EEL 4914 – SENIOR DESIGN 1

PROJECT DOCUMENTATION

UCF

COLLEGE OF ENGINEERING AND COMPUTER SCIENCE

GROUP #8

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PHOENIX BOARD - WIRELESS CHARGE SMART LONGBOARD

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1.0 Executive Summary

In today's age, a growing number of people are doing whatever they can in order to reduce our carbon footprint and mitigate the effects of global warming. A part of this has been to make our methods of transportation more environmentally friendly. While electric cars are making wonderful strides in this regard, there has also been a large movement to make smaller, more personal vehicles electric. This has culminated in the creation of multiple electric scooters, skateboards, bicycles, etc., and they are becoming an increasingly popular mode of short-distance transportation. The use of this is so common in fact that cities like San Diego have implemented systems of bikes and scooters that can be rented and can be "borrowed" by virtually anyone with a Smartphone. Electric skateboards have received just as much attention and have really taken off on college campuses. These boards help students zoom through campus when that time between lectures is too short to make the trip on foot or when they're running late for an exam. Although using electric motorized vehicles to travel short distances is a great tool in itself, our team believed that there was a way to further expand on the idea of clean energy and implementing it into an electric longboard. A longboard was chosen as opposed to a skateboard because they generally tend to be more stable and have an easier learning curve, therefore making this an accessible technology by a larger number of people.

The goal of our project, the Phoenix Board, is an electric longboard that is recharged through the combination of solar and wireless technologies. This motorized board will be controlled via downloadable Smartphone app and will have multiple safety features, such as a weight sensor for rider detection and an obstacle avoidance system. The obstacle avoidance system will be comprised of a camera and sonic sensors in order to avoid and minimize collisions. The Phoenix Board will also be equipped with LEDs in order to improve the visibility of riders at night, further ensuring their safety. There is not a single board on the market at the moment that incorporates all these features, so we are pushing to be the first in this regard. The Phoenix Board could be the first of many solar-powered transportations designed with the individual in mind. Ideally, our board will be on par on close to industry standards in terms of top speed, distance range, battery life, ease of use, and charge time, all while ensuring making the experience feel as smooth as any other longboard and maybe even a little more exciting. This would hopefully encourage others in the industry to turn to solar-powered alternatives while reducing costs, of both the manufacturing process and of energy used by these products.

This report will serve as the documentation for the process of designing and building the Phoenix Board. This project involves many complex technologies due to our individual desire to learn more about different specialized fields of knowledge we had encountered throughout our undergraduate programs. We then took our individual ideas and meshed them together into what would become the Phoenix Board. The information contained in this report includes but is not limited to the constraints of the project, similar products, industry standards, part selection, time management and financial management.

2.0 Project Description

The Phoenix Board is an electric longboard that will be tailored towards short to medium range travelling. Two examples of ideal situations for the use of this board are for getting around a large college campus or in metropolitan areas with high traffic congestion but short travel distances. At the core of this board will be a PCB designed by one of our group mates and will be customized to support multiple systems on the board. Amongst these systems will be a mounted camera and sonic sensors that will aide object/collision avoidance, LEDs for a “Night Mode” which will enhance rider visibility and a weight sensor system that will ensure the rider is on the board to further reinforce the safety concerns of this project. Along with that, the PCB will also be in charge of monitoring the power and charge on the board during times of operation as well as during charging in order to ensure the battery does not overheat and voltages are being converted properly for every device. Since the board will be motorized and will have the task of generating enough force to move a person there will be plenty of research done in order to determine whether a hub or belt motor will produce the best results. The charging of the board’s battery will be done through a combination of solar panels and inductive charging and we believe this will definitely make our project stand out. To go along with all the hardware, we will be designing a mobile app that will act as the remote controller for the motor and will keep track of various metrics that will be recorded while riding. This app will be available for both iOS and Android devices and will be a crucial component in testing various features of the board we wish to implement.

2.1 Motivation

The motivation for this project came about due to our initial agreement to incorporate everyone’s ideas into the project. This was an extremely important requirement for us as it would help ensure that we were all invested in the project because of our individual concepts for it, but also that we would remain focused and driven on its completion. The three main things we wanted it to include were some kind of wireless technology, robot vision and for it to incorporate solar energy. With these three concepts in mind we developed various ideas that could incorporate them, with these ranging from a smart door with a solar welcome mat to a smart shopping cart that would follow shoppers around, but ultimately decided on a solar-powered electric longboard. This idea resonated with us because we could see that this would be exceptionally rewarding upon completion, but it would provide plenty of challenges in the process of doing so. It will also be a tremendous help in preparing us for the job market as the experience we gain with robot vision, wireless and solar technologies will hopefully help us stand out amongst other job applicants. With this project we will all be collectively advancing our understanding of these topics because even though we each had a specific technology we wished to work with, we all agreed that we would be fluid and dynamic throughout this project in order to help one another out as much as possible. Due to this, we will all be attempting to learn and contribute to the implementation of the various technologies being used which would also help in further rounding us out as engineers.

2.2 Goals and Objectives

In developing the Phoenix Board, our team spent a large amount of time making sure that our goals and expectations for this project were reasonable but also innovative enough where putting in the time to develop and fully realize this project would be worthwhile. The fundamental backbone for many of our functions and features focused on creating a product that would provide the user with an enjoyable experience, with great reliability and efficiency, with a minimal footprint, and the ability to self-sustain over an extended period of time. In order to further organize ourselves and to prioritize our efforts we split up all the features we wanted to include on this board into core features and stretch features. The core features are composed of what we felt was absolutely necessary for our project and would therefore receive the most focus. The stretch features are composed of the items we wanted to add to our project so that it stood apart from anything else that has been made or just additions we thought would make the board more fun/interactive but did not need to be implemented. The deciding factor on stretch features would ultimately be time and whether there was enough of it to implement each feature properly and test it thoroughly.

Core Features:

- Motor functions properly (accelerates/decelerates).
- Battery receives charge.
- PCB communicates with all necessary peripherals.
- Mobile communications are consistent and precise.
- Weight-sensitive safety mechanism to stop board in the case that the rider is no longer on it for whatever reason.

Stretch Features:

- Board self-parks within charging distance of solar panel.
- Robot vision is developed thoroughly (accurately assessing dangers while minimizing false flags).
- LEDs for Night Mode are responsive and allow user customization.

2.2.1 Efficiency

The most important measurement parameter when considering wireless charging technology. The components used for this design were carefully researched and selected to ensure that we get the best efficiency possible. This includes using component that will generate an efficiency of over 95%, with others just below an efficiency of 90%. By utilizing circuit design techniques learned in classes at the University of Central Florida, we will ensure that our design is fully efficient and will serve its purpose.

This project will be utilizing solar energy technology for charging and will be required to charge within a certain time frame. Thus, to ensure this happens we have decided to have an independent charging source that will take a 12-volts input from the solar panel and charge the skateboard using inductive charging technology. Because of the instability of the solar power, we will utilize a solar charge controller that will serve the purpose of stabilizing the voltage, so we get the desired output. For high powered batteries such as a

36 volt that will be used in this project, energy loss in the charger can add significantly to the charging times. Therefore, the design will need to be as efficient as possible. Our goal is to have our system designed with over 90 percent efficiency.

2.2.2 Reliability

Through our development process, we’ve taken the time to ensure that the quality of parts being used are both high quality and readily available. Additionally, by adhering to the standards and constraints listed later on in this document, we are able to build a device that follows good engineering practices and protocols. Altogether, this should contribute to a product with strong reliability and thus a better overall user experience.

Due to the fact that some of the peripherals we intend to use vary so much from one another, multiple tests will have to be developed and run numerous times in order to ensure that they both work individually and in tandem with one another. For our battery, we will be running various tests throughout development and with the different peripherals to accurately determine the battery drainage. This will ensure that once the board is fully operational, we will be able to precisely advertise the expected number of hours the board will be able to run on before the battery dies. This kind of testing will usually be with the goal of fully draining the battery and will aid in the setup of the other testing for the battery as we will also need to accurately determine the amount of time it takes the board to charge. With our charging tests we will also be able to test the process under different conditions as it will be a more thorough assessment if we allow the charging to happen at various times of the day and tweak the settings of our charger controller, solar panel and any DC-DC converters we have within that system in order to optimize the process.

For the safety features on our board, we will need to make sure that whenever one of them is executed, the board should respond both quickly and consistently in order to minimize any damage done to itself, the rider, and any nearby individuals. This kind of testing will be the most dangerous due to the fact that the safety mechanisms may fail to engage or may do so incorrectly but it is due to this reason that it is so important to run these diagnostics; it is better to find the flaws early in development and with few people around than for a rider to discover one in a busy location which could lead to serious injuries for multiple people as well as damage to property. Due to the time constraints of this project, it is hard to put an exact figure on the number of riding hours we want to subject the board to in order to test all of this and its other features out thoroughly, but we are generally of the mindset that more is better. Another factor that may affect this testing is the weather, as this board will not be designed to handle adverse weather, such as rainfall, but that is quite a common occurrence during Florida summers.

The remaining reliability testing will revolve around our app and every single one of its features. Due to the fact that the app/mobile phone will be used to control the board, it is essential that all of its features perform dependably. This reliability tests for this will involve both pure software tests, to make sure the app is responsive and behaves correctly, as well as tests while riding the board, to guarantee the fidelity of features such as our GPS tracking and ride tracking. While we do aspire to add multiple unique elements to our app, all will be subject to strict standards and may ultimately be removed if their performance is not consistently correct.

2.2.3 Self-Sustained

Part of the reason we wish to implement solar power into this project is because of its benefits to sustainability. By using this method, a Phoenix board owner would only have to worry about the weather in order to use their board and then charge it up. This allows the user to enjoy their board without worrying excessively about its footprint. Solar energy is also still considered in its relative infancy and will only continue to get more efficient and more cost effective, meaning down the line this project could see a serious improvement on these developments alone. Another big factor in sustainability will be the kind of motor we use. Through some preliminary research, we have found that when it comes to belt or hub motors, hub motors generally require less maintenance and therefore would prove the most beneficial in this regard. This is however based on preparatory work and may be subject to change based on actual findings when in-depth research is done.

2.3 Design Requirements

After some careful consideration, our team came up with some rudimentary design requirements. These were intended to be both challenging yet doable with the proper motivation and work ethic. Due to our inexperience, we expect these to change in some way or to possibly be removed altogether during the implementation phase.

1. PCB 1 - Communications
    a. This PCB will be used for the communication between the peripherals, smartphone and the skateboard. Since this is the initial planning stage, we are not yet sure whether mobile communications will be done via Wi-Fi or Bluetooth.
2. PCB 2 - Battery
    a. This PCB was intended to be used for the battery charging phase of the design. However, we later discovered that a simpler circuit was required, which we incorporated in the design with the addition of the wireless charge circuit which holds a circuit for the transmitter coil and one for the receiver coil.
3. Microprocessor
    a. A MSP processor will be used but this is yet to be decided until we finalize what peripherals we will have and what will work best with/for them.
4. Power Supply
    a. Main source of power for both PCBs.
5. Battery
    a. For this project, a 36-volt 10S3P lithium battery will be used that will be able to deliver 12 - 19 miles per charge.
6. Communication
    a. All communication will be done through a mobile app wirelessly. We are yet to confirm whether it will be compatible to iOS, Android or both.
7. Sensors
    a. Sensors will be used to provide real time information through to the app and will be displayed on the screen.

   b. These sensors include: temperature sensor, speedometer, weight sensor, odometer, gyroscope, LEDs and a camera.
8. Vision
   a. A camera mounted to the front of the board will be used along with the OpenCV library to detect objects and using the other sensors, be used to slow the board down to prevent potential collisions.
9. Motor/Motor Hub
   a. N5055, 270KV, 1400W motor will be used for this project.
   b. This motor will be able to deliver speeds up to 27 mph, with strong linear acceleration and braking.
10. Charging
   a. The charging will be done using inductive charging technology, utilizing a transmitter and a receiver and will be powered by solar panels.

The final implementation made some significant changes to the original design requirements. These include consolidating our PCBs into a single one, changing our microprocessor to an ATMega2560, reducing our total sensors to a weight sensor, ultrasonic sensor, and LEDs. We completely removed the vision requirement, and lastly, changed our motors to dual 6364 hub motors.

2.4 Responsibilities

Our team is composed of two computer engineers and one electrical engineer. Since these fields are so closely intertwined, it was agreed upon at the start of this project that we would all be open to working on any and all parts of the project should the need arise, although we did split the work up in a way that would highlight our strong suits. In dividing the work like this, our hope was to progress through our objectives and meet our deadlines as efficiently as possible but doing so in a way where everyone knew what was going on with all or most aspects of the project at any given moment. This not only allowed us to further strengthen and build upon what we already knew, it also allowed us to accelerate our understanding on some of the topics we were less familiar with collectively. Aside from our technical responsibilities, our other main priority was communication within our group. To this extent, we formed one main group chat within a messaging app and would periodically check in. Furthermore, we agreed to meet at least twice a week either in person or via an online chatting service, Discord. At the end of one meeting we would set up the next in order to keep a continuous flow of information in the group so that we could all be held accountable and we could all assist each other as needed.

2.4.1 Electrical

As stated previously, at the onset of this project we agreed that we would all be flexible in our responsibilities and with helping each other out but would try to position each other in the most suitable roles. For that reason, our electrical engineer was tasked with the bulk of the electrical work, with complimentary work being done by the computer engineers as needed. The main priorities for the electrical engineer would revolve around the power systems and their different components, such as the battery, solar panel, and PCB to name a few. The PCB design was initially designed with the EAGLE software, which required the efforts of everyone in order to allow our EE to have the easiest time possible with minimal complications. This includes help in finding datasheets and part specifications in order to properly design the PCB. Along with that, the EE will be in charge of properly managing DC-DC conversions so that all peripherals and subsystems operate at their proper voltages. Finally, the EE will be in charge of calculating the correct voltages and settings needed for the solar panels and MPPT charge controller, if necessary, in order to optimize the charging process. Again, there will be help here from the CpEs to aide in correct any of the settings on the software side.

During the initial planning stage, we encountered some issues that drove us to make some changes to the design. One of those changes was the PCB. We learnt that designing the PCB with easyEDA was a better option, so we eventually resorted to that which definite made the process much easier. The schematic and board files were generated, and the PCB was ordered using the same website.

2.4.2 Computer

Along with helping our electrical engineer out, the computer engineers' main focus will be on programming and developing an app that will work in tandem with the board. This process will begin with the designs and early mock-ups of the app, most likely done on Photoshop or another image editing software. With this as the foundation, the computer engineers will be tasked with implementing each of the mobile features, some of which include establishing a wireless connection between the mobile device and the board, a GPS tracking system that will use APIs and technology already embedded in the Smart Phones, and converting the phone into the remote controller that will control the board's speed. All of these features, and any subsequent ones, will need to be thoroughly tested on simulations, on actual phones and then in conjunction with the board. Use case models will also be developed and through these we will try everything in our power to "break" our app in order to find any glaring bugs or issues. By doing this, we hope to increase the safety of the board by removing all erroneous behaviors from the app. Since there are two CpEs on this project, the programming will be split pretty evenly between the two and we hope that all or most of it can be done together so that there be no confusion between sections that can occur from the use of different variables and things of that nature. Working together will also add a second set of eyes that could pick up any syntactical errors because even the most minor mistake could have serious repercussions and could also waste a significant amount of time.

2.5 Block Diagram

Figure 1 is a basic layout of the Phoenix Board's systems and how they interact with one another. The board will consist of a power subsystem, marked in red, that will control the battery, solar charging, and several other switches / sensors related to power management. There is an onboard sensor suit subsystem, marked in yellow, which will control the ultrasonic sensor, the onboard LEDs, the weight sensors, and the camera. Lastly there is a mobile device subsystem, marked in blue. This will primarily control the boards speed, in addition to tracking current sensor statistics coming from the board.

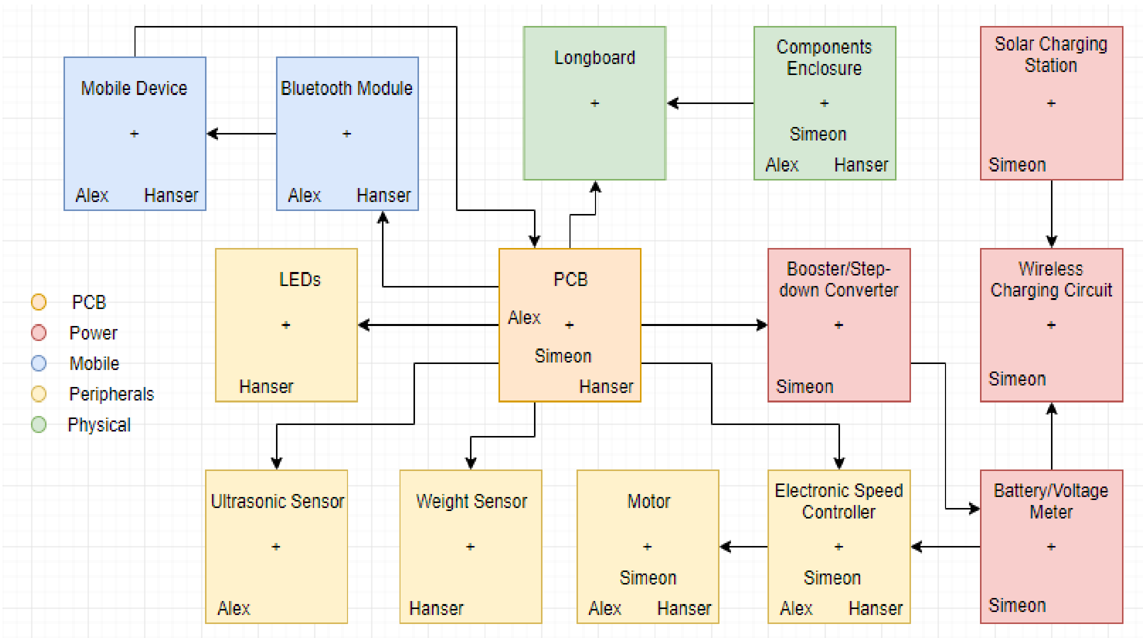

Figure 1: Block Diagram

2.6 Project Milestones

In order to progress through our work in a smooth and regular pace we have set Project Milestones for ourselves, seen in Tables 1 and 2. The majority of these dates are not set in stone but will serve as a pacing guide for us in order to take on this massive project at a reasonable rate. It is our hope that by following this, we may get through our work without any problems but of course that is rarely the case, and therefore this pacing guide will be all the more necessary. In order to avoid an avalanche of work at the last minute, we will push to keep on track with the milestones presented below but some of the tasks set before us may take longer or shorter than expected and that is yet another reason why we must remain adaptable.

