architecture Final Draft	10/14/20	10/14/20
Design Analysis	10/15/20	12/8/20
Lvel 2 architecture	10/15/20	11/13/20
Circuit Design	10/26/20	11/20/20
Software/Coding	10/26/20	11/27/20
IND. Prototypes	10/30/20	11/9/20
PCB Design	11/25/20	12/8/20
Full Desing layout	11/25/20	11/25/20
Team Design presentation	11/2/20	11/13/20
Prototyping/Control Testing	12/1/20	1/8/21
Proto#1	12/1/20	12/9/20
Proto#2	12/15/20	12/23/20
Proto#3	12/25/20	1/4/21
Working/Fully functional prototype	1/11/21	1/11/21

Name	Begin date	End date
Research: Lit Review	9/21/20	10/2/20
Requirements	9/29/20	10/14/20
Requirments Docu...	9/29/20	10/12/20
Requirements Fini...	10/12/20	10/12/20
Architecture Draft#1	10/6/20	10/13/20
Architecture Final ...	10/14/20	10/14/20
Design Analysis	10/15/20	12/8/20
Lvel 2 architecture	10/15/20	11/13/20
Circuit Design	10/26/20	11/20/20
Software/Coding	10/26/20	11/27/20
IND. Prototypes	10/30/20	11/9/20
PCB Design	11/25/20	12/8/20
Full Desing layout	11/25/20	11/25/20
Team Design pres...	11/2/20	11/13/20
Prototyping/Control T...	12/1/20	1/8/21
Proto#1	12/1/20	12/9/20
Proto#2	12/15/20	12/23/20
Proto#3	12/25/20	1/4/21
Working/Fully fun...	1/11/21	1/11/21

Figure 5.1 The LiPo Crew Task List & Gantt Chart

6. Conclusion

Dataforth along with our client, John Lehman, has presented our team with a unique challenge for our senior capstone project. Our goal is to design a safe and easy to use battery charger for lithium polymer (LiPo) batteries. By conducting in-depth research on battery chargers, in addition to our prototypes, we can ensure that no externalities would cause any future problems for our final design. Our team now has the overall design plan for our project on paper and the next step will be to implement parts of our design with hardware and software for validation through testing. The LiPo Crew is confident in our current standing heading into our winter break, but we know that the most challenging obstacles will present themselves when testing the functionality of our system.

Before we could start our prototypes, there was a significant amount of research necessary to procure the most optimal solution for designs. Our biggest decision was choosing the ideal battery management system (BMS) chip to fit our project's needs. The BMS chip is a crucial part of our design because it will be monitoring, calculating, and reporting data from our battery pack to ensure that it is charged properly while preserving the overall battery health. A decision matrix was utilized in determining our choice because it allowed us to conduct a numerical analysis of the BMS chips that were being considered. By taking the time now in the early phases of our design, we have reduced the overall risk of the system, saving us valuable time for future testing.

Although our main focus is to charge lithium polymer batteries, implementing a more inclusive battery charger could help to provide a better marketing product. This may include lithium-ion and lithium-iron batteries. As referenced in section four, our level-one system architecture was split into four major components to reduce the risks of errors in our final design. Inevitably, this will allow us to build a deeper understanding of the intricacies within our entire system. These four main components include an LCD interface and fault detection system, a cell disconnect and state of charge indicator, battery cell temperature readings, and finally a constant current and constant voltage supply. Understanding these prototypes aided in formulating the level-two system architecture as well as the overall design functionality.

Performing a functional decomposition, provided the ability to break down our system architecture into four fundamental level-two subsystems. These four subsystems include our power delivery system, LCD/User-input (fault detection), MSP430 interconnections, and our battery management system. While our team is still in the process of determining the most capable circuit design for the respective subsystems, we strive to deliver a fully functional system prototype by January 11, 2021. The LiPo Crew has addressed the time constraint of winter-break by implementing weekly client and team meetings to ensure a cohesive transition into our testing and construction phase.