INITIAL PROJECT MILESTONE			
SPRING 2019 - SENIOR DESIGN I			
TASK	DURATION	DATES	GROUP MEMBER
Project selection	2 weeks	1/21 - 2/1	Completed
Divide and conquer document (10 pages)	2 weeks	2/1 - 2/15	In progress
Meeting with Professor	1 day	02/5 - 2/5	ALL
Research and Documentation	6 weeks	2/15 - 3/29	ALL

Table of content	6 weeks	2/15 - 3/29	ALL
Hardware	6 weeks	4/1 - 5/17	SIMEON
Batteries/Power distribution	4 weeks	4/1 - 4/26	
Solar Panel	4 weeks	4/1 - 4/26	
PCB design	4 weeks	4/1 - 4/26	
PCB 1	6 weeks	4/1 - 5/17	
PCB 2	6 weeks	4/1 - 5/17	
Software	6 weeks	2/15 - 3/29	ALEX/HANSER
Mobile Application	6 weeks	2/15 - 3/29	
Processor	6 weeks	2/15 - 3/29	
Communication	8 weeks	2/15 - 3/29	ALEX/HANSER
Odometer		2/15 - 2/22	
Speedometer		2/15 - 2/22	
Weight Sensor		2/15 - 2/22	
Gyroscope		2/15 - 2/22	
LEDS		2/15 - 2/22	
Camera		2/15 - 2/22	
Physical	4 weeks	3/29 - 4//25	ALL
Board		3/29 - 4/5	
Housing		3/29 - 4/5	
Prototype		4/8 - 4/19	
45 PageDraft		3/15 - 3/29	
Updates/Corrections		3/29 - 4/1	
Final Report		4/12 - 4/22	
Presentation		4/25/2019	

Table 1: Senior Design 1 Tasks

SUMMER 2019 - SENIOR DESIGN II			
TASK	DURATION	DATES	GROUP MEMBER
Order parts	3 weeks	4/25 - 5/17	ALL
Parts confirmation	1 week	5/17 - 5/24	ALL

PCB Design and assembly	2 weeks	7/1 - 7/19	ALL
Troubleshooting/Testing		7/19 - 7/24	ALL
Prototype enhancement		7/25	ALL
Peer presentation		7/25	ALL
Final presentation		7/26	
Final document		7/27 - 8/2	ALL

Table 2: Senior Design 2 Tasks

2.7 Project Budget

As seen in Table 3, we have devised a preliminary budget based on the products we believe we will need to purchase for this project. This budget is subject to change as the project progresses and does not reflect an actual BOM.

Budget & Financing

Item Description	Price/Unit	Amount	Estimated Price
Longboard	$45-70	1	$60
Temperature Sensor	$4.95	2	$10
Load Sensor (50kg)	$11	3	$33
Battery Charge Sensor	$10	1	$10
RGB LED Strip Light	$15	1	$15
Accelerometer (with Gyroscope)	$10	1	$10
Pressure (Force-Sensitive) Switch	$9	2	$18
Solar Panel (s)	$110	1	$110
Battery	$140	1	$140
Solar charge controller	$35	1	$35
Voltage Regulator	$40	1	$40
PCB Fabrication	$50	2	$100
Bluetooth Module	$15	1	$15
Camera	$30-50	1	$40
Ultrasonic Sensor	$6-$8	1	$7
Motor	$140	2	$140
Total			$758

Table 3: Budget and Finance Breakdown

Although originally, we believed our budget was fairly accurate given our initial research, we ended up going significantly over budget for a number of reasons. The first reason is that we originally did not account for the speed controller(s) as we were not aware that we even needed them. Once we found that out our budget definitely seemed to be on the lower end because speed controls can be quite pricey. Another reason our costs went up is because we needed to buy duplicates because some of our equipment came damaged or was damaged during testing. Seen below is the Bill of Materials of the project in Table 4.

Items	**Cost**
ATMEGA2560-16AU	$ 13.00
BARREL JACK	$ 3.00
1N4733A Diode	$ 2.00
1 K ohm Resistor	$ 2.00
.33u Farad Capacitor	$ 2.00
16 MHz Crystal	$ 3.00
Pin Headers	$ 25.00
Battery Meter	$ 12.00
PST Connector	$ 5.00
Buck Convertors	$ 90.00
Solar Male and Female Connector	$ 18.00
Fuse Holder with Fuse	$ 20.00
Tactile Switch	$ 6.00
PCB Manufacturing and shipping	$ 30.00
Voltage Regulator	$ 12.00
90 mm Hub Motor Kit	$ 220.00
Dual ESC 4.20 100A	$ 160.00
Junction Box	$ 8.00
36 Volt Battery	$ 136.00
Assorted Nuts and Bolts	$ 20.00
Solar Panel	$ 87.00
Electric Skateboard Battery & Electronics Enclosure	$ 38.00
TAS606 Load Cell	$ 60.00
DSD Tech HC-05 Bluetooth Serial	$ 9.00
CHINLY 16.4 ft WS2812B	$ 21.00
SMAKN Ultrasonic Module HY-SRF05	$ 7.00
Retrospec Zed Bamboo	$ 60.00
Total Cost	**$ 1,069.00**

Table 4: Bill of Materials

2.8 House of Quality

Our House of Quality diagram, seen in Figure 2, is used to help visualize how expected customer demands will affect our development process. The weight and importance ratings help us quantify which customer demand has the most relative importance and simultaneously, which parts of the development process contribute the most value towards these customer demands. The legend below helps demonstrate the strength of that potential relationship.

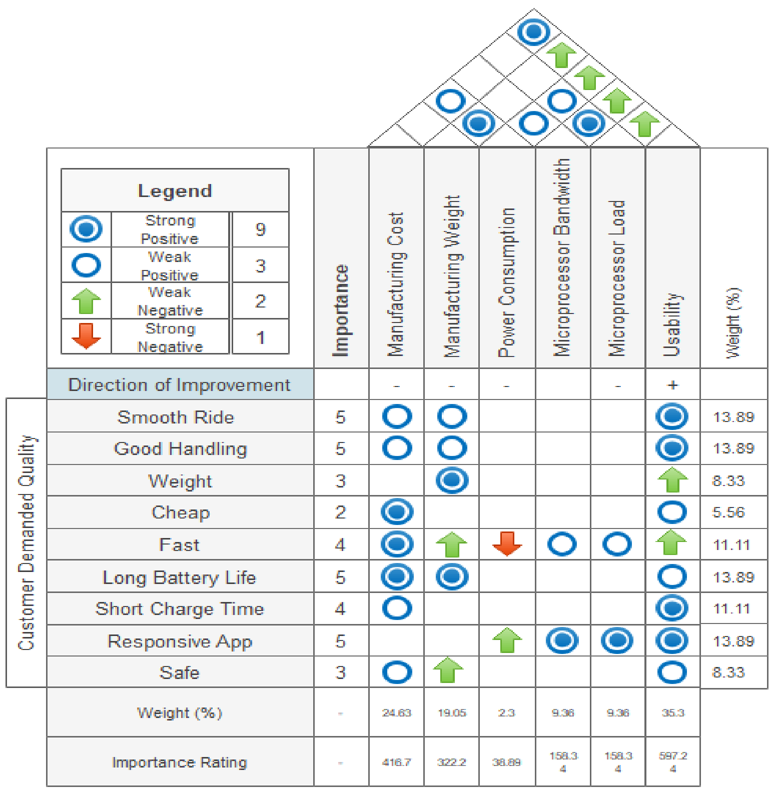

Figure 2: House of Quality Diagram

Overall, we observe that for customer demands, a smooth ride, good handling, long battery life, and responsive app have the most weight. For the development process, usability has the highest importance, followed by manufacturing cost, and manufacturing weight.

3.0 Related Standards and Constraints

Given the complexity of the numerous systems at work within the Phoenix Board, the development process required extensive time and research to ensure that what we were creating was realistically creatable, compliant with existing laws and standards, and in line with our original goals and design philosophy. As such, the following portions detail the various standards that we adhered to and the multiple constraints that we worked under to create our product.

3.1 Project Standards

In order to ensure that our smart board is compliant with existing standards for similar products and technology, we've taken the time to research and address several different standards that directly affect our development.

3.1.1 FCC Standards

The FCC strictly regulates the development and use of electronics utilizing any kind of Radio Frequencies. In order to ensure that the Phoenix Board is safe for use and in proper legal standing, the board has been developed with the following standards for operation in mind.

3.1.1.1 CFR Part 15 - FCC Regulations for Radio Frequency Devices

This set of regulations set forward by the Federal Communications Commission (FCC) dictate the proper use of radio frequency devices. They contain a series of standards and guidelines that devices that generate radio frequencies. Several important definitions include incidental radiators which are devices which may unintentionally generate RF energy during operation such as DC motors, intentional radiators which purposely generate and emit RF energy, and unintentional radiators which generate RF energy for use within the device but are not intended to emit RF energy. With the various systems at play within our smart board, this set of standards provides us with guidelines to use for proper development.

3.1.1.2 CFR 15.5 - General Conditions of Operation

This standard essentially guarantees that no person has exclusive rights over a given frequency. For our device, we would have no right to control a specific frequency, such as the 2.4 GHz that the Bluetooth Low Energy BoosterPack emits on. It also stipulates that our devices must not emit any harmful interference and in the event of such a case, we must immediately cease operation of said device. We will ensure that our smart board's communications are safe and secure so as to only communicate between the board and app (via Bluetooth) and to not generate any possible interference to disrupt the functionality of other parts of the smart board.

3.1.1.3 CFR 15.23 - Home-built Devices

This standard describes how authorization is not needed for devices that are home built, constructed in small quantities, and not intending to be marketed. It also stipulates how in the absence of the proper tools for ensuring compliance, builders are expected to employ best engineering practices. We have continuously done our best during the development process to ensure that we are properly building a functioning prototype that strictly adheres to said practices.

3.1.2 Bluetooth Standards

The Bluetooth Special Interest Group (SIG) is a non-profit standards organization which is responsible for maintaining and overseeing Bluetooth standards, licensing, and marketing. In order for a device to be Bluetooth compliant and market itself as providing Bluetooth services, the manufacturer must complete a certification process with the Bluetooth SIG. This kind of certification is done at the company-wide level.

Bluetooth is split into two different operating modes, Bluetooth Basic Rate/Enhanced Rate and Bluetooth Low Energy. Our initial Bluetooth BoosterPack Module (BOOSTXL-CC2650MA) uses Bluetooth Low Energy conforming to Bluetooth 4.2 standards. According to Bluetooth 4.2 standards, the Low Energy radio needs to operate at the 2.4 GHz Industrial, Science, and Medical (ISM) band. The system uses frequency hopping transmission to transmit data. It contains 40 channels, split into 2 MHz bands. The overall architecture of a Bluetooth system is split into Host, Primary Controller, and zero or more Secondary controllers. Because of the ease of use and compatibility of the Bluetooth BoosterPack with our MCU and the relative short distance the board will maintain with the rider's phone, this system looked to be the easiest to develop with. Our final Bluetooth HC-05 module uses Bluetooth Classic 2.0.

3.1.3 Power Standards

The Institute of Electrical and Electronics Engineers (IEEE) has developed hundreds of industry-driven consensus standards in several applications relating to the technology used in the integration of photovoltaic (PV) systems. For this project we will focus more on the standards relating to PV solar energy and its integration in the power systems. As a result of the advancement of technology new business opportunities are becoming more prominent, which results in the synchronization of codes and standards that must be developed with each new technology.

The U.S. Department of Energy, DOE and its laboratories have unique opportunities in developing and improving standards and test procedures for grid connected devices and systems. By providing leadership and technical assistance IEEE is partnering with industry experts to accelerate and revise foundational codes and standards governing the manufacturing and use of PV systems.

3.1.4 Battery Standards

The standards for battery are limited to maintenance, testing schedules and procedures that can be used to optimize the life and performance of the battery. The user is responsible to exercise caution when using any form of battery and evaluate these practices against their operating experience, operating conditions, manufacturers recommendations, resources and needs. Maintenance and testing programs were developed using specific guidelines by the manufacturer and should be followed, especially since different type of batteries were developed using different material which would require knowledge of safety procedures for full and effective functionality.

3.1.5 C Programming Standards

For our C coding, we chose to follow the Recommended C Style and Coding Standards, a modified version of the original Indian Hills C Style and Coding Standards paper. These standards are more or less the C coding that our group has learned during our academic career.

Our group has taken steps to ensure that we adhere to these standards so as to ensure that our code is easily compatible amongst our team, regardless of who has completed it. We make sure to use ample comment space to help any team members clearly understand what the purpose of a section of code is. White space and proper blocking are also used to make the code more readable, especially as the volume of needed code begins to expand.

Other examples of good coding standards include using clear, capitalized, pre-defined CONSTANTS to create consistent test values and assist with debugging. Clearly defined sentinel values and error states are used to further improve our debugging and code clarity.

Lastly, in order to ensure that memory is correctly allocated and sparingly used, the best possible variable instantiation is used to minimize memory usage while still allowing for the system to remain robust. We have a large volume of data being transferred back and forth from our companion app to the smart board via Bluetooth, and if the board's MCU were to run out of memory, potentially dangerous conditions could arise for the rider. Thus all possible failure states must be avoided when possible and safely handled, should the need arise.

3.1.6 Wireless Charging Standards

The wireless charging market has been operating under the Wireless Power Consortium (PWM) and the Power Matter Alliance (PMA) standards until recently when it was merged into one company that is now focusing on Qi systems. Qi is the WPC standard for inductive charging and involves coupling electromagnetic field (EMF) from a transmitter coil with a closely coupled Rx coil placed over the top. In essence, a tightly coupled coil (inductive) allows for maximum power transfer while a loosely coupled coil can be placed anywhere in the field.

3.2 Project Constraints

Given the complexity of the different systems at work, our board has a variety of constraints to take into account. Manufacturing cost was one of our most immediate and ongoing constraints, making sure that we were able to minimize this while still using supported parts that were readily available. Simultaneously, keeping our project design realistic and attainable within the given time frame has also been prominent. Below is a detailed breakdown of each category of constraints.

3.2.1 Economic Constraints

As mentioned above, this was one of our most important constraints that has affected every step of the development process thus far. Our project does not have any active sponsors and as such, is being paid for out-of-pocket by our team, split evenly amongst the members.

Beginning from scratch with an open design concept leaves a lot of room for costs to balloon and as a group, we've made conscientious decisions to keep that in check. This has had an effect on our design process, ensuring that with every new feature we add and every feature we tweak, the marginal benefit is weighed versus the marginal cost. Even so, our current board cost is around $1100. This is important as other competing electric smart boards offer prices that can be comparable to our current cost and therefore any future plans to market and sell the board would need to remain competitive to have a realistic chance of entering the market.

3.2.2 Time Constraints

Time is one of the most finite resources we have. With our current work, school, and personal schedules, it takes a considerable effort to stay on track and make sure that our team is consistently meeting our deadlines, given how limited our time to complete the project between both semesters is. Our final paper is due by the end of April 2019 with a final prototype being due by the end of Summer 2019. This gives us a tight window for development, prototyping, testing, and finalization.

As such, we've had to plan out our board's desired functionality and conduct research on each component and its possible implementation. From there, physical prototyping will need to take place, leading up to as lengthy a testing phase as possible prior to finalizing the prototype for presentation.

3.2.3 Size and Weight Constraints

With our board being electric powered, there are a plethora of factors that can affect the battery life of our board, which ultimately affects the user experience with the board. The weight of the board itself, the weight of the user, the desired speed the board is traveling at, and the current temperature are a small sampling of the constraints we need to be aware of when designing our board.

Other size constraints include the size of the board itself and how much flexibility do we have with mounting our PCBs and other desired components. Components like a larger battery can increase the stability of the board by lowering the center of gravity but at a potential cost to the handling/turning capability of the board.

3.2.4 Social Constraints

Our smart board is designed for any user interested in using an electric longboard with a more robust user experience. Ideally, the board would be competitively priced compared to other electric longboards available, while still being profitable but without the potential label of being labeled "frivolous" or "luxury". The board should be able to support users of different sizes and weights with a minimal difference in performance, if any at all. The battery life for the board should be as long as possible with as minimal a charge time as possible from both solar and wall charging.

Regarding the app, by using React Native, we can ensure that the software needed to run the board will work on both iOS and Android, thereby increasing the potential audience. We would want to ensure that the app is easy to use on different size phones, with no discernible change in experience. Additionally, we can have room to develop multiple language versions of our app, should the market for this arise.

Lastly, it is our desire to make the board as available to any level of existing experience. Whether a complete novice or a long experience rider, the board should allow either to have fun and have potential to improve over time.

3.2.5 Environmental Constraints

From the beginning, our goal has been to create a fast, efficient, electric-powered longboard with solar powered charging. As such, this helps minimize the footprint that our smartboard leaves on the environment. We also want to make sure that our battery is as efficient and safe as possible, properly housed on the board and protected to prevent and potential hazards or toxic elements from accidentally being released during use.

3.2.6 Health and Safety Constraints

Safety is one of our most paramount constraints when designing our smart board. The nature of skateboarding itself can be dangerous if not done properly and safely. With improper use, the rider can injure themselves as well as others. Even a loose board with no rider can be a potential hazard. As such, our design has several built-in safety features. We are including weight sensor to detect if a rider is no longer on the board. This ensures that if the board is in motion and the rider is suddenly not detected, the board can begin to slow the motor to a stop.

The smart board will also have a front mounted camera coupled with an ultrasonic sensor as a form of collision detection. Should an object or obstacle be detected and the rider is going over a certain threshold speed, then the board will engage an emergency slowdown of the boards motor. This helps keep the rider safe without instantly stopping the board and potentially ejecting the rider.

The smart board’s electronic components housing needs to be strong and secure. Taking into account uneven surfaces and obstacles, there can be any number of things that can potentially impact the housing. It’s important that all interior components are cushioned to protect against this as well as sealed to prevent any water or moisture from entering and damaging the components. We are in the process of examining different materials to construct the housing, including plastic or metals such as aluminum.

Our smart phone app will allow for riders to set maximum speeds of the board. This helps ensure that newer, inexperienced riders can’t operate the board at potentially dangerous speeds. Additionally, the board would need a connection to the app to avoid any situations where either the smart board or the rider’s phone may run out of battery. In case of this, the board would engage an emergency slowdown and notify the rider of a potential error via the app or board LEDs, whichever are appropriate. Lastly, to prevent any kind of unauthorized access to the app or the board, we would ensure that the connection between the two is secure and cannot be overridden or hijacked from an outside source.

3.2.6.1 Risk Analysis of Different Ride Mode Vs. Different Rider Proficiency/Experience

Due to the nature of our project, there are inherent risks that are being taken by any individual who chooses to operate it. This will be a motorized vehicle that does not have any restraints and therefore a collision could lead to the injury of one or multiple people.

		Rider Proficiency/Experience			
		None	Beginner	Intermediate	Advanced
Ride Mode	ECO	Medium - 4 -	Low - 2 -	Low - 1 -	Low - 1 -
	Beginner	Medium - 5 -	Medium - 4 -	Low - 2 -	Low - 1 -
	Intermediate	High - 8 -	High - 7 -	Medium - 4 -	Medium - 3 -
	Advanced	Extreme - 10 -	Extreme - 9 -	High - 6 -	Medium - 5 -

Risk Rating Key	Low (1-2) Proceed as Planned ---------------- Minor Injury Possible	Medium (3-5) Proceed with Caution ---------------- Minor Injury Possible	High (6-8) Not Recommended ------------------- Serious Injury Possible	Extreme (9-10) Highly Not Recommended ------------------ Severe Injury Possible

Figure 3: Risk Analysis Diagram

As such, we have created the risk analysis diagram seen in Figure 3 and plan to implement different ride modes in order to more clearly define the possible dangers as we see them. The ride modes will act as a safety gate for the less experienced riders in order to mitigate the harm they may put themselves in. Although we will do our best to ensure that our project is as safe as possible, there is also the understanding that accidents may occur and it may lead to injuries of varying gravity, even at lower speeds and by very experienced riders.

3.2.7 Manufacturability Constraints

With designing our smart board and having to cover the cost of components ourselves, being aware of the availability of components has been key to being able to create a proper prototype. Our research phase helped us find the best balance of recent tech with ready availability. This helps keep the net cost of the prototype down while simultaneously allowing us to quickly replace any failed components at a minimal dollar and time cost.

3.2.8 Sustainability Constraints

The long-term use of our smart board is important, especially given the cost of materials and components. A rider should be able to go considerable distances with daily use over an extended period of time. As such, components such as the motor should be able to withstand this kind of heavy use without becoming damaged or burning out. As mentioned above, the housing for electronic components should be secure and capable of withstanding occasional impacts whilst remaining waterproof. The internal battery should be able to maintain as much of a charge as possible over time, taking gradual battery degradation into account, while still being safe and secure to avoid any potential toxic or fire hazards. Charging the battery should still be as quick as possible from either solar or standard electrical sources with minimal degradation to charge speed over time.

The companion app should be available on either mobile operating system, allowing for easy updates to the system software. Using React Native allows for us to support and update one version of the companion app, pushing out updates quicker and avoiding developing two separate versions at the same time. With proper updates, the app should be able to work correctly over later phone operating systems.

3.2.10 Political Constraints

After careful research and consideration, we were unable to determine any political constraints which would have an effect on our smart board.

3.2.11 Ethical Constraints

We want to ensure that our rider's information is safe and secure, especially since a companion app is being used. As mentioned above, we are developing our app with security in mind, taking steps to ensure there are no exploitable security vulnerabilities. Fortunately, there will not be any outside user data stored elsewhere and all communications will be done via Bluetooth between the board and app.

As mentioned above, we also want to ensure that the components we use, especially with regards to the battery, are safe and secure for the rider to operate. We strive to ensure that the components used are properly built from reputable manufacturers and that there are no potentially dangerous faults lurking in our board design.

3.2.12 Software Constraints

We are using React Native to develop our app, ensuring that the app runs natively on either iOS and Android. This software uses a React JavaScript framework which has a wide array of flexibility, including a very active development community which is constantly creating new libraries and APIs for improving software performance as well as component integration.

Additionally, its performance is tied to the speed of the actual platform running it. As long as we can ensure a minimum level of processing power and memory, we can guarantee a safe baseline level of functionality to properly run the smart board.

4.0 Project Research

Our team began with a general idea of what we were looking to create. In order to realize this idea and create something realistically attainable, we conducted days of extensive research on the various components and systems needed.

4.1 Overview

A detailed and extensive research is required for this project and will be centered around making a very efficient board that will provide the user with a comfortable ride as well as an easy interface to communicate with the board effectively. This is essential to the design as it will allow us to gather all the necessary information and enable us to make intelligent decisions on factors relating to having a reliable, efficient design that will utilize some of the best technology that exists today. The topics researched were the choice of motor, microprocessor, charger controller, and battery amongst many other integral systems that this project required.

4.2 Existing Projects

There are quite a few projects out there that have similar outcome, but so far, we were unable to find one with the same features as the one we are designing which makes it unique and very special to us as designers. We will, however, use similar projects as a reference especially in helping us to figure out how some of the technologies work, the challenges faced and how to avoid them. Table 5 shows a comparison between what was done and what we will do.

	Related Project	Phoenix Board
Charging	Plug In	Inductive Charging
Solar Powered	No	Yes
Microcontroller	Arduino/ARM	ATMega2560
SmartPhone Compatible	Android Only	Android and IoS

Table 5: Existing Project Comparison

4.2.1 Other Existing Projects

The market for electric modes of transportation, such as scooters, bikes and skateboards has really taken off in the past few years as more people are turning to these for short-to-medium distance commutes and many companies are blossoming with these powerful products. As would be expected, we took a look at others in this field who have had success in order to learn from them as well as to be able to distinguish ourselves from already existing products, which has allowed us to see some of the standards set by the industry in its current form and build on top of them. One of the biggest takeaways from this was noted early on in the research, as we could not find any boards that were marketed for being solar-charged. The closest thing there were a few concept ideas found online but nothing concrete, and this we knew would set our product apart.

4.2.1.1 Halo Board - 2nd Edition

The Halo Board 2nd Edition is an extremely well-made product and amongst the top names in the current market for electric skateboards. It is 9.75 in. x 36 in. x 5 in. (WxLxH), and has a double kick cutaway design putting it at right about the center in the trade-off of stability vs. maneuverability. A unique feature this board boasts is its handle, seen in Figure 4, which has been built into the deck of the board which makes it easier to carry around in times or places where riding is not allowed or recommended. The trucks are made of aluminum and are 9.25 inches wide for a wide, stable base and it is the trucks in the back that handle the motor as this board is rear-wheel drive. It is made out of a “superlight, super strong” T700 Carbon Fiber guaranteeing consumers that their board is sturdy and can take the occasional hit while weighing only 14 pounds. This point is further proven by the fact that the board has a weight limit of 286 pounds.

This product also uses regenerative brakes which help recharge the batteries as you brake which helps it achieve its 14 miles of ride time per battery charge. This board also offers a substantial amount of torque, being able to generate speeds of up to 26 MPH with 3000 Watts of power, and with its Torque Management acceleration algorithm the consumer experiences a smooth ride regardless of their speed. The Halo board can handle hills of up to 25% gradient. The Halo Board 2 is water resistant to small splashes but is not however waterproof so it is best to avoid submerging the board or battery in or water or to ride in heavy rain.

The board offers two ride modes, one with a lower maximum speed made for beginners and crowded areas. The motors for this board are dual in-wheel hub motors that produce very little noise, require no maintenance and allow the user to kick push once the battery has died. In order to control the board a remote control is included which displays the ride speed, board battery life, control battery life and overall signal strength. The battery used on this board is a 7Ah Certified FireSafe Lithium Ion battery and it requires 3 hours to fully charge. Price: $1,497 USD.

Figure 4: Halo Board and Controller

4.2.1.2 Evolve Skateboards - Bamboo GTX Series

Another great board that is currently on the market is Evolve Skateboards' Bamboo GTX Series, which comes in a street version and an all-terrain version, with the street terrain built for smooth and hard surfaces while the all-terrain can handle any hard or compact surface. The deck is made of 7-Ply Canadian Maple 2-Ply Bamboo and boasts a sleek Drop-Through Symmetrical Cutaway design, making it a fairly stable board. For an actual look at this design, reference Figure 5. The board has street version has a range of up to 31 miles and the all-terrain can go up to 18.5 miles but these values vary depending on the weight of the rider and the terrain.

Figure 5: Bamboo GTX and Controller

Another factor that is depending on those variables is the speed which can vary from 22 - 26 MPH and 22 - 25 MPH for the street and all-terrain versions, respectively. These boards can also handle the 25% hill gradient that Halo boards could handle. The weight of the street version is 19.4 pounds and the all-terrain weighs 21.6 pounds, making these the heaviest boards amongst the similar products we researched. These boards also cannot handle as heavy a load, maxing out at 220 pounds. The board's motor is a gold plated 3000

W high performance censored dual brush out-runner motor that runs on a 36 volt 10Ah Lithium Ion battery.

The remote control for the Evolve boards includes four speed modes, a programmable safety/deadman switch, a reverse function, battery indicator, USB charger and a leash. The charge time for this board is approximately 4-5 hours but with Evolves optional “fast charger” this can be reduced to 2.5 hours. And the Evolve board also has regenerative brakes which give power back to the battery as you brake and is also rear-wheel drive. Price: $1,779.99 USD.

4.2.1.3 Boosted Boards - Boosted Plus

The Boosted Plus has a “Super Flex Composite Deck” which aides in a smooth ride and, as can be seen in Figure 6, has a Double Kick Cutaway design, which again is a great choice in balancing maneuverability and stability so that riders of any experience level may quickly become comfortable with it. Like its competitors, the Boosted Plus can handle slopes of up to 25% gradient and has regenerative brakes, which seem to be an industry standard. This board measures in at 11.3 in. x 38 in. x 5.7 in. and weighs 17 pounds. It has a top speed of 22 MPH and a range of approximately 14 miles, all powered by a 2000 W motor.

The wheels for the board, the Boosted Stratus, are 85 mm and are customized with an H-Core for stability and support. The wheels are further supported by the 190 mm CNC Precision Machined trucks which have added material in high-stress areas. The Boosted Plus, like its competitors also uses a rear-wheel drive system. This board happens to have the quickest charge time of the three, even beating out Evolves “fast charger” with a full recharge time of 1 hour and 45 minutes. The remote for the board uses Bluetooth technology and has multiple LEDs that showcase the board’s battery life, the signal strength, remote battery life and gives you control of the speed as well with a dial and a trigger. Price: $1,399 USD.

Figure 6: Boosted Board and Controller

We have compiled, to the best of our ability, as much information on each of these boards and consolidated it into Table 6 in order to compare their specs up against one another in a neater and faster form. Please reference the table below.

	Halo Board	**Evolve Skateboards**	**Boosted Boards**
Range (miles)	14	19	14
Top Speed (mph)	26	22 - 26	22
Hill Climbing (grad)	25%	25%	25%
Ride Modes	2	4	4
Weight (lbs)	14	19.4	17
Max Load (lbs)	286	220	250
Dimensions (WxLxH)	9.75 in. x 36 in. x 5 in.	-	11.3 in. x 38 in. x 5.7 in.
Power (W)	3000	3000	2000
FWD vs. RWD	RWD	RWD	RWD
2-Wheel vs. 4-Wheel Drive	2	2	2
Braking	Regenerative Brakes	Regenerative Brakes	Regenerative Brakes
Deck	100% Japanese T700 Carbon Fiber	7-Ply Canadian Maple 2-Ply Bamboo	Super Flex Composite Deck
Wheels (mm)	Halo Street Wheels - 83	Evolve GT Street Wheels - 97	Boosted Stratus - 85
Trucks	9.25 in. Aluminum	Evolve Super Carve	190mm CNC Precision Machined
App	-	-	iOS and Android
Remote	Ergonomic Bluetooth Halo Remote	Magnetic Trigger Controls	Ergonomic Bluetooth Remote
Charging Time (hrs)	3	4 - 5	1.75
Price (US)	$1,497.00	$1,779.99	$1,399.00

Table 6: Board Comparison

4.2.2 Rear-Wheel Drive vs. Front-Wheel Drive

The arguments for rear-wheel drive and front-wheel drive both have their advantages over the other but overall there doesn't seem to be much of a consensus about this in the electric skateboarding community. The three boards examined above all used rear-wheel drive but when customer service representatives were asked about this (via Live-Online chats) both Halo and Evolve said there was no reason behind this. The customer service representative for Boosted however said it was the most effective way to "put the power down." For more information on the difference between these two methods we turned to cars as similar principles would apply albeit on a larger scale. With this we found that the main benefit that front-wheel drive could have on our board would be better steering traction. Along with this there was the mention of better fuel economy which may or may not apply to the board since it is electric but if it did this would mean that our battery's charge could last longer. The cons to this however are that there would be a limited amount of power going to the front wheels and there would be a lot more wear and tear on the front wheels which could require increased maintenance. The pros of having rear-wheel drive are that the front wheels would be subjected to less wear and the weight distribution would be more even, allowing for better handling of the board. The cons here would be that the traction takes a significant negative impact during rides with poor weather conditions but as this board will not be made to be waterproof this is something that would be best avoided anyway.

4.2.3 2-Wheel Drive vs. 4-Wheel Drive

When it comes to this option there again was not a lot of conclusive data found. With that in mind however, from what little was found it seemed to indicate that 2-wheel drive was more than enough to handle most riders. Aside from that, the conversation of 2-wheel drive then leads back to the question of front or rear-wheel drive, therefore any information that was mentioned previously also can be taken into consideration here. In the electric skateboarding community, 4-Wheel drive is used more so in competitive racing but the majority of electric skateboard enthusiasts do not take their riding to this degree. The only other benefit to 4-wheel drive is that the increased traction provides the means for the board to be taken on more uneven terrain such as sand but this could also potentially require larger wheels that can handle bigger obstacles. A con to 4-wheel drive though is that it does add some weight to the board and would therefore make it harder to carry and could also reduce the battery's efficiency.

4.3 Component and System Specific Research

The Phoenix Board has a number of onboard systems, relying a suite of sensors to provide continuous information to both the user and the onboard power system for safe and reliable usage. The following sections consist of research on each of these systems, further broken down into each electrical component they consist of and any relevant information.

4.3.1. Electrical System Overview

The electrical of this design will be unique simply because there are not too many similar projects that exists. This means that the system will be carefully designed with all the considerations for safety and durability and also to ensure that the system performs beyond expectations.

There is a variety of energy storage options in the power industry today and the competition seems to be on-going. Deciding on what is used is on the shoulders of the user and has a lot to do with their need and the purpose the storage will serve. Since there are capacitors, compressed air, pumped hydro and not to mention, rechargeable batteries, each with their own merits on the technology and the application, it is inevitable that the user spends some time to carefully analyze their needs so the most suitable choice can be made.

4.3.2 Battery

A battery is a collection of one or more cells that creates a flow of electrons in a circuit through a chemical reaction process. While some batteries were designed small and can run for prolonged periods, they may not last very long. Other batteries, built for long life will be a little bigger in size, or should I say, bulky. Another battery may be just right, having relative size, long lasting and having other factors such as reliability, environmental impact, safety, maintenance cost, just to name a few.

Battery is one of the most crucial and important devices one could ever design. The manufacturers are aware of this and have responded by offering different types of batteries that suit every need. This storage device has so many applications in many different areas, it’s hard to do without them. Since we’ll be using batteries in our design, let’s talk a little about the types and their purposes.

4.3.2.1 Lithium-ion Battery (Li-on)

The basic concept of li-on batteries was conceived in the 1970’s as having a charged lithium ion shuttling back and forth between the cathode and the anode during charge and discharge.

Lithium is the lightest of all metals and has the greatest electrochemical potential and provides the largest energy per weight. Although most of the li-on batteries are similar in design, there are some things that separates them from other types of batteries. The li-on battery is charged on an algorithm with high capacity, low internal resistance and low self-discharge. This makes the battery a preferred choice among batteries. The downside to the li-on is it requires protection circuit to prevent thermal runaway is stressed, and the inability to withstand elevated temperatures if charged at a high voltage.

There is a wide variety of batteries that can be used to provide power to the skateboard design, but just a few that we provide adequate power and reliability that we anticipate for the project. As a result, one of the preferred choices for battery comes with 30 - 18650 lithium cells and weighs approximately 1.44kg. This 10S3P lithium battery is packed with 36V, 6Ah of power and can deliver adequate power to skateboard.

4.3.2.2 Lead-Acid Battery

Lead acid battery was invented by a French physician Gaston Plante in 1859. This system is known to be the first and oldest of all the battery types in the world of rechargeable battery, especially for commercial use. Lead-acid batteries are toxic, but they are dependable and inexpensive on a cost-per-watt base and is more commonly used for automobiles, golf carts, forklifts, marine and other uninterruptible power supply (UPS) since the charging is simple. The grid structure of the lead acid battery is made from a lead alloy and is heavy and less durable than its competitors such as lithium and nickel type batteries when deep cycled. With a moderate life span, lead-acid batteries have a very good charge retention and works well in cold temperatures.

One important consideration to make when using lead-acid battery is that the voltage limit shelters the battery. Although the performance is improved at high voltage levels, the correct voltage limits must be observed when using because of the grid corrosion that is formed on the positive plate that is permanent even if the sulfation caused by low charge is reversed in time. Sulfation robs the battery of performance but can also be reduced by adding carbon on the negative electrode.

It is recommended that lead-acid batteries be charged in three stages. Constant-current charge, topping charge and float charge. Constant current charge allows the battery to charge for 5-8 hours or up to about 70%

4.3.2.3 Sealed Lead Acid

The sealed battery is a type of lead-acid battery that contains less electrolytes and can combine oxygen and hydrogen to create water and prevent dry out during cycling. These batteries are mainly used for UPS, emergency lighting and wheelchairs because of the low cost, dependable service and low-maintenance. They are designed with a low over-voltage protection potential that prevents the battery from generating gas during charge.

Energy storage is something to consider when it comes to solar energy. The fact that there will be occasions when the solar panels just will not produce enough energy to carry out required tasks, you want to ensure there are no setbacks, especially during a time when reliability is of utmost importance. Thus, these batteries are great choices to eliminate the worry and take the guessing out of the equation. They are reliable, have the capacity to withstand different temperatures and offers a dependable source for energy storage.

Since we will be using solar panel for our design a storage battery will provide the peace of mind throughout our demonstration, with a constant source of power that will enable us to fulfill the requirements and demonstrate our understanding of the engineering principles.

4.3.2.3 Nickel Battery

There are two major types of nickel battery, Nickel Cadmium (NiCd) and Nickel-Metal Hydride (NiMH). The NiCd type battery is known to be a strong and silent worker that requires fast charging and is the only battery type that performs well under rigorous working conditions. NiCd remains a popular choice in many industries that uses applications such as two-way radios, emergency medical equipment and power tools. Although the NiCd has a low energy, high self-discharge and contains toxic metals it provides over 1000 charge/discharge cycles if properly maintained. In addition, the NiCd has a long shelf life and a good load performance which allows charging and recharging at low temperatures.

The NiMH battery in comparison to the NiCd battery has a 30 – 40 percent higher capacity. Its performance is driven by its high energy density and the use of metals that are environmentally friendly. In the early days, the metal hydride alloys were unstable in the cell environment resulting in a slowdown of development of the NiMH. Over the years, new hydrides were developed that were stable enough for use in a cell, thus, improving the stability if the NiMH. These batteries, though bulky and containing high pressure steel canisters costing thousands of dollars are mainly used for satellite applications, wireless communications and mobile computing.

Refer to Table 7 for a side-by-side comparison of the various battery technologies.

Specifications	Lead Acid	NiCd	NiMH	Li-ion[1] Cobalt	Li-ion[1] Manganese	Li-ion[1] Phosphate
Specific energy (Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80% DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	1.00V		2.50–3.00V		2.50V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 65°C (–4 to 49°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months[10] (toping chg.)	Full discharge every 90 days when in full use		Maintenance-free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		

Table 7: Breakdown of Battery Specifications

We've chosen to use the lithium ion battery for our design. This battery will be 36 volts, with 10S2P7 configuration capable of providing power for a range of 800 - 1200 watts. Table 8 below gives a clear description of the lithium battery of choice.

Battery Type	Lithium Ion
Nominal Capacity	7 - 10 Ah
Nominal Voltage	36 volts
Configuration	10S2P
Charge End	42 volts
Discharge End	30 Volts
Charge Current	<10 Ampere
Weight	2.5 KG

Table 8: Battery Specification

4.3.3 Solar Energy Overview

Solar energy is the energy converted into either thermal or electrical energy directly from the sun. According to the Solar Energy Industries Association (SEIA), solar energy is the cleanest and most abundant renewable energy source available. Here in Florida, the sun is over 80 degrees Fahrenheit for most of the year, which means that users would benefit greatly from solar energy.

The solar market has grown significantly over the last 5 to 10 years, with an average growth rate of 50% each year. Solar is used in a variety of ways, including providing power to homes and businesses. Throughout 2018, more than 64 gigawatts (GW) of solar was installed in the United States which is enough to power more than 12.3 million homes. Producing electricity from solar was the second discovery made after the initial discovery where solar power was used for heat. A French physicist named Edmund Becquerel realized that the sun's energy could produce a "photovoltaic effect."

Florida is known to be the sunshine state, which means there is a lot of sunshiny days. If you live in Florida, you'll know that there is 80 to 90-degree weather for most of the year. Using solar panels is a terrific way to convert the free energy from the sun into useful electrical energy, while saving money on maintenance and electric bills.