7. Appendix

Appendix A: Individual Prototype & Flowchart Figures

Appendix B: References

Appendix A

Individual Prototypes and Flowcharts

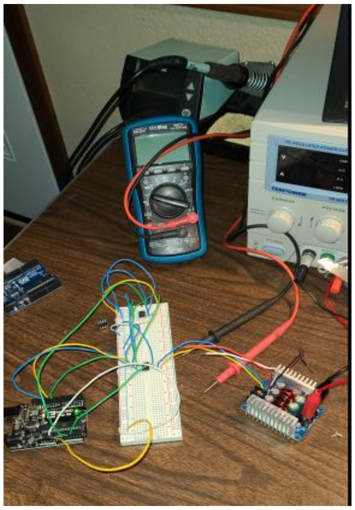


Figure A. Luis's constant current and constant voltage supply

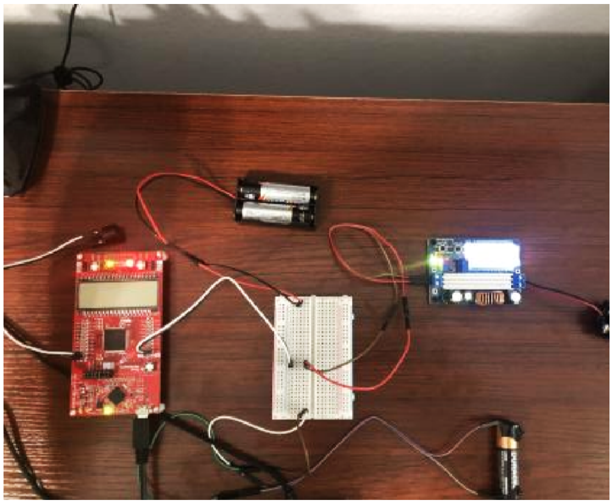


Figure B.1. Jonathan's cell disconnect and state of charge indicator

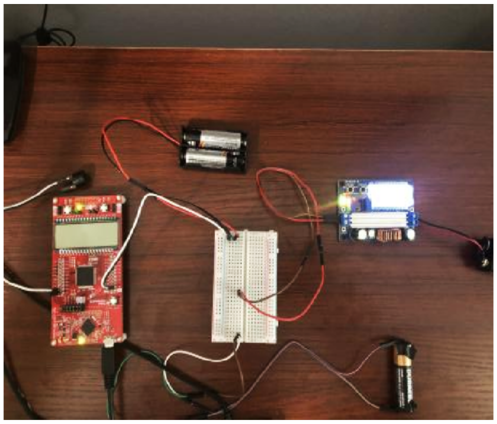


Figure B.2. Jonathan's cell disconnect and state of charge indicator

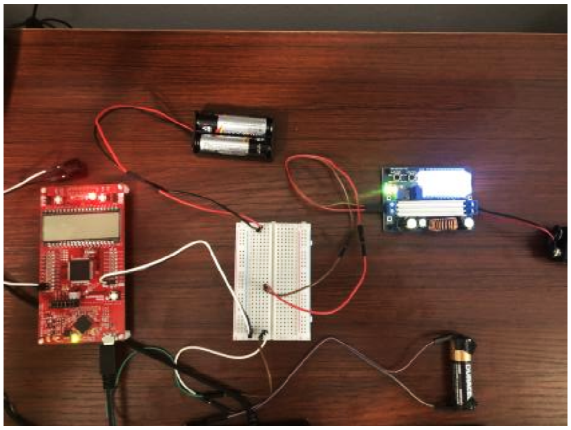


Figure B.3. Jonathan's cell disconnect and state of charge indicator

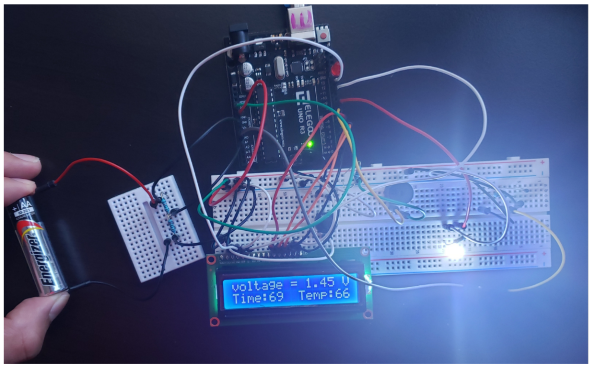


Figure C. Elray Santiago's LCD Interface Prototype

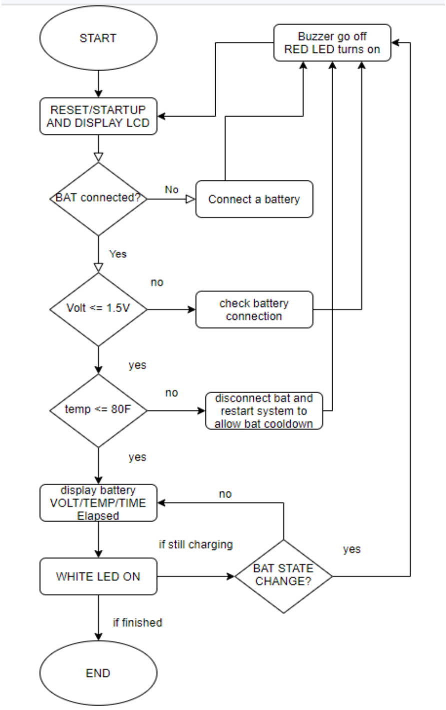


Figure D. LCD Interface Flowchart in accord to Figure C

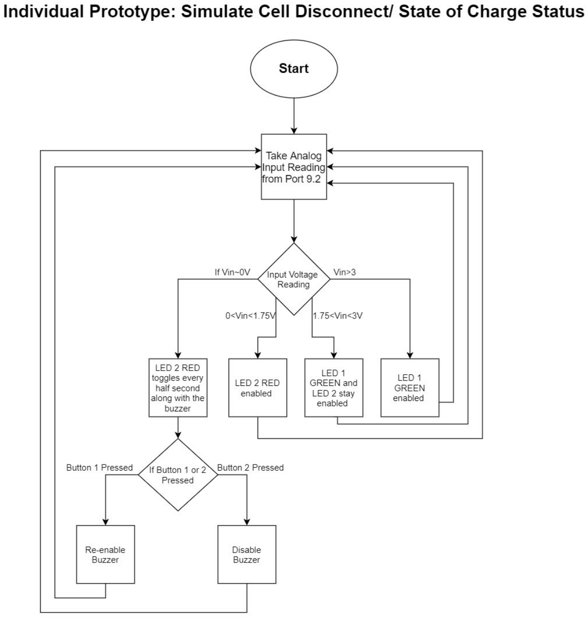

Individual Prototype: Simulate Cell Disconnect/ State of Charge Status

Figure E. Simulate Cell Disconnect/State of Charge in accord to Figure B

Appendix B

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