Most solar power systems use 12-volt batteries, like what you will find in cars, but can deliver far more power than what it would take to charge these batteries. For this project, we chose to utilize solar for the charging portion which will be coupled with wireless charging technology. There are multiple different options for solar technology, which we will be looking at in the options below, however, the practical and environmental nature of solar power has been a major influence worldwide. Because of this, equipment sales have been soaring and the production has seen significant increase since the nineteenth century.

There are two main disadvantages with using solar. The cost of the equipment is probably the biggest since the more efficient the panels are, the more likely it is that they will also cost more. According to the Director of the Department of Energy National Center for

Photovoltaics, Larry Kazmerski, the best way to best way to lower the cost of solar energy is to improve the efficiency of the cells. Any improvements in reducing the cost of solar will incorporate the electric companies that might be willing to help by offering benefits or other incentives.

The next disadvantage of using solar is the amount of sunlight. This means that the placement of the panels including the geographical location, time of day, seasons and clouds are all factors affecting the performance. There are stipulations that having solar placed facing the east and south is ideal so there is a direct beam of sunlight directly on the solar panels.

Figure 7 is a simple description of the connection between the solar panel, voltage regulator, solar charge controller and ac or dc output.

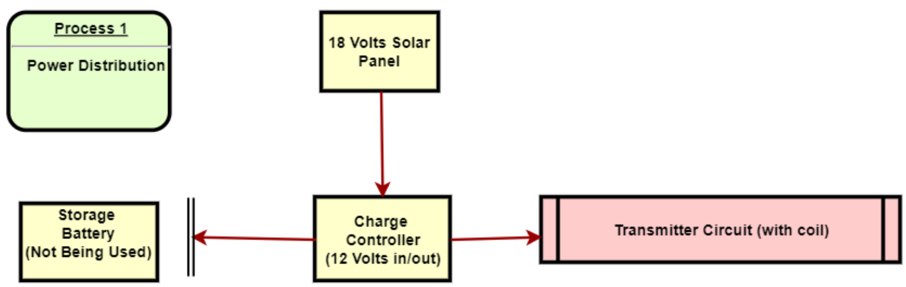

Figure 7: Typical Solar System Design

Figure 8 is a description with the connections for the skateboard. This includes a detailed connection from the receiver, incorporating the boost converter that converts the 12 volts to 36 volts that is required by the battery.

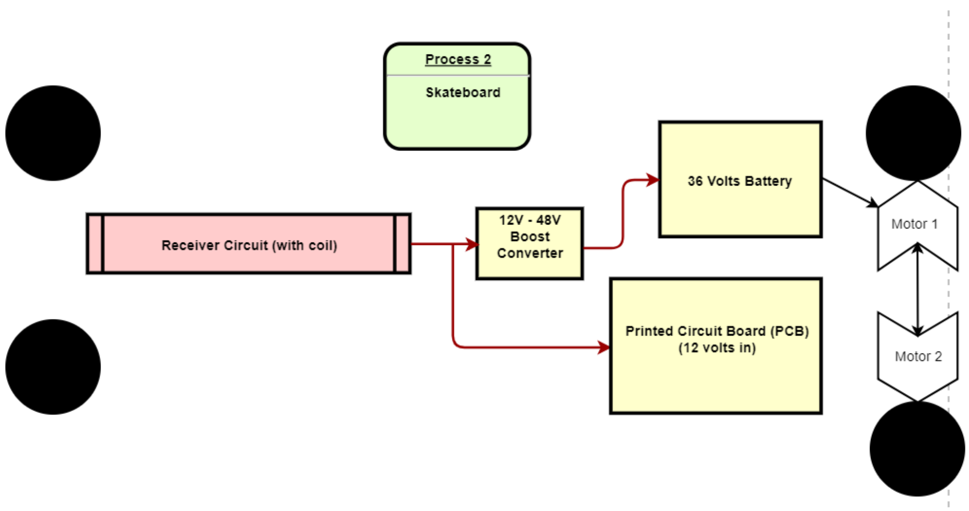

Figure 8: Connection for the Skateboard

4.3.3.1 Photovoltaic (PV) Solar

In the year 1880s, selenium photovoltaic (PV) cells were developed with the ability to convert light into electricity with efficiency between 1 and 2 percent. Today, PV cells represents more than 90 percent of solar on the market with multiple options to choose from depending on the needs of the end user.

By using photovoltaic cells (PV), solar energy can be directly converted into electricity. After this conversion, the electricity is then used to power lights, livestock feeders, computers and other variety of equipment, including our solar powered wireless charge skateboard without any form of connection to the electric grid.

Other applications of solar include hybrid solar system, solar farm, rooftop PV, stand-alone solar power system, solar grid connected system and of course, the solar home system. To generate electricity PV cells, require daylight and does not require direct placement in the sunlight which means they can still generate electricity even on cloudy or overcast days. This is dependent on the cell's conversion efficiency which contributes to more generation if higher. The lower the efficiency, the less generation.

PV power has advantages over other sources such as wind, hydro and solar thermal which requires turbines with moving parts can have the potential to be noisy and will require maintenance. Driving on interstates in different sections of Florida there are acres of land which are used as solar farms. These properties are secured from wild animals and require little maintenance. As the sun beats down on the panels the energy is being utilized reducing the demand from coal fired power plants. The unused energy is stored using battery storage and is dissipated when the sun goes down. At that time, there is not much demand for the energy produced by these panels, so the supply and demand curve will most likely synchronize.

4.3.3.2 Thermal Solar

Thermal solar technology can be used for a variety of things, including water heating for homes or commercial properties. In order to keep buildings cool, solar energy is absorbed during the day and radiate stored heat to cooler atmosphere at night. The opposite is also true, where they are used in cold temperatures to maintain warmth.

Thermal power generation system is comprised of two main components, reflector and receiver. The purpose of the reflector is to capture the sunlight and focus it onto the receiver. A tracking system is put in place that keeps the sunlight focused on the receiver throughout the day. There is a heat transfer fluid in most systems that heated and circulated in the receiver to produce electricity. Some thermal power systems may have a storage system component that allows the energy to be stored during the day and the heat from the system will then be used to produce electricity in the evening or on cloudy days.

4.3.3.3 Monocrystalline Solar Panels

Monocrystalline is the oldest and most developed of all the technologies and is a type of PV cell material manufactured from a single crystal silicon structure that is dipped into molten silicon and is slowly pulled out of the liquid producing a single continuous crystal ingot. The cell is composed of a single crystal, the electron that generates a flow of electricity, resulting in more efficiency than other types of panels such as the polycrystalline, converting more than 22 percent of the sunlight into electricity.

Monocrystalline solar panels were made using the highest-grade silicon and have the highest efficiency rates. So far, we are yet to settle on exactly the type of solar panel to use. After going through the different options, we discovered that there are pros and cons to everything, including the choice of panels. These panels have a longer lifespan, with some manufacturers having a warranty of 25 years on their products with the hope that they will last much longer.

Although they are the most expensive, monocrystalline panels seem to have the ability to exceed its competitors, making it the preferred choice for our project.

4.3.3.4 Polycrystalline Solar Panels

This type of cell is one of the newer PV cell technologies that vary in the manufacturing process. These panels are also made of silicon, but instead of a single crystal, the fragments of silicon are melted together to for wafers for the panel. Because of the amount of crystals in each cell there is less freedom for electrons to move, resulting in the polycrystalline panels being less efficient.

Depending on your preference, either panels are good options, but of course, there are some things to consider, such as; cost, efficiency, aesthetics and longevity. In November 2015, a 21.25 percent efficiency was recorded allowing Trina Solar to produce modules with efficiency between 18-20 percent, placing them close the monocrystalline cells in terms of efficiency. Typically, these panels have efficiency ranging between 14-16 percent which is not as efficient as the monocrystalline.

4.3.3.5 Thin Film Solar Panels

Thin film solar panel was developed originally for space applications because of its power-to-size and weight ratio compared to polycrystalline and monocrystalline panels. These panels are produced by printing or spraying a thin layer of semiconductor PV material onto a glass, metal or plastic foil substrate. The thin layer material is applied so that the overall thickness of the PV cell is smaller than other crystalline cell, thus, the name “thin film.”

The process of printing or spraying the thin film is the main factor behind the fast and cheaply priced manufacturing cost for the thin film PV cell. As a result, the efficiency of this thy of panel can be less than 10 percent. Another factor contributing to the low efficiency is the poor cell conversion efficiency due to the non-single crystal structure that require larger sized panels.

Thin film panels are the newest of the two panels mentioned above, monocrystalline and polycrystalline, can be easily identified because of the solid black appearance that has no frame. In some industries it is referred to as the worst of all the panels because of its low efficiency. The substance used in the manufacturing process varies, and are broken down into the following four types.

4.3.3.5.1 Amorphous Silicon

A non-crystalline form of silicon that are formed by vapor-depositing a thin layer of silicon material on a substrate material such as glass or metal. It has been on the market for over 15 years and is widely used in pocket calculators, some private homes, buildings and remote facilities. The major advantage of amorphous silicon solar cells is their low manufacturing costs, making them competitive. Because of the low efficiency attempts have been made to improve the cells resulting in a more complicated process that are likely to increase the cost.

4.3.3.5.2 Cadmium Telluride (CdTe)

CdTe cells are the second most common PV technology in the world after crystalline silicon. These thin film cells are inexpensive and can be manufactured quickly providing a lower-cost alternative when compared to other silicon-based technologies.

4.3.3.5.3 Copper Indium Gallium Selenide (CIGS)

CIGS is a cell with one of the highest efficiency alternatives for commercial thin film solar. Several companies have confirmed that these cells have been generating efficiency that exceeds 16 percent.

4.3.3.5.3 Dye-sensitized Solar Cell (DSC)

DSSC solar cells were invented by Professor Michael Graetzel and Dr. Brian Regan in 1991. Since then, the technology has been disruptive in the production of electricity in a wide range of indoor and outdoor conditions enabling the conversion of natural and artificial light into energy for electronic devices. The dye catches photons from the incoming light and uses their energy to excite electrons. The electron is conducted away by nanocrystalline titanium dioxide while the chemical electrolyte in the cell closes the circuit so that the electrons are returned back to the dye. Essentially, the DSSC cells is simple a photoactive material that produces electricity once it is sensitized by light.

4.3.3.6 Other PV Cells

PV cells are not just limited to the ones mentioned in the different section above. Although they are the most commonly used types, accounting for more than 95 percent of cells on the market there are other types of PV cells that are currently being developed. Multijunction PV cells are one of the developing technologies, designed to maximize the overall conversion efficiency of the cell by creating a multi-layered design where two or more PV junctions are layered on top of the other. Another option is the dye-Sensitive PV Cells which is a type of technology that utilizes liquid, gel or solid to produce a photo-electrochemical PV cell.

For our design, we’ve decided to utilize a 50 watt, 18 volts monocrystalline solar panel, manufactured by Fesjoy. The panel was made with a 25% higher conversion rate and was designed to be waterproof, while maintaining optical performance. Table 9 below gives a full description on the panel, which is the reason it is the preferred choice for our design.

Monocrystalline Solar Panel	
Max current	3.3 Ampere
Max Voltage	18 volts
Max Power	50 watts
Short circuit current	3.5 Amperes
Open circuit voltage	21 volts

Table 9: Solar Panel Rating

4.3.4 Charge Controller Overview

A solar charge controller or charge regulator is a voltage/current device that protects against overcharging by regulating the voltage and current coming from the solar panels going to the battery.

The charge controller is necessary in virtually all solar power applications that incorporate batteries. The controller's purpose is to regulate the direct current (DC) power going from the solar panels to the batteries. Without a charge controller the voltage leaving the solar panels at about 16 to 20 volts will damage the battery, since most batteries require between 12 to 14 volts to be fully charged. In other power generators, such as alternating current (AC), a transformer would be used for this purpose.

Charge controllers were developed to prevent overcharging batteries, which will significantly reduce the battery life and essentially damage them to the point where they will be unusable. The controller also prevents reverse current flow especially during times when the solar panel is not generating electricity, which will drain the batteries. In doing this, the charge controller will detect when no energy is coming from the solar panel and open the circuit, disconnecting the solar panels from the battery, thus, stopping reverse current flow. This is very crucial in protecting the task of utilizing the energy from the sun all day and will also protect the investment.

Prior to the expansion of the solar there were not many options for regulating the voltage from a solar panel. If a consumer has a 12-volt battery that requires charging, there were only able to use a 36-cells solar panels which produces close to 18 volts to do the job. A 24-volt battery would require two of these panels connected in series for a 72-cell panel. Additionally, when the sun gets hot during the summer times the voltage will drop but will still be enough to charge a 12-volt battery.

Before selecting a type of controller, one needs to be knowledgeable about the functionality and features which will enable them to make an effective comparison. A charge controller is not always necessary especially if the power is 5 watts or less, for each 50 battery amp-hours. For our design, we did not implement the use of a charge controller. This is because we decided not to use a storage battery. The intent was to get power directly from the solar panel to the circuit. Charge controllers are most effective when connected to a battery.

4.3.4.1 Maximum Power Point Tracking (MPPT) Controller

MPPT controllers is an electronic DC – DC converter that optimize the match between the solar array (PV cells), and the battery bank. They convert a higher DC voltage from the solar panels down to a lower voltage. These controllers offer the potential of increasing charging efficiency up to 30%. Wow! By using the MPPT controllers, you will have the ability to have an array with higher input voltage than the battery band allows and can current of up to 80 amps. The warranty in these controllers are typically longer than the competitors, such as PWM controller. It offers great flexibility and is the only way to regulate grid connected modules for battery charging.

Since we are using solar energy as our lead device for charging, the need of a Maximum Power Point Tracking (MPPT) solar charger is necessary to derive the most amount of available power from our solar panels. This is done by checking the photovoltaic (PV) module and then comparing it to the battery voltage which will vary depending on the charge the battery has. The controller then determines what the best power level needed from the PV module is and converts it to the optimal voltage needed in order to get the maximum current into the battery, thus making the charging system as efficient as possible with something as inconsistent as the sun's rays/weather. This is a charge controller uses an algorithm that maximizes the current going into the battery from the photovoltaic module and minimizes any variations of the current-voltage characteristics.

Although MPPT controllers cost more than other controllers, they are effective when it comes to transmitting higher voltages in cables from the solar panels to the charge controller, thus, reducing power loss. In addition to being more expensive, this controller is generally larger in size and forces the solar array to be comprised of like PV modules in like strings.

Let's assume there is a 12-volt battery. The MPPT takes that 17.6 volts at 7.4 ampere and converts it down so the battery gets 10.8 amperes at 12 volts. That equates to 130 watts using ohm's law, P = IV. Because the MPPT converter is a high frequency converter, the DC input from the solar panels is changed to high frequency AC, before converting it back to a different DC voltage and current, matching the panels to the battery.

4.3.4.1.1 BQ24650 Model

The BQ24650 is the first MPPT solar charger controller we looked at that showed a lot of promise. This device works in conjunction with a solar panel that inputs 5V to 28V. This device is extremely accurate, providing precise charge voltage regulation within ±0.5%, charge current regulation within ±3% and input voltage regulation within ±0.6%. This will allow our system to run at a very efficient rate regardless of the irregularities that come with photovoltaic cells. The controller will support a battery that ranges from 2.1V to 26V and is available in a 16-pin configuration. The BQ24650 is compatible with batteries containing Li-Ion/Polymer, LiFePO4, and lead acid chemistries. It is also capable of restarting the charging cycle if the battery voltage falls below the threshold, and provides an input voltage regulation that will reduce the charge current if the input voltage falls below a programmed level.

This synchronous switch-mode battery charge controller also provides various safety features such as battery temperature-sensing which is something we initially wanted to keep track of in order to ensure our charging system would work at an efficient level but would not comprise our components due to the heat amassed during the charging process. The temperature sensing will ensure our battery does not overheat and should that seem to be happening, the controller includes a thermal shutdown which urns the converter off should the threshold of 293°F be exceeded and will remain off until the temperature drops below 266°F. Another great feature included in this controller is overvoltage protection, which effectively stops the high-side FET from turning on until the battery voltage goes below 102%. Price: $2.30 | 1ku

4.3.4.1.2 CSD18540Q5B Models

The CSD18502Q5B and CSD18540Q5B are low resistance pins that belong to the same family of charger controllers and are designed to minimize losses in power conversion applications and provide up to 90% power-supply efficiency. Both of these charger controllers offer DC-DC conversion along with a synchronous rectifier which is used for improving the efficiency, thermal performance, power density, manufacturability and reliability all while decreasing the overall of the power supply system.

The primary difference in these controllers is their drain-to-source voltage, with the CSD18502Q5B having a value of 40V while the CSD18540Q5B has a value of 60V. Along with that, the former controller provides 3.2W of power dissipation while the latter provides 3.8W. The operation junction for the CSD18540Q5B is also slightly larger, ranging from -67°F to 347°F while the other controller ranges from -67°F to 302°F; this however should not be a crucial difference towards our application as we do not expect to reach temperatures this high with our battery. Price: $0.87 | 1ku / $0.86 | 1ku

4.3.4.2 Pulse Width Modulation (PWM) Controller

The PWM solar panel control regulator is said to be a more modern controller, and is another option for regulating the voltage. These controllers are built on a time-tested technology, and have been well established for use in the solar power system industry. The way they work is by connecting the panels to the battery for a period of time before disconnecting them. The current flowing between the two components is monitored for any changes, and the battery voltage is kept in check by these controllers, thus, preventing any damage or overcharging. The power applied to the batteries is lowered as the batteries get closer to being fully charged. This application allows the batteries to be fully charged with less stress and subsequently, extend battery life. PWM controllers are known to be durable, inexpensive and are available in many sizes for a variety of applications. The downside to this controller is that its limited to 60 amps and the input nominal voltage must match the nominal voltage for the battery band for it to function.

For our design, we chose to use the MPPT solar charge controller because of its level of efficiency. Although they are regarded to be more expensive than the traditional PWM controller, they have a lot more features and allow the solar panel to operate at their optimum power output voltage. This means that the MPPT is capable of taking all the voltage that the solar panel is outputting, thus, making the overall performance of the system more efficient.

4.3.4.3 Charge Controllers

These controllers come in one or two stages and rely on various relays or shunt transistors to control the voltage in one or two steps. For this to be effective, and to protect the equipment connected to it the controller shorts or disconnects the solar panel after reaching a certain voltage. Although they are not very popular on the market, they are known and have been proven to be very reliable with very few components to break.

Charge controllers serves a significant role in solar power distribution. They control the voltage of a device and opens the circuit, halting the charge when the battery ascents to a certain level. A thorough understanding of the different charge controllers and their purposes is necessary when seeking to use any one of these devices. Since there are several types, one must know the power requirements to maintain the desired outcome.

4.3.5 Voltage Regulator

A voltage regulator is essentially a device that generates a fixed output voltage of a preset magnitude that will remain constant regardless of any changes to the input voltage or load conditions. Since the output of a regulator is fixed, provision is made for a local regulation, internal current limiting, thermal shutdown control and safe area protection for the project.

Voltage regulators are used in cars, laptops, smartphones and every electronic device that needs protection from fluctuating voltages. This fluctuating voltage can cause damage to the component, and also create the risk of injury to users. The voltage regulator plays the vital role of keeping the voltage stable from input to output. They also work to protect the electronic circuitry from any potential damage, including frying of the microcontroller because of the spike in voltage.

There are two main types of voltage regulators, linear regulators and switching regulators.

4.3.5.1 Linear Voltage Regulator

Linear voltage regulator uses an active pass device that is controlled by a high gain differential amplifier. It compares the output voltage with a precise reference voltage and adjusts the pass device to maintain a constant output voltage. It is very effective and is commonly used when designing low power circuits by using power transistors, BJT or MOSFET, that plays the role of a variable resistor, raising or lowering the output voltage of the circuit as the input changes.

The linear regulator power dissipation is directly proportional to its output current for a given input and output voltage, so typical efficiencies can be 50% or even lower. Using the optimum components, a switching regulator can achieve efficiencies in the 90% range. However, the noise output from a linear regulator is much lower than a switching regulator with the same output voltage and current requirements. Typically, the switching regulator can drive higher current loads than a linear regulator.

The downside to using the linear regulator depends solely on what it is being used for. Energy is wasted as the conversion between current and heat is done, which is the reason linear regulators are preferred for low power applications.

4.3.5.2 Switching Voltage regulator

A switching regulator converts the dc input voltage to a switched voltage applied to a power MOSFET or BJT switch. The filtered power switch output voltage is fed back to a circuit that controls the power switch on and off times so that the output voltage remains constant regardless of input voltage or load current changes.

Switching regulators require a means to vary their output voltage in response to input and output voltage changes. One approach is to use PWM that controls the input to the associated power switch, which controls it's on and off time. The regulator's filtered output voltage is fed back to the PWM controller to control the duty cycle when in operation. If the filtered output tends to change, the feedback applied to the PWM controller varies the duty cycle to maintain a constant output voltage.

The downside to this type of regulator is the fact that it the faster the regulator switches, the more time will be spent moving from a conductive to a non-conductive state, which results in a reduction of the conversion efficiency. More noise is also introduced in the circuit.

For our project, the linear voltage regulator will be considered if there is too much voltage loss when we have everything installed and are in the process of testing. This is to ensure that the output voltage is constant and consistent with the requirements for the project.

4.3.6 DC - DC Convertor

A DC - DC converter is an electrical circuit that takes any direct current (DC) input voltage and converts it to another DC voltage. This is widely used in electronic system with different applications to convert higher voltage to lower voltage and vice versa. The converter is one of the main parts of this project. An understanding of the fundamental concept of how they work must be achieved in order to effectively design the converter and for it to work effectively. The goal for designing this converter is to successfully have this device reducing the voltage from 12 volts to a steady operating voltage of between 3 to 5 volts that will be required to provide power to the sensors, cameras and other components that will require that amount of voltage.

Figure 9 below is an example of a DC - DC convertor that was generated using the Webench tool from ti.com.

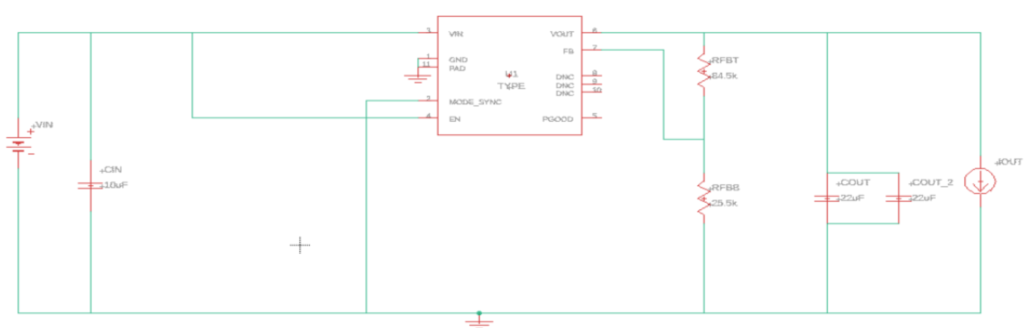

Figure 9: DC - DC Converter Circuit (Webench)

Figure 10 shows another option for DC - DC convertor that was developed using the eagle software. The circuit will convert the 12 volts source to 5 volts that will enable us to have that well needed 5 volts for the components that require 5 volts. The 12-volt source will be connected using a DC power socket and the power will be supplied through the receiver circuit.

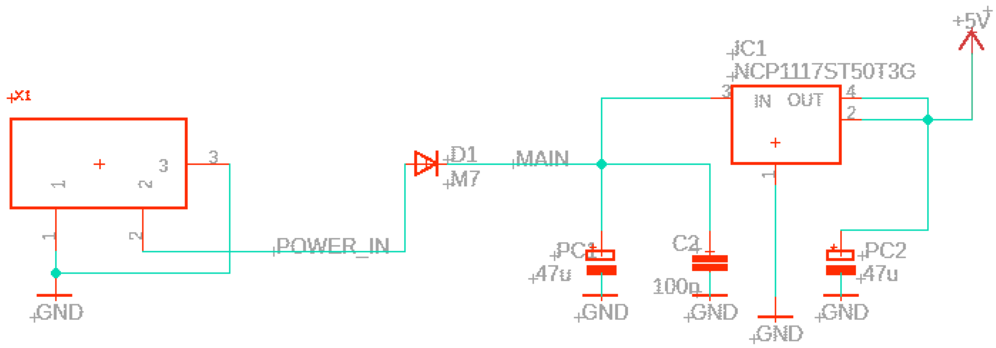

Figure 10: DC - DC Convertor Circuit

4.3.6.1 Boost Converter

The boost converter will be ideal to fulfil the requirements of this project. Our battery requires a steady 36 volts supply from which we will not be able to get from the 12 - 24 volts solar panels. Typically, solar panel comes standard at about 17 volts, which does not meet the requirements. Therefore, utilizing this converter will carry out the task of boosting the voltage to 36 volts. This converter takes an input voltage range of between 11 - 20 volts and sends out 48 volts at 4 amperes, with over 94 % efficiency. It operates in temperatures ranging from -40 degrees Celsius to +85 degrees Celsius. For safety, the converter is designed with over voltage, under voltage, overload, over-heat and short circuit protection.

We used two boost convertors for our design, both built to be waterproof and will be capable of withstanding rugged operation while maintaining reliability. These convertors will be installed on the skateboard. A 12 to 48-volt convertor will take the 12 volts from the wireless circuit and boost it to 48 volts to be supplied to the 36 volts battery. For the PCB to operate, the other convertor will take the 36 volts from the battery and convert it back to 12 volts so that all the components are powered from the battery. These are waterproof and will be installed next to the receiver in an enclosure for protection.

4.3.7 Longboard

Although selecting a longboard may seem like a mindless task at first, it can have great implications on the way riders can effectively use the board and thus is worth a closer look. When selecting a board, a few key factors that should be looked at are the length of the board as well as its width, its flex, style and shape. These factors all contribute to the stability and maneuverability of the board and allow for various configurations. A longer board provides more stability than a shorter one but sacrifices maneuverability to do so turns cannot be taken as sharply.

This same concept applies to the width of the board with the wider board providing more stability overall. Although new riders may think opting for the longest and widest board will be their safest bet, they should also keep in mind that a bigger board will ultimately weigh more. The flex of the board is concerned with its ability to absorb shock and it too affects the overall stability but this factor is largely preference-based and differs from rider to rider. The style of the board refers to how high or low the deck goes in relation to the trucks of the board. The higher the trucks, the less stable the board and the options for this part of the board range through quite a few different styles, as shown below.

Along with that it is also shown that there are various shapes the boards may come in and this further affects the maneuverability, refer to Figure 11 for these shapes and the relationship between that and maneuverability/stability. All these factors contribute to how the ride feels and affect what kind of ride you have overall. Since we did not want to constrict our riders to a certain kind of ride based on their terrain, we were leaning towards a board that would provide a "freestyle" form of riding, which is open to riders of all skill levels and is only limited by proficiency.

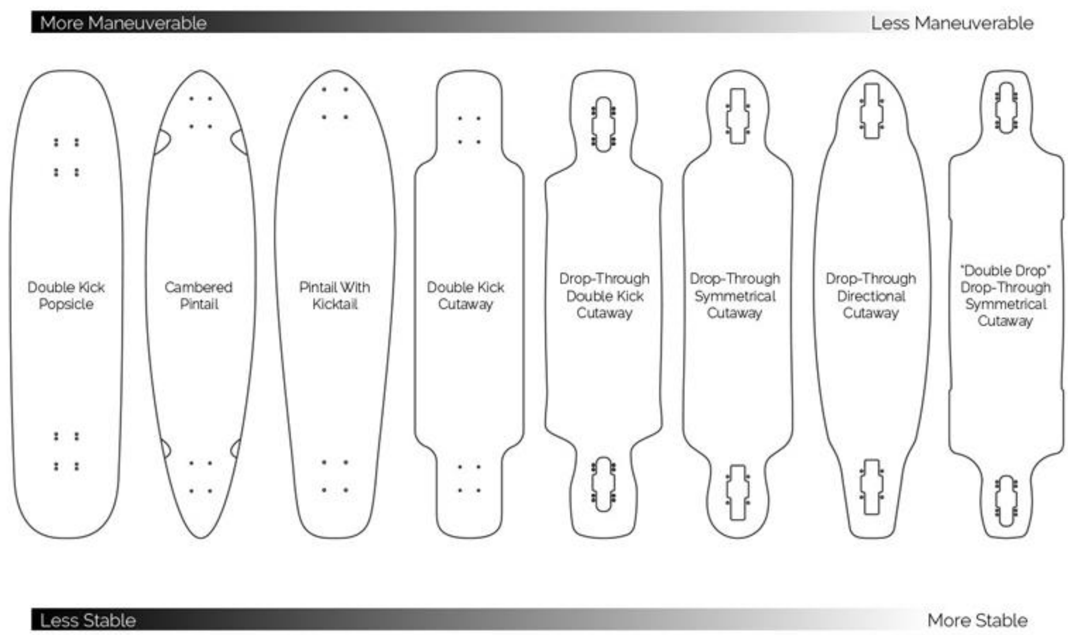

Figure 11: Board Style/Shape/Maneuverability/Stability Diagram

4.3.7.1 Retrospec Zed Bamboo Longboard

For our longboard we wanted to ensure we would have ample space to place all of our components on the board and for that reason we chose the Retrospec Zed Bamboo Longboard, which is geared more towards beginners. This is a 41" board of the cambered pintail design which provides 26" of space from axel to axel, which should be more than enough space lengthwise to put all of the components we would want on our board and as it rides high this is ideal so that our components do not drag or come in contact with the floor or any minor obstacles that could damage it.

The wheels are 70mm which aide in keeping the board high off the ground but if need be these can also be changed to 90mm to provide even more space. From the diagram above this board leans toward the unstable side but, its width helps to counteract that slightly and we were more concerned with maneuverability as this would be used in highly populated areas and control was not something, we wanted the rider to have to give up. The Retrospec also has a kicktail which will allow the rider to easily pick up their board should they so please. At 8 lbs this board is relatively light for its size and can support riders of over 220 lbs. Price: $59.99

4.3.8 Motor

The Phoenix Board relies on an electric motor for propulsion. In order to determine which motor would be best for our design and fit realistically within our goals and budget, our team conducted research into the various types of motors and assemblies. The findings are detailed in the following sections.

4.3.8.1 Types of DC motors

The DC motor is an electrical device that serves the purpose of converting electrical energy into mechanical energy. The voltage is applied to the armature winding through carbon brushes riding on the commutator. Throughout our research, we came across a number of different motors that could be used in the project and will serve the purposes we would require them to serve. DC motors are designed with two major electrical elements, the field windings which are energized by a separate DC source as the armature current does not flow through the field winding and the current carrying armature, connected to the supply end through the commutator segments and brushes.

Motors generally come in three forms: single phase, two phase and three phases. Three phase motors are used in the industrial sector where large machines are being used that require adequate power to run big machines. The current in the stator of a three-phase motor sets up a rotating magnetic field that rotates due to the 12 degrees phase offset in each phase of the power supply. This magnetic field induces a current in the bars of the rotor that sets up its own magnetic field.

A DC motor is used for much smaller applications including automotive, aerospace, medical equipment, automation and instrumentation. They normally come in two forms, brushed and brushless motors. A brushless motor does not use brushes for commutation. Instead, they are commutated electronically. These types of motors are widely used because of the speed versus torque characteristics, high dynamic response, efficiency and higher speed ranges.

Our project requires the use of a motor. After careful research we were able to find some option for comparison that will help us to decide on the absolute best motor that will generate enough torque for speed enhancement and efficiency.

4.3.8.1.1 Hub vs. Belt Motors

The first major decision concerning our motor for this project was whether it would be a hub motor or a belt motor, although this was an easy decision after our initial findings. Due to the fact that they are an integrated system, hub motors outclassed belt motors. More specifically, hub motors produce less noise since there is no belt/pulley system to create friction and noise. Hub motors produce less drag which allows the battery life to last longer and thus gives the user extended utility. These motors also allow the user to free-roll, so that the user will have the ability to continue skating with relative ease if the battery should die.

On the other hand, belt motors provide quite a lot of resistance to the rider should they wish to return to the “kick-push” method of a standard board. Hub motors are also lighter since they are integrated systems, provide a more efficient braking and require less maintenance for the same reason. Belt motors are not without their perks however, as they do generally provide a higher level of torque. The smoothness of a ride using either motor is debated; this is because with a belt motor since the system as a whole is larger, more vibration can be felt throughout the board which riders are largely not fond of. However, depending on the hub motor there isn’t a full-sized longboard wheel that is used but a thinner urethane sleeve around the motor which reduces the shock absorption of the system and could lead to a bumpy ride.

4.3.8.1.2 Dual Belt Motor

This is our only consideration for a belt motor. This product stood out to us because of its simplicity and ease of integrating it onto a board. The specifications indicated it had a max speed of 21.7 mph and a max range of 12.4 miles while dissipating 680W of power on each motor. The motor itself had a net weight of 11.6 lbs. and could sustain a 286 lbs. person. This motor also came with its own Samsung 42V, 4.3AH battery and a 100-240VAC, 42V charger. Also included was a controller and an app, which communicated with the controller via Bluetooth. Price: $284.

4.3.8.1.3 Electric Skateboard Wheel Hub Motor Kit

Like the previously mentioned motor, this system came with the same controller and app to communicate with the system, and similarly as well this system output 680W of power. This motor can also go to a max range of 12.4 miles but has a drastically slower max speed at 18.6 mph, with the max weight it can sustain being 287 miles and the net weight of the system itself being 10.4 lbs. Price: $100-300.

4.3.8.1.4 180KV N6354 Outrunner Motor

This motor comes in at a meager 1.2 lbs. although at least two would be needed raising that to 2.4 lbs. and if we wanted to put a motor in every wheel that would total out to 4.8 lbs., although this does seem a bit excessive. Each motor provides 2000W of power, a max speed of 31.1 mph and a voltage of 24V - 48V. Water and dust resistant. This hub motor does not include a speed controller, although there is one that is suggested to be paired with it, the “Upgraded V2.1 Dual Belt Motor Sine Wave FOC ESC Speed Controller”. Price: $69.00 for 1 / $65.55 for 2 / $58.65 for 4.

4.3.8.1.5 90mm Powerful Hub Motor

This motor weighs 1.9 lbs. (per wheel) and operate at 24V while outputting 600W of power. They have a max speed of 15.5 - 17.4 mph. They are waterproof. 90mm wheels are nice and large which should help out with reducing any roughness to a ride and should be large enough to overcome a fair number of cracks and debris the rider may face. Price: $70.80.

4.3.8.1.6 Dual 90mm Hub Motor Kit - Replaceable PU

Upon further research of motors and motor assemblies, we came across M Boards' dual 6364 hub motor kit. The total weight of this kit is 9.57 lbs. but that is due to the fact that it brings everything we need already put together in a sleek design. This includes the other set of trucks that will not be motorized and come in at a length of 275 mm. The size of the motor is 74.5 mm * 52 mm and since they motor is located inside the wheels; the wheels end up being 90 mm. This, as mentioned previously, is great because it means the board can overcome some obstacles with more ease and some obstacles that it simply would not have been able to clear before. The motor operates between 24V - 42V giving us a sizeable range to work with and, per the specs, provides 88% efficiency. This motor has a Kv rating, which is a measure of revolutions per minute when 1V is applied with no load, of 75 which is about a very good rating for hub motors and helps put into perspective the kind of torque that should be expected from the motor. The general principle with this is that a lower Kv rating will result in higher torque but a lower max speed and a higher Kv rating will provide less torque but higher speeds.

After looking into all these motors, we finally decided on the Dual 90mm Hub Motor kit for various reasons. The first thing that made this really stood out for us was that it would make the installation process significantly simpler due to the fact that everything was being provided as a kit. Otherwise, we would have had to spend more time trying to get an appropriate truck mount and also a second set of trucks for the front of the board. Along with that, we believe this motor will be able to provide the kind of speed and power we want out of our board and due to the urethane sleeves being replaceable, we can thoroughly test it and wear out a set of sleeving while still having the other set readily on hand.

4.3.9 Ultrasonic Sensor

A key safety feature on the Phoenix Board is the ability for the board to detect incoming obstacles and in the event that there is no additional user input attempting to avoid it, safely slow the board to an emergency stop. Part of this subsystem relies on the use of an ultrasonic sensor.

Ultrasonic sensors utilize a transducer to emit ultrasonic waves to measure the distance to an object at a given moment. The transducer ends the pulse out and receives the echo. They utilize Formula 1 to calculate this distance:

$$L = 1/2\, T\, C$$

Formula 1: Ultrasonic Sensor Distance Formula

with L being Distance, T being Time from emission to reception and C being sonic speed. The product of T and C is halved as it the distance to the object is the halfway point of the full bounce back of the signal.

What makes an ultrasonic sensor so valuable is their ability to function independent of light, smoke, dust, color, and most materials. They can be successfully used in both indoor and outdoor environments. The readings detected can be used to establish not just distance, but presence, level, and position of objects.

4.3.9.1 Elegoo HC-SR04 Ultrasonic Module Distance Sensor

The HC-SR04 is a popular option. It has a ranging distance of 2 cm – 400 cm. It uses a +5V DC power supply, has a quiescent current of < 2 mA, an effective angle of less than 15 degrees, and a resolution of 0.3 cm. The full measuring angle is 30 degrees. Price: $8.78 (pack of 5)

4.3.9.2 SMAKN Ultrasonic Module HY-SRF05 Distance Sensor

The SRF05 is another popular option. It has a ranging distance of 2 cm – 450 cm. It uses a +5V DC power supply, has a quiescent current of < 2 mA, an effective angle of less than 15 degrees, and a resolution of 0.3 cm. The full measuring angle is 30 degrees. It's big difference is a 5th OUT pin. This allows the SRF05 to operate in two modes: mode 1 operating like an HC-SR04 and mode 2 allowing for the ECHO and TRIG to run off the same pin, thus saving a wire but adding additional work to the processor to process the two. Price: $6.60 (per unit).

For a side-by-side comparison of Ultrasonic Sensors, refer to Table 10.

Category	HC - SR04	HY-SRF05
Price	$8.78 (pack of 5)	$6.60 (per unit)
Power Supply	+5V DC	+5V DC
Quiescent Current	< 2mA	< 2mA
Ranging Distance	2 cm - 400 cm	2 cm - 450 cm
Resolution	0.3 cm	0.3 cm
Full Measuring Angle	30 degrees	30 degrees
Effective Angle	<15 degrees	<15 degrees
Pins	VCC, GND, TRIG,ECHO	VCC, GND, TRIG, ECHO,OUT

Table 10: Ultrasonic Sensor Comparison

Ultimately, we decided to use the SMAKN Ultrasonic Module HY-SRF05 Distance Sensor as the ultrasonic sensor for the Phoenix Board. One of the main reasons for selecting this module was the extended range on the sensor, outperforming the Elegoo module by upwards of 50 cm. Additionally, even though both modules were nearly identical in power consumption, effective angle, and resolution, the added flexibility of being able to select the additional mode to run the TRIG and ECHO functions on the same pin was very valuable. Lastly, based on user reviews, the HY-SRF05 sensor generally performed better over the HY-SR04, providing better accuracy and better optimization for running continuously, which as a key safety feature, we would absolutely need.

4.3.10 Camera

In order to boost the accuracy and safety of our emergency collision avoidance system, our ultrasonic sensor will be paired with an on-board camera. This camera would send a scaled down camera feed (to save on bandwidth and processing power) to our mobile app and from here utilize computer vision, specifically OpenCV, to run object detection software. This system is reliant on

In order to implement the Computer vision component of our application, we need an onboard camera that will be compatible with our microcontroller, consume a minimal amount of energy, and not consume too much bandwidth, so as to still be able to share the Bluetooth data stream with the other sensors/components providing data to the mobile app.

Due to various constraints, most notably our limited amount of time and the bandwidth of our Bluetooth module we decided not to implement the camera into our project. Instead, all of the object detection would be handled by our ultrasonic sensor which is much easier to set up and puts a much lower load on our Bluetooth communications. Along with that, in order to get the camera working properly and reduce the number of false flags we would be receiving there would need to be extensive testing and debugging which we simply could not devote the time for.

4.3.10.1 Adafruit TTL Serial JPEG Camera with NTSC Video

The Adafruit TTL Serial JPEG Camera with NTSC Video is a good candidate for the camera for this project due to its small size, it's lowered (0.3 MP at 640 x 480, 30 fps) resolution, and its serial nature, meaning the memory limitations of the MSP430F5529 should be easier to manage. This would ensure a quicker transfer of data from the camera over the RX/TX lines of our microprocessor. The module is set by default to transmit at 38400 baud with a max of 115200. The image sensor is a CMOS ¼ inch. It has a dynamic range of 60 DB, an SNR of 45 DB, and a viewing angle of 60 degrees. It's current draw is 75 mA, uses a +5V DC operating voltage, and has three lines (TX,RX,GND). Price: $39.95

4.3.11 Mobile App / Framework

In deciding which IDE to develop on, we split our research into two tracks, native application development for both Android and iOS and explicit, Android-only development. For native applications, three IDEs were researched: React Native, NativeScript, and Ionic. These three were some of the three most widely used frameworks available, with large development communities and vast resources, including custom APIs. For Android-only, we researched Android Studio. This is the most widely used IDE for Android Studio, as it is created by Google for Android development, and thus has a massive amount of support information, documentation, custom APIs, etc.

4.3.11.1 React Native

React Native is a JavaScript framework used to write applications that can run natively on both iOS and Android. Originally developed by Facebook, it allows the use of both JavaScript and React for mobile app development. It uses Reacts JSX syntax for building the app's UI. JSX syntax allows for inline JavaScript code to mimic HTML syntax, allowing for the familiarity of HTML design and the ability to inject JavaScript into the application without having to call an outside JavaScript file. Unlike React which is comprised of web components, React Native utilizes native components. Most app components will run natively on both platforms; however, some platform-specific development may be needed.

Some of React Native's most important features are its use of Reacts state and props concepts. React components take in parameters for usage, called "props". In addition, in order for components to keep track of existing data and changes, "states" are used. Generally, props are set ahead of time and are fixed for the duration of the app while states are used for when the app is live and changing.

For debugging, React Native uses the Chrome Developer Tools although additional plugins are often needed, including Native Debugger and Reactotron as being two of the most common ones. React Native has a small internal library of APIs and the vast React community has a wide array of additional plugins available. As for performance, as the program is being natively rendered, speed is dependent on the platform itself. The better the phone, the quicker the performance. Price: Open Source

With regards to the project, React Native has access to Bluetooth API files, Location tracking and mapping API files (for odometer / trip tracking purposes), and computer vision can be configured to run on React Native using OpenCV.

4.3.11.2 NativeScript

NativeScript is a JavaScript based framework used for building native apps for both iOS and Android platforms. Originally developed by Progress, the framework encourages the use of TypeScript or Angular for the JavaScript although plain JavaScript is also usable. Code is structured with an XML-based language for UI declaration, CSS for styling, and JavaScript for functionality.

For debugging, NativeScript uses Chrome Developer Tools and/or Visual Studio Code NativeScript extension. NativeScript allows for hardware access using internal plugins with additional plugins being available via the NativeScript marketplace. Additionally, all native APIs are accessible via JavaScript. As for performance, as the program is being natively rendered, speed is dependent on the platform itself. The better the phone, the quicker the performance. Price: Open Source

With regards to the project, NativeScript has access to Bluetooth API files, Location tracking, and mapping API files (for odometer / trip tracking purposes). However, it does not have any existing computer vision API support and would need to have the API files created from scratch.

4.3.11.3 Ionic

Ionic is a hybrid native app framework created by Max Lynch, Ben Sperry, and Adam Bradley of Drifty Co. The framework creates native apps by rendering the app in a Webview, essentially creating a website and viewing it as an app on either iOS or Android. It supports traditional web development languages including HTML5, CSS, and JavaScript (JavaScript follows the Angular JavaScript syntax). It's the easiest to learn of the IDEs researched as its development complexity is very similar to that of a traditional website.

Debugging is virtually identical to standard web development debugging. Ionic uses Ionic Native to support additional APIs and extensibility although if no additional APIs are available, the files must be written from scratch and require a reasonable amount of backend knowledge of the hardware. As for performance, because the app renders like a website, its performance is the worst compared to the other traditional frameworks. Cost: Free edition available.

With regards to the project, Ionic has access to Bluetooth API files, Location tracking, and mapping API files (for odometer / trip tracking purposes). However, it does not have any existing computer vision API support and would need to have the API files created from scratch.

4.3.11.4 Android Studio

Android Studio is the official development environment supported by Google for Android development. The IDE supports Java, C++, and Kotlin for languages. Debugging is done via the internal debugger within Android Studio which also includes a simulator for simulating expected app UI and functionality. In addition, Android Studio uses a Gradle tool to build Android packages which manages dependencies and allows for custom build logic. Android Studio provides a full library of APIs for accessing necessary Android functionality. As for performance, app performance is tied to the speed of the platform it's running on. Cost: Open Source

With regards to the project, React Native has access to Bluetooth API files, Location tracking and mapping API files (for odometer / trip tracking purposes), and OpenCV has an entire library dedicated to Android files.

Ultimately, we decide to utilize React Native as the IDE for our mobile app. This framework provides us with the most platform flexibility as it renders apps natively to either iOS or Android. In addition, our team already has experience working with JavaScript and therefore picking up and understanding the React JSX syntax has been relatively straightforward. Lastly, due to React Native's wide use in several highly popular apps including Facebook, Instagram, and Pinterest, learning and understanding this framework can be a very valuable skill set to develop.

For a side-by-side comparison of Mobile app IDEs, refer to Table 11.

Category	React Native	NativeScript	Ionic	Android Studio
Language	React JavaScript framework,	XML-style language for UI, Angular/Typescript JavaScript Framework, CSS	HTML5, CSS, JavaScript	Java, C++
Cost	Open Source	Open Source	Free Available	Open Source
Category	React Native	NativeScript	Ionic	Android Studio
Debugging	Chrome Developer Tools, additional plugins needed	Chrome Developer Tools and Visual Studio Code NativeScript extension	Ionic Native	Built-In debugger
Performance	As fast as platform running app	As fast as platform running app	Slowest of the IDEs	As fast as platform running app
API / Extensibility	Small built-in library of APIs, more available from React Native community	Access hardware APIs via NativeScript plugins, can access all native APIs via JavaScript	Ionic Native, if API not available, must be written from scratch	Full library of built-in APIs and tools to access needed functionality
Vision Capable	Yes, compatible with existing OpenCV library	No existing library readily available	No existing library readily available	Yes, OpenCV library available

Table 11: Mobile App IDE Comparison

4.3.12 Embedded System IDE

For MSP430 development, two different IDEs are primarily used: Texas Instruments Code Composer Studio and Robert Wessels' Energia. These two frameworks were both created for microcontroller development, with some varying differences discussed in the following sections.

4.3.12.3 Code Composer Studio

Code Composer Studio is the IDE used by TI and created for use with TI microcontrollers. The framework contains various tools including a C/C++ compiler, a source code editor, project build environment, and debugger.

Writing code in CCS consists of creating "projects" and selecting the proper device name. CCS allows for user to import header files (.h) using the #include tag at the beginning of their code. The user then builds the project and runs CCS powerful debugger. The debugger gains control of the MSP430, clears its memory, programs its memory with the application, and lastly resets the microcontroller. From here the user can run the program.

For coding in the C language, CCS explicitly requires a loop mechanism (e.g. while(1)) to continuously loop through the main code running on the MSP430. It does not contain a built-in delay function and therefore loops are often used as a way to introduce delays. Beyond that, most other coding resembles standard C code.

4.3.11.2 Energia

Energia is an open-source IDE based on the Wiring (developed by Hernando Barragan) and Arduino frameworks that has been specifically developed with expanding said features to TI microcontrollers. The framework claims to have been developed with both beginners and experienced developers in mind. It was originally built with providing functionality to the MSP430 Launchpad but has since been expanded to support other TI Launchpads.

Writing code in Energia consists of creating “sketches” which are done via the built-in text editor. The framework uses the mspgcc compiler (developed by Peter Bigot) for compiling and verifying sketches. The languages supported include C and C++, with the ability to include additional header files. It also allows for outside libraries to be added in for references to expand existing functionality beyond what is initially included. Once the sketch has been compiled and verified, it is then uploaded to the microcontroller. Lastly of significance, the framework contains a Serial Monitor which allows the user to select the proper baud rate and see what data is being sent to the board. One of Energia’s biggest drawbacks is its lack of a proper debugger. In fact, one of the easiest workarounds for this is using CCSs built-in support for Energia sketches and debug within CCS.

The basic structure of a Energia sketch includes two methods: void() which is used for setting up the code and is only run once, and loop(), which is where the main body of code is run, constantly repeating. Other important core functions include pinMode() for setting whether a pin is an input/output, digitalWrite() for outputting values on a pin, and delay() for creating time delays in milliseconds.

Category	**CCS**	**Energia**	**Arduino**
Languages Supported	C / C++	C / C++	C / C++
Cost	Open-Source	Open-Source	Open-Source
Debugging	Powerful Built-in Debugger	No explicit debugger, recommended to import sketch into CCS for debugging	Built-in Debugger
Platform(s) supported	Wide range of TI products including MSP430 line	Limited to MSP430 and a selection of other TI launchpads	Arduino based products

Table 12: Embedded System IDE Comparison

4.3.11.3 Arduino IDE

The Arduino IDE is the default IDE developed for use with Arduino products. Writing code is done by creating sketches in the built-in text editor. The framework supports multiple languages and libraries, including C and C++. It's especially useful in that the volume of Arduino ready-to-use libraries and documentation is vast and easy to obtain.

Initially, our team decided to use Code Composer Studio for all embedded systems development. Due to having to switch architectures from the MSP430F5529 to the ATMega2560, we ultimately switched to the Arduino IDE. For a side-by-side comparison of Embedded System IDEs, refer to Table 11.

4.3.12 Wireless Technologies

With our project we want to be able to have a strong and consistent communication link between the board and the mobile device used by the rider in order to ensure there is full control over the ride at all times. Our main options for this were Wi-Fi and Bluetooth as they were the most practical in terms of the usage we needed/desired but they were also designed for very specific and different purposes, with Bluetooth also being further divided into two classes: Bluetooth Classic and Bluetooth Low Energy (BLE). The abbreviated version of these differences boils down to Bluetooth being effective at short-range and is ideal for the pairing of one device to another, whereas Wi-Fi is more suited for longer ranges and works with multiple devices on a network. With this project we will also be including inductive charging in order to minimize the amount of cable needed to support the board, thus making things easier for the user.

4.3.12.1 Wi-Fi

Wi-Fi, which is short for "wireless fidelity", is a wireless technology which was originally made to eliminate wires on Local Area Networks (LAN) and relies on the TCP-IP protocol, a protocol that requires every device to obtain its own IP address and authenticate itself. This allows users to connect one or multiple devices to the internet, but it is not always ideal as some products do not have a user interface to input a password or other authentication that is needed to access the network. The connection of these devices is based around a central base station that sends out a signal that has to be both strong enough and wide enough to cover the desired area, with some signals being strong enough to extend to about 300 feet.

The IEEE Wi-Fi standard 802.11ac can transmit at a speed of up to 1.3 Gbps which is very useful for bigger files and data. Wi-Fi typically works on two radio frequencies, the UHF band which is 2.4GHz and the SHF band which is 5GHz, the latter of which has had more users and devices using it as the former frequency has become quite crowded in our modern age and has had to accommodate for the increased number of devices around the world. Wi-Fi is also vulnerable to interference from other devices that use the same frequency such as microwave ovens, cordless phones, and other Bluetooth devices which rely on the previous Wi-Fi standards of 802.11b and 802.11g.

The difference between these standards and the previously mentioned 802.11ac is as follows: the 802.11b standard was the most popular for quite some time but also the slowest with transfer speeds of 11 Mbps; 802.11g is significantly faster, providing speeds of up to 54 Mbps and, like the b standard, only operates at the 2.4GHz frequency; the 802.11ac, which also happens to be the newest standard, boasts the fastest transfer speed which sits at around 450 Mbps and works on both the 2.4GHz and 5GHz frequencies.

4.3.12.2 Bluetooth Classic

Bluetooth operates at a much shorter range than Wi-Fi, with a typical range of around 30 feet or less, and is more ideal for connecting two devices together as opposed to an entire network of devices in Personal Area Networks (PAN). Devices that use Bluetooth in order to communicate with each other typically require you to "pair" the devices, or create an initial link between them. This differs from Wi-Fi as it is a more manual job, unlike Wi-Fi detection and pairing; devices with their Wi-Fi activated are constantly searching for a network to join and may actually join one should it be found and have no password requirement.

Due to this shorter range and less complicated security measures, Bluetooth expends a lot less energy than Wi-Fi to employ in a system. Unlike Wi-Fi, Bluetooth does not require an internet connection and is not as prone to interference even though it also operates on the 2.4GHz frequency. This lack of interference is due to the weaker signals produced by Bluetooth devices which in turn create small, isolated pockets of devices which need not interact with one another. The other reason is that Bluetooth technology uses a technology called spread-spectrum frequency hopping, allowing devices to operate between 79 unique frequency channels which can be sifted through 1,600 times per second. The transfer speeds of Bluetooth are a lot slower, only 25 Mbps, making it impractical for the transfer of large files.

4.3.12.3 Bluetooth LE (BLE)

Bluetooth LE (Low Energy) or BLE is a newer Bluetooth technology which is ideal for devices that must operate for extended periods of time on small energy sources and is particularly suited for small data updates. Pairing to these devices is simpler than a typical Bluetooth enabled device due to the fact that BLE devices can advertise themselves and aren't limited to a single connection at a time, instead of being able to connect multiple BLE devices to a central hub, such as a smartphone. BLE however is not designed to send large files or transfer a high amount of data at high speeds, with its transfer process breaking down the desired payload into 20-byte chunks before recombining them on the receiving end.

Initially, we decided to utilize Bluetooth Low Energy (BLE) for our wireless communication mechanism. Power management and potentially extended periods of use are key components of the Phoenix Board. A rider needs to be able to maintain a continuous, reliable connection between the mobile app and the on-board electronics to ensure optimal and safe operation of the Phoenix Board. However, for ease-of-use and installation, we switched to an HC-05 Bluetooth classic based module. For a side-by-side comparison of wireless technologies, refer to Table 13.

Category	Bluetooth	Wi-Fi
Frequency	2.4 GHz	2.4 and 5 GHz
Cost	Low	High
Bandwidth	Low (800 Kbps)	High (11 Mbps)
Specifications Authority	Bluetooth SIG	IEEE, WECA
Year of Development	1994	1991
Category	**Bluetooth**	**Wi-Fi**
Primary Devices	Mobile phones, mouse, keyboards, office/industrial automation devices, activity trackers	Mobile phones, notebook computers, desktop computers, servers, TV
Range	5 - 30 meters	32 m (indoors) / 95 m (outdoors)
Power Consumption	Low	High
Latency	200ms	150ms
Bit-rate	2.1 Mbps	600 Mbps
Hardware requirement	Bluetooth adapter on all devices connecting with each other	Wireless adaptors on all devices of the network, a wireless router and/or wireless access points

Table 13: Wireless Technologies Comparison

4.3.12.3 TI SimpleLink™ Bluetooth® low energy CC2650 Module BoosterPack™ Plug-in Module

The CC2650 Module is as its name implies, a simple way to add Bluetooth low energy capabilities to a LaunchPad development kit. The kit, which is programmed with wireless network software, allows you to add BLE to any application with a UART interface. The module is Bluetooth 4.2 specification certified and is also pre-certified for FCC/IC, CE, and ARIB radio standards. The module is also accompanied by software examples for MSP430 applications. Lastly, the module is designed as an easy to use BoosterPack for MSP430, quickly snapping onto the on-board expansion pins of the MSP430. Price: $29.00 (USD)

Our choice to use this BLE module was made quite simple due to how easy it is to integrate with our microcontroller as they are both parts made by TI and are extremely compatible. The module is “plug-in” because it is so easily attached to the microcontroller which will save us time in configuring them and instead will allow us to allocate that time towards getting the Bluetooth connection between the board and the mobile app to be established.

When we first purchased this Bluetooth device, we believed it would be of great use due to its “plug-and-play” compatibility with our microcontroller but unfortunately this was not the case. The module plugged into the microcontroller perfectly but getting it to communicate was very difficult because it was tailored for a different MSP430 than the one we were using.

4.3.12.4 DSD Tech HC-05 Bluetooth Serial Pass-through Module

DSD Tech’s HC-05 is a two-in-one Master and Slave module that uses Bluetooth 2.0. It meets Bluetooth V2.0 SPP protocol standards and has a working range of 3.6 to 6 V. This module operates at a default baud rate of 9600 and it can be switched via AT commands as master or slave mode. The HC-05 has a 2.4 GHz digital wireless transceiver which is great for our project since we will be needed in our components to communicate very quickly and concisely. The module is quite small, sizing in at 27mm x 13mm x 2mm. It contains 6 pins, +5 V, GND, TX, RX, EN and STATE. The module is connected to one of the microcontroller’s UARTs and allows for communication between our mobile application and PCB. Using the HC-05, the PCB receives the current desired speed and LED configuration data, while transmitting a speed reset flag to the app in the case of an emergency stop, triggered by either a rider stepping off the board or an obstacle being detected.

4.3.13 Wireless Charging

Wireless charging is not new, but is a relatively good option for people who are seeking convenience. By having the ability to charge wirelessly, the user will be able to keep their devices longer, not having to experience the damages done by connecting and disconnecting a charger cable which eventually will damage the charging port after some time. Wireless charging also enables the user to have constant charge. A typical example of this is mobile phones. Since they are one of the more prominent wireless charging devices, the user can set the phone down on the nightstand, desk, in the car, or even on a surface that is designed to provide wireless charging capabilities.

Another benefit of wireless charging is the time it takes to actually charge the device. Speed is crucial to achieving the level of convenience needed to get through each day. With a wireless charging ability, the device can be charged and the same pace or even faster than the conventional cable charging. This is because the power transferred is similar to what would be used if the cable was being used, thus, providing adequate power needed to function effectively in charging the device.

There are two main types of wireless charging, inductive and resonance. Both options use magnetic fields to provide fast and safe charging, but we discovered that using the inductive coupling (inductive).

4.3.13.1 Inductive Charging

The inductive charging method is a method utilizing modern wireless technologies for charging in opposition to walking around with a mile of cable and having no space in a traveling bag for what's important, such as textbooks. It is simply the design of the charger in opposition to the charging process, having a closely coupled system that allows for more efficiency. In some instances, this would mean that the construction of the charger must be done using transformer which is split in two parts. The primary winding is housed in a unit connected to the main supply, while the secondary winding is housed in the same sealed unit which contains the battery along with the remaining electronic components.

For this to be effective a constant voltage and current is required since we are using the lithium-ion battery which is vulnerable to damage if the upper voltage limit is exceeded. For this reason, it is recommended that the charging method switches to constant voltage before the cell voltage reaches its upper limit. Thus, the charger must be capable of controlling both the current and the battery voltage. Figure 12 below shows a graph with the behavior characteristics for the cell voltage with respect to time.

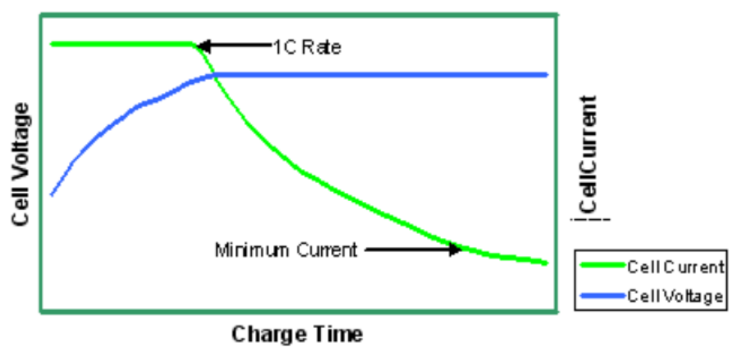

Figure 12: Charging Characteristics for Lithium Ion

For our design, we are using this method of charging to add more unique features and efficiency. The inductive charging makes use of a transmitter that will be a part of the circuit connected to the solar panel and a receiver that will be installed on the skateboard, similar to the transformer method and will send and receive electromagnetic power through inductive coils which provides a wireless transmission of power to that receiving part. This receiving part will in fact be installed on the skateboard and will be connected to the battery. Our ultimate goal for this project is to ensure that the battery is charged without the risk of overcharging either from errors in the specification or merely a spike in temperature that can cause damage to the equipment and possible those in its surrounding. The computer team will be working to ensure this requirement is met and that all safety procedures are followed.

One technology that we would love to incorporate in our design is a wireless charging system that will allow the device to be charged without having to plug in to a power outlet.

By doing this, we will make use of an application or a web portal that will control the device that is being charged, with the option to turn charging on or off. This technology works like that of a 2.4GHz Wi-Fi, which allows you to connect or disconnect using a simple transmitter and receiver system that converts radio frequency (RF) signals into DC power.

4.3.13.2 Resonant Charging

Resonant charging is another option for wireless charging. The physics behind this method of charging along with the resonant power transfer is complex, but offers more freedom by offering more loosely coupled charging. resonant charging gives the freedom to allow multiple devices to be charged simultaneously within different charging ranges for different applications and allow control over which device is charged first.

The charging efficiency of resonant charging is much less that inductive charging, but offers more in terms of convenience. Although this method of charging is not the cheapest nor the most efficient, it can be beneficial depending on the needs of the user. A typical example of resonant charging method is the interactive customer displays seen in supermarkets, or even a background charging of devices in the living room.

There are a few other downsides to using the resonant charging, in opposition to the inductive charging which can have a negative impact depending on the application. Since there is a minimum distance at which both coils can maintain resonant operation, it is recommended to keep that minimum to prevent collapsing of the oscillating magnetic fields. this will result in ceasing of the power transfer.

4.3.14 Microcontroller

The microcontroller will be the brain behind running all of the various subsystems at play on the Phoenix Board. It will be responsible for running and maintaining our power management subsystem, our sensor suite, and all of our communication between the board and the mobile app. As such, we did extensive research into which microcontroller would best fit our desired goals.

4.3.14.1 MSP430F55XX

The microcontroller is necessary for communicating between the mobile application and the system via Bluetooth connectivity. It will take the commands from the app and distribute the instructions so that the board will function effectively. It is also needed to communicate between various sensors and LEDs that will be used on the project to perform various unique tasks. The MSP430F55XX mixed signal microcontrollers are preferred choices for design in the electronic field because of their ultra-low-power modes, optimized to produce extended battery life in different applications. Consisting of 16-bit reduced instruction set computer (RISC) CPU, 16-bit registers and constant generators that contribute to maximum code efficiency.

For our design, we chose to use the MSP430F5529 microcontroller. This microcontroller has integrated universal serial bus (USB) and physical layer (PHY) supporting USB 2.0. It is known for its high performance 12-bit analog to digital converter (ADC), shutdown mode, offmode, standby mode, real time clock module (RTC), a hardware multiplier and 63 input/output (I/O) pins. The 5529 is compact with a low voltage supply range of 3.6 V down to 1.8 V and is designed as a uses ultra-low voltage power. With a quick response time, the 5529 is fully integrated with extended memory and has a system clock up to 15 MHz. Other microcontrollers have similar capabilities, but have less I/O pins. The 5529 has a hardware multiplier that supports 32-bit operations and a 12-bit analog to digital converter (ADC). We love the MSP430F5529 for multiple reasons, including its ability to capture and compare registers, using 16-bit timers and data loggers.

Figure 13 is the actual schematic design that will be used to construct the PCB design for the MSP430F5529 microcontroller. The circuit was modified using the eagle software.

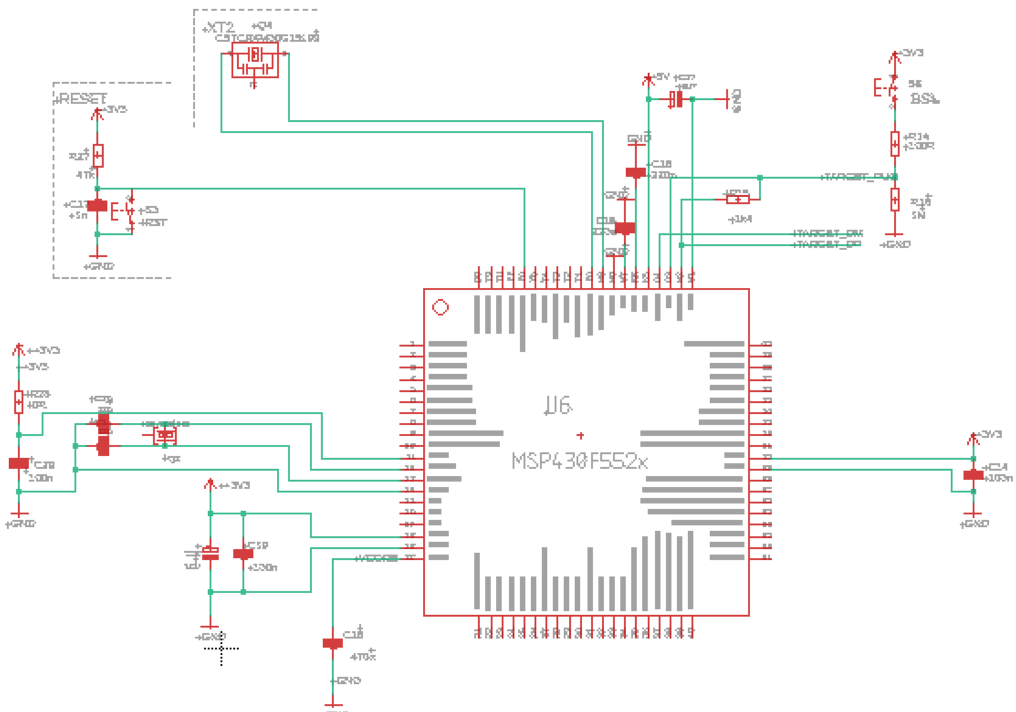

Figure 13: MSP430F5529 Emulator Schematic Design

Figure 14 is another part of the microcontroller that has the main purpose of connecting a USB cable to the PCB for communication between said PCB and the computer. The USB typically has a 5 volts output from the computer and will allow us to be able to utilize the coding software to communicate with the other parts of the project. Doing this is ideal for performance and full functionality of the board and all its features.

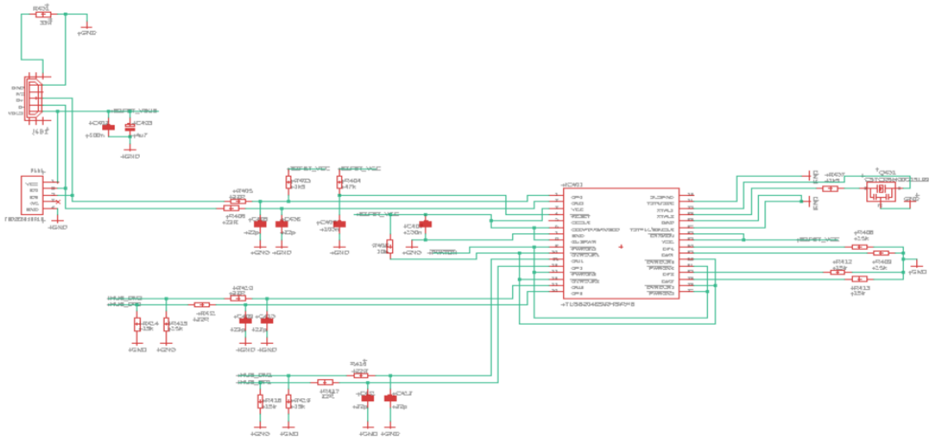

Figure 14: Schematic Diagram for USB Communication

At the end of designing the circuit, we will move forward with the implementation of the PCB design, which will lead us to carry out the required tasks, and ensure that the circuit is fully functional.

Although initially we sought to use the MSP430 microcontroller in our design, we ultimately ended up pivoting to the Atmega2560. The reason for this change in our design was due to the fact that our progress was being bogged down too heavily by trying to force the usage of the MSP430. With the MSP, we were having trouble locating information on its use with several of our components, which were geared heavily towards Arduino use. Along with that, there weren't many libraries that could be used for the embedded programming of our peripherals with this microprocessor but a switch to an Arduino-based processor could easily remedy a lot of these issues.

4.3.14.2 PICAXE

The picaxe microcontroller is designed to be the brain of an inductive charging circuit. The chips are used in a variety of projects and is relatively simple to use because of serial connection and the basic development environment. It is very good for educational applications and is a great microcontroller for entry level designs.

4.3.14.3 ATMEGA2560

The Atmega2560 is a high-performance, low-power 8-bit AVR RISC-based microcontroller produced by Microchip and it is the microprocessor we based our final design around. With this microprocessor we increase the amount of Flash memory available to us as the Atmega2560 comes with 256 KB of it, along with 8 KB of SRAM and 4 KB of EEPROM. As with the MSP430, something that is crucial for the functionality of this project is that our microprocessor provide us with a multitude of I/O lines, of which the ATmega has 86 and more than meets our demands. This chip also has 32 general purpose working registers, a real time counter, six flexible timers/counters with compare modes, and pulse-width modulation. A big factor for us in choosing this microprocessor was that it had four UARTs and at the time of our switch to this microprocessor we were aware that we would be needing at least three of these interfaces. This microprocessor operates in the voltage range of 4.5 - 5.5 V and can achieve a throughput of 16 MIPS at 16 MHz

After switching to the ATmega, controlling and interacting with our peripherals became substantially easier as there was a plethora of libraries, examples and documentation for using our peripherals with an Arduino-based board. This made the embedded programming much easier and we were able to run multiple tests on all of our parts with some flexibility. This switch also eased the PCB design which had been very slow to progress due to the difficulties presented with the MSP430 and the lack of documentation and support that was available.

4.3.15 Printed Circuit Board (PCB)

The printed circuit boards (PCB) will be designed using easyEDA online design tool which allows the creation of schematic designs and the transition into the board layout. From the website, we would also be able to order our PCB and all the necessary parts that are needed. Initially, we started out using the Eagle software which posed a great deal of challenges, including not having all the library component that are needed for a complete design. To eliminate this problem, we spent a great deal of time importing all the necessary libraries to the software which we assume will make it easier to move forward with the design without having to go back and forth. Following the schematic design, we then will transfer the files to the board layout where we will be rerouting all the wires either by autorouting, which is a feature provided in the software, or by manually routing to ensure they are all connected correctly. The schematic design will be transferred automatically to the board design for easier design. Once the traces are checked and corrected, depending on the amount of errors, we will move forward to having the PCB cleaned up and fabricated.

The process to design a PCB using the Eagle software demands time. This is crucial because the design has to be able to communicate with the different components for us to achieve the success we desire. Some members in our group already have a little exposure to the software which will be a little easier on our side, although there is a learning curve. Designs are different and have different requirements. This means that using eagle before may be helpful, but since this is a project that we are actually designing, we anticipate the challenges.

In addition to the PCB, we have the option to utilize resources from Webench, a tool from Texas Instruments that allows you to design a DC-DC converter with all the specifications necessary to aid the design of the PCB. This will be very helpful especially when working with lower voltage levels. To help with this design, we will be doing a surface mount temporary design which will incorporate the use of all the components required to design the PCB. By doing this, we will get a hand on exposure to all the needed pieces that will enable the design to work effectively. Following the schematic and board design, we will move on to having the board fabricated.

There are several options available for fabrication and companies vary by price and reputation. This process can take a few days, as well as a few weeks. To ensure that we have our PCB don on time, we will ensure that the design is done in advance with the hope of very few errors. This way, we can work toward making the design more efficient and will have more time to spend fine-tuning the project. Figure 15 is the completed board design that was done prior to submitting the files for fabrication.

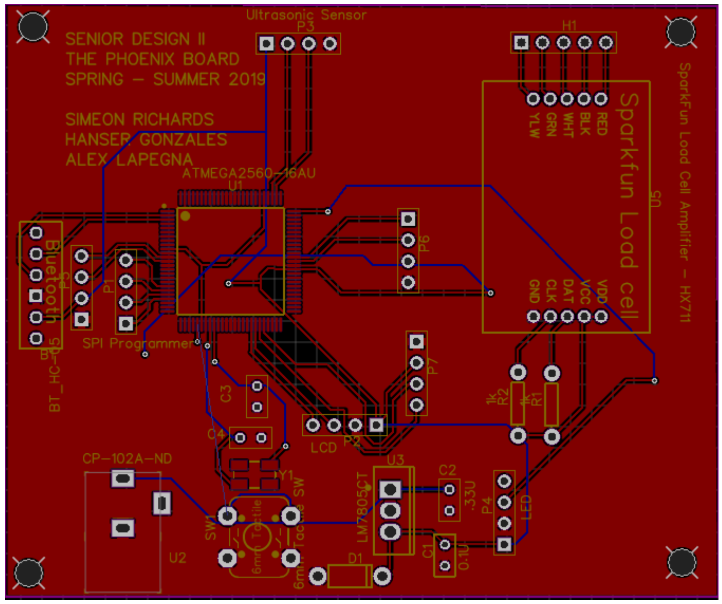

Figure 15: Completed PCB for Fabrication

The final step in this process will be to have the physical board in hand so we can assemble and solder the other component for our project. This was completed during Senior Design 2.

4.3.15.1 PCB Vendors

Throughout our research, we came across several options for PCB. Some, of course, have higher prices with better results for the design by using material that is sturdy and durable, while the others are a little cheaper and uses fewer durable materials. Several questions were asked about the companies and which one to use to the point where it was left to the budget review to help with the decision making.

The PCB is a requirement for our project and it is inevitable for us to design our own. To do this, we have decided to use easyEDA/JLC PCB because of the ability to quickly design a schematic, create a board layout and have it ready for fabrication along with the bill of material. So far, we are yet to decide on a company that will manufacture the PCB once the design is completed. After looking into quite a few options we are still debating that one from the list should meet certain requirements before a final decision is made.

Once the design is completed in eagle, we will request quotes from at least 3 different vendors before making a final selection. Once the circuit board is in our hands, we will proceed to have the parts placed on the board. This can be done either by ourselves in the lab with the potential of more risk and damages done, or we can use a professional installer with the skills, knowledge and experience to have it done well. Either method works, but in the end, we will all agree on the best option that will save us time and money.

Refer to Table 14 for comparisons of the different vendors, and what they offer.

#	Vendor	Description
1	All PCB	Specializing in high quality, low cost PCB prototype and production online.
2	**EasyEDA/JLC PCB**	An online PCB design tool, manufactured by JLC PCB from their website
3	Custom Circuit Boards	High quality PCB fabrication services in 24 hours, with multilayer options
4	Advanced Circuits	PCB manufacturing company with same day service

Table 14: PCB Vendor Comparison

4.3.16 LEDs

For this project we wanted to include Light Emitting Diodes (LEDs) in order to provide riders with a safer night-time experience. These LEDs would be set up underneath the board and provide a steady source of light for the rider so that they can be easily spotted in times of low light. We considered three types of LEDs for this project: single-color/non-addressable, RGB/non-addressable and RGB/addressable LEDs.

Addressable LEDs provide a greater range of control for the user as each LED has its own chip which allows every LED to be controlled individually in terms of color and intensity (brightness), whereas non-addressable LEDs act as a single unit, with the lights having the same intensity and color. The other main difference is whether the strip of lights would be single-color or if it would have the capability to display any RGB color. The current market seems to favor addressable LEDs as that is what is the easiest to find but that specific level of control over the lights is not something that is strictly required for the application we have in mind.

For our design we went with the CHINLY 16.4 ft WS2812B individually addressable LED strip. This LED strip is convenient in that it runs off of +5 V and only requires one Data In to run the entire strip. The color and intensity are set using the FastLED Arduino Library. These LEDs use pulse-width modulation in order to be programmed so we had to make sure our signals to them were concise. Each LED draws around 0.6 amps when powered so they require their own dedicated 5V line.

4.3.17 Weight/Load Sensor

For this project we wanted to incorporate the rider's weight in two different ways. First, we wanted to have a weight-sensitive switch that would indicate the rider is both on the board and in a proper position as a requirement to accelerate the board. This would ensure the rider was in a non-compromising and safe position prior to increasing their speed which inherently comes with more risk. Second, we wanted to be able to incorporate the rider's weight into the calculation of distance that could be traveled as a lighter person should theoretically be able to go further than a heavier one since they require less force and energy to be moved.

For our load cell we chose the TAS606, which can translate up to 440 lbs. (200 kg) of pressure into an electrical signal. With this, we set up a simple threshold within our software in order to make sure a person would register as being on the board but a random object with some weight to it would not, which could potentially put others in harm's way if it was the case.

4.3.18 HX711 Load Cell Amplifier

This weight sensor has an operational voltage of 2.7V to 5V and an operational current of less than 1.5mA, with 10SPS or 80SPS output data rate and a simultaneous 50Hz and 60Hz supply rejection. The cell uses a two-wire interface (Clock and Data) for communication and should work with whichever microcontroller is ultimately decided on for this project, many of which have numerous libraries already written to facilitate the use of this device and read data from it. The load cells use a four-wire Wheatstone bridge configuration and can be used as a scale, process control or for presence detection which matches the requirements we were looking for. This sensor also includes an on-chip power supply regulator for load-cell and ADC analog power supply as well as active low noise PGA with a selectable gain of 32, 64 and 128. Price: $9.95

When it comes to weight sensors, the HX711 seemingly has no real competitors as there are no other products on the market that have this design or utility. The closest thing to mimic it is the Gravity: Digital Weight Sensor, a weight sensor designed for Arduinos. Besides the fact that it is "based on HX711", per their website, the sensor can only detect 1 kg of weight which is far too low of a threshold for this project and would leave us with either an overly sensitive feature or an excessive amount of spending and weight added to the board to get enough of these to use effectively. Thus, with the closest competitor to the HX711 not being a viable option, this decision was limited to a degree.

4.3.19 Battery Enclosure

Although the name of this component is the battery enclosure, this part is the main shielding for all of the electronic components of the board, except for any peripherals like LEDs or a hub motor. Since the components of the board are below it and this puts them at risk of being damaged by rough terrains, large cracks or stray debris, it is crucial that the enclosure is strong enough to take strong impacts without breaking. Along with that, the protective cover should allow adequate air flow so that the electrical components that are at work when the board is running do not overheat.

There are many companies and businesses that sell battery enclosures of varying sizes and materials but that is not the only way to acquire one. There are many methods shared amongst the electric skateboard community in order for someone to produce a custom battery enclosure. Regardless of whether the enclosure is bought or made, the installation of this is of great importance and should be handled with care and with the appropriate tools in order to ensure all the components of the board remain attached and undamaged. Another feature of the enclosure which should be carefully considered is the height. The enclosure cannot be too short, or it will not properly house your components or possibly attach to the board at all.

On the other hand, it cannot be too tall, or the components may swing around, becoming loose or damaged, or it could cause you to hit debris on the ground that would be otherwise avoided. The last thing to note about enclosures is that they do on occasion interfere with the signal between the remote controller and the board although it is not clear which materials or designs are most prone to this.

For our project we decided to use the DIYE Electric Skateboard Battery & Electronics Customizable & Scratch-Proof Battery Enclosure. The main reasons for this selection was actually quite simply: it was a tough exterior with some flexibility, and it was large enough to house our plethora of components. It measured in at 21 x 7 1/40 x 1 3/4 (in. x in. x in.) exterior and 19 1/9 x 5 3/4 x 1 1/2 interior. Along with this we used an ordinary Tupperware to protect some wires that would be better off outside of the enclosure. Although design-wise, the best move for these wires was to have them outside of the enclosure, we felt they should be covered as well. And finally, to protect our components further we also used some high-grade foam in order to prevent them from being damaged by impacts.

4.3.19.1 Custom Battery Enclosures

Custom battery enclosures are a very popular topic in the electric skateboard community as can be a great way to save money while adding some creativity and individuality to an electric skateboard build. Online, many methods can be found to make an enclosure but not many of these methods are well documented. A very popular method to do this is to make the enclosure by 3D printing. This would require a 3D model as well as access to a 3D printer and a material would have to be chosen as well. Something as strong as carbon fiber would be durable enough to handle most impacts but this material can be quite expensive and could defeat the purpose of saving money with this method.

Another option is to form a mold, with either a Styrofoam plug or a combination of duct tape and cardboard, and then coat it with several layers of fiberglass and resin. This eventually forms a tough shell perfect for covering your components and can be painted over for further customization. Price: Varies.

4.3.19.2 10S5P Battery & ESC 2 in 1 Enclosure with Indicator and Switch

This enclosure comes with wiring, a power switch, battery indicator, charging cord, a foam pad and the screws for locking with the deck. Its total weight, including wiring, is 0.473 kg. The dimensions of the exterior of the enclosure are 335 mm. x 195 mm. x 60 mm.

(LxWxH), while the interior dimensions are 170 mm. x 135 mm. x 52 mm. Price: $39.00 (USD)

4.3.19.3 ESC Enclosure for V1.1 Single and Dual Belt / Hub Motor ESCs

This enclosure includes a power switch, foam and a battery indicator and is attached to the board's deck with wood screws. The dimensions of the exterior of the enclosure are 195 mm. x 158 mm. x 33 mm. and the interior dimensions are 153 mm. x 148 mm. x 33 mm. and weighs in at 0.279 kg, making it smaller than the 10S5P. It is made out of a 3 mm thick ABS and has a black glossy finish. Price: $29.00 (USD)

4.3.19.4 Eskating's ABS Enclosure Cases

These enclosures are vacuum formed and made of Black Pinseal ABS. They include a waterproof gasket which gives them a variable height, adding 2 - 5 mm of internal height. Of particular instance are a larger and smaller enclosure which have very similar designs. The external dimensions of the smaller enclosure are 370 mm. x 215 mm. x 41 mm. and its internal dimensions are 320 mm. x 165 mm. x 38 mm. The external dimensions of the larger enclosure are 570 mm. x 215 mm. x 41 mm. and the internal dimensions are 520 mm. x 165 mm. x 38 mm. These enclosures do not include the screws needed for attachment. Price(s): $29.11 (USD) and $43.66 (USD)

4.3.20 3D Printing

3D Printing is the process of creating a real object based on a 3D model or design, saved in STL format. These models can be made by scanning a set of 3D images or by designing it on a computer using computer-assisted design (CAD) software. This has been an extremely useful tool in acquiring custom parts nearly on demand and products that are already assembled as well. The great reduction in tooling or time expended allows for multiple design iterations and concepts to be tested. Along with that, 3D printing can be used for so much that it can and will continue to affect more and more fields of science, technology, art and so forth.

There are many important structures in the anatomy of a 3D printer that are all essential in producing high quality prints. These include, but are not limited to, the print bed, filament, extruder, bed or print surfaces, hotends and cooling fans. The print bed is the surface on which you will be printing and it typically consists of a sheet of glass, a heating element and a kind of surface to help the plastic stick. These may be heated or non-heated but heated helps reduce the warping that can occur with certain plastics during the cooling process. The bed or print surface aides the process by helping the plastic to stick to the bed during printing but then allows it to be removed with ease once printing is complete. Most printers will have an all-purpose surface but for better results a different surface is suggested depending on what material is being used.

Filament refers to the plastic that the printer will consume and it usually comes in spools. Printers use two filament sizes, 1.75 mm. and 3 mm. The extruder is what does the most work during printing. This is where the plastic is drawn in, melted and pushed out. It is composed of two key parts, a hot end and a cold end. The cold end is where the filament is drawn in and pushed through by a motor. The hot end melts the material and squirts it out. A cooling fan is sometimes used after the filament is deposited in order to help the object retain its shape.

At the University of Central Florida, we have access to a 3D printer, which could be useful in the case of producing a battery enclosure but the rules and costs must be obliged by and this could quickly skyrocket the cost of the project. UCF's cost for a lab manager is $40 an hour (after the first half hour) and printing costs $7 per cubic inch. This also does not include the costs for the material necessary which is also a very important factor to determine as each has unique properties which could help or hurt our project.

4.3.20.1 Acrylonitrile Butadiene Styrene (ABS) / Acrylic Styrene Acrylonitrile (ASA)

ABS is a very popular plastic in 3D printing, being one of the first materials used with industrial 3D printers. This material is known for its toughness and impact resistance and it can withstand higher temperatures before it deforms, making it a good fit for both outdoor and high temperature applications. ABS should be printed in open spaces or well-ventilated areas as it produces a pungent odor, which could be harmful if inhaled in large quantities, while being printed. This material also contracts significantly when cooling which may lead to dimensional inaccuracies. In order for a 3D printer to print this it must have its bed heated between 95 - 110 °C (203 - 230 °F), its build surface must be Kapton tape and ABS Slurry, the extruder should be between 220 - 250 °C (428 - 482 °F), with no cooling fan required. In order to minimize the warping effects, which are mostly seen in the first few layers of the print and could potentially ruin the entire print, is to increase the temperature by 10 or 20 °C for the first few layers.

ASA is a common alternative to ABS which uses a different kind of rubber in its formulation and is commonly used in outdoor applications instead of ABS because of its superior resistance to severe weather conditions and UV. The bed and extruder for ASA are much like ABS with a 5-degree difference in the lower threshold of the bed (90 °C) and five in the upper threshold of the extruder (245 °C). The build surface should have Kapton tape, PET sheets and ABS/ASA Slurry. Average Price of Generic ABS Filament per Kg: $25.00 USD. Average Price of Specialty and Infused ABS Filament per Kg: $40.00 - $75.00 USD. Average Price of ABA Filament per Kg: $30.00 - 45.00 USD.

4.3.20.2 Polyethylene Terephthalate (PET)

PET and PETG (a Glycol Modified version) are semi-rigid with good impact resistance but a surface softer than ABA or ASA, making it more prone to wear. The material is essentially odorless when printing and along with smooth negligible warping it has a glossy surface finish, although this can sometimes have thin hairs on it due to stringing. This material is also water resistant and there are several variations in the market (PETG, PETE, and PETT). When printing, the bed of the 3D printer should have a temperature of 75 - 90 °C (167 - 194 °F), extruder temperature of 230 - 250 °C (446 - 482 °F) and the build surface should have painter's tape and glue stick. No cooling fan required. Average Price of Generic PET Filament per Kg: $35.00 USD. Average Price of Specialty and Infused PET Filament per Kg: $45.00 - $70.00 USD.

4.3.20.3 Nylon

Polyamide (or Nylon) has a high durability due to the toughness and semi-flexibility of material, making it a great option when looking for high impact and abrasion resistant material. The filament for this material must be taken care of with special attention because Nylon is hygroscopic, meaning it readily absorbs moisture from its surroundings. This could lead to several print quality issues and compromise the entire product. There is no unpleasant odor when printing this and it is also prone to warping. The 3D printer looking to use this material should have a bed at a temperature of 70 - 90 °C (158 - 194 °F). The extruder temperature should be in the range of 225 - 265 °C (437 - 509°F) although it should be noted that reaching temperatures of 250 °C and above could require an upgrade in the hot end used. The build surface should have glue stick and PEI, and no cooling fan is required for this print. Average Price of Nylon Filament per Kg: $80.00 - $110.00 USD.

4.3.20.4 Carbon Fiber Filled

These filaments are short fibers infused into a PLA (Polylactic Acid) or ABS base material to increase the strength and stiffness. Other popular filaments that can be carbon fiber filled are Nylon, PETG and Polycarbonate. The pieces printed with this will be much lighter and more dimensionally stable, with less warping being done. The print settings will be largely similar to the normal settings of the base material but there is an increased likelihood of oozing while printing and clogging so special hardware could potentially be required to avoid damaging the printer. The extruder also requires a wear resistant hardened steel nozzle. Average Price of Carbon Fiber Filled Filaments per Kg: $45.00 - $90.00 USD.

As far as a final decision on what will be done for the enclosure, this is still not entirely decided as we must first determine exactly how we will be laying out our components on our board. This also applies to purchasing a pre-built enclosure as we will need to ensure how our components will be laid out so that we know there will be sufficient space within the enclosure to house everything. However, we did decide that should we go the route of 3D printing, we will most likely be using general ABS or ASA as they are both quite durable substances, relatively easy to work with, and the most affordable option we have regarding filaments. Another option we are still debating is making the enclosure ourselves with one of the many "at home" methods found online, but we hope to avoid this due to the fact that these methods are not always very well documented and could lead to defects in our design later on.

4.3.21 Fuel Gauge Chip

In order to continuously monitor and maintain our on-board battery, a high-quality battery fuel gauge is needed. This way the board's electronics can run properly which in turn provides the rider with up-to-date battery information, ultimately improving overall user experience.

4.3.21.1 BQ34110 Multi-Chemistry High-Cell Count Battery Fuel Gauge with Integrated Rarely Discharged Module

TI's BQ34110 Battery Gauge Module is used for both single and multi-cell batteries. It supports up to 65V, capacities up to 32 Ah, and currents upwards of 32A. It uses Compensated End-of-Discharge Voltage (CEDV) gas gauging, able to provide State-of-Charge, Time-to-Empty, State-Of-Health, and Watt-Hour-Based Charge Termination. The gauge also has an internal temperature sensor for managing battery temperature. The gauge is able to send data via a 400 kHz I2C bus. Dual ALERT pins are available for, both of which are programmable and provide functions such as host interrupt/alert and battery charger control. Price: $2.04

4.3.21.2 BQ34Z100-G1 Multi-Chemistry Impedance Track Standalone Fuel Gauge | Battery Gas Gauge

TI's BQ34Z100-G1 Battery Gauge module supports up to 65 V, capacities up to 29Ah and currents upwards of 32A. It uses an Impedance Track fuel gauge which works independently of battery series-cell configurations. It's capable of Aging Compensation and Self-Discharge Compensation. The gauge has an internal temperature sensor for managing battery temperature. For communication, the gauge supports two-wire I2C and HDQ Single-wire communications. In addition, it has Direct Display Control for one to four LEDs, with the option to expand to five or more via a port extender. Price: $2.10

4.3.21.3 BQ78350-R1 CEDV Li-Ion Gas Gauge and Battery Management Controller

TI's BQ78350-R1 Battery Gauge module supports three flexible configurations, up to 108 V, capacities up to 320Ah, and currents up to 320A. It uses Compensated End-of-Discharge Voltage (CEDV) gas gauging, able to produce a full array of protection features for Voltage, Current, Temperature, and system components. The gauge has an internal temperature sensor for getting current temperature. For communication, the gauge supports the SMBus 1.1 interface. In addition, it drives up to 5 LEDs or an LCD display for indicating remaining battery charge. The BQ78350 is unique in that it must be paired with a bq769x0 battery monitor. For our purposes, the bq76940 would be sufficient to cover all voltage requirements. Price: $2.41 (BQ78350-R1), $3.60 (BQ76940)

Initially, we decided to go with the BQ34Z100-G1 Multi-Chemistry Impedance Track Standalone Fuel Gauge. However, due to the difficulties in testing the fuel gauges mentioned, a simple LCD based battery meter display was selected, which is spliced onto the main lines leaving the battery. For a side-by-side comparison of fuel gauges, refer to table 15.

Category	BQ34110	BQ34Z100-G1	BQ78350-R1 (with BQ76940)
Maximum Voltage (V)	65	65	108
Maximum Capacity (Ah)	32	29	320
Maximum Current (A)	32	32	320
Gas Gauging Method	CEDV	Impedance Track	CEDV
Supported Communications	I2C	I2C, HDQ	SMBus1.1
Price	$2.04	$2.10	$6.01

Table 15: Fuel Gauge Comparison

4.3.21 Fuel Gauge Chip

The Texas Instruments' bq28550 single cell Li-on battery gauge is the preferred gas gauge selected for this project. The gas gauge provides added current and voltage protection and required host microcontroller firmware support for implementation. The fuel gauge features a comprehensive, single cell battery manager that integrates essential functions such as gas gauge, protection control, enhanced charging and authentication. On the display, information about the battery gas gauge will be displayed, including information about the state of charge in percentage, run-time to empty, charge-time to full, battery voltage and temperature.

Some of the key features of the bq28550 includes protection functions such as short-circuit, overcurrent charge and discharge, overvoltage charge and discharge, undervoltage charge and discharge and firmware control of discharge. It also uses an accurate gas gauging algorithm to report the status of the cell

These features influenced our decision to include the chip in our project and we are looking forward to the interactive engagement that will be presented once we are in the process of completing this design. Figure 16 is the circuit showing how the fuel gauge chip will be used, and how the schematic will be used in the project design.

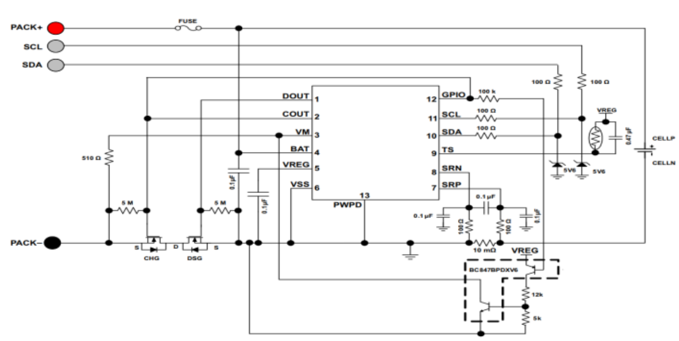

Figure 16: BQ28550 Battery Fuel Gauge

4.3.22 Electronic Speed Controller

During our initial phase of research, we did not take into account the need for an electronic speed controller. At the time, we were unaware that this is in fact is how the motors are controlled. An ESC is used to provide a PWM signal to the motors to increase/decrease the throttle. Typically, these are paired with a nunchuk or some other kind of wireless controller but in our case, it will be via our mobile application. The ESCs we looked at are based on VESC, which is an open-source ESC designed by Benjamin Vedder and includes a robust software suite known as the VESC Tool.

4.3.22.1 Dual FSESC 4.20 100A with Anodized Aluminum Heatsink

This model of VESC can support batteries ranging from 3S to 13S, which translates to a range of 8 to 60 V, and provides 100 A of continuous current in dual-motor mode. Each motor is connected to the VESC via three motor signal lines and a Hall sensor connector, totaling 6 signal lines and 2 sensor connectors. It has a USB port for easy configuration and testing using the VESC Tool software. Lastly, the VESC has a UART connection which we use to get the speed instructions from the PCB.

This model was very responsive and using the VESC Tool software we were able to easily configure this VESC in dual motor mode and had both of our motors running properly. Unfortunately, during our testing a pair of wires came loose and created a short circuit directly on the microcontroller of one side of the VESC, effectively leaving us with only one working ESC/motor. While we believe this ESC could have done the work of powering our motors on its own for the final version of the Phoenix Board, because of the loss of half of the ESC we had to look elsewhere for a replacement.

4.3.22.2 HGLRC FSESC VESC V 4.12 50A SK8-ESC Open Source for Electric Skateboard/E-Bike/EScooter

In order to quickly replace the ESC we had damaged, we turned to the HGLRC FSESC VESC. This ESC is also based on the open source VESC project by Vedder and is compatible with the Tool software as well. This model also provides reliable and progressive braking, which will be a very useful tool for us in stopping the motors should the object detection software or weight sensor be triggered. This model also supports 3S to 13S batteries and operates at the same voltage as the Dual FSESC. Figure 17 below shows the ESC that we will be using for our design. The top image is the single ESC and the bottom image is the dual ESC.

Another great and easily programmed device, this ESC is very reliable and just as efficient as the dual motors. Due to the use of this ESC however, we had to increase our use of UARTs and were using 3 out of 4 available UARTs by the end of development.

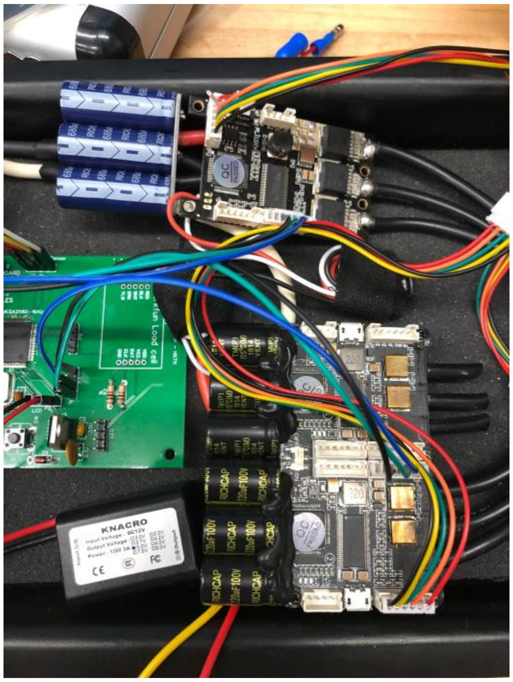

Figure 17: ESCs Inside Board Enclosure, Single ESC (above) and Dual ESC (below)

5.0 Prototype Design and Construction

With research on the individual components and subsystems complete, our team moved on to prototype design and implementation. The following sections detail our design decisions along with supporting diagrams to further illustrate our desired implementation for the final prototype.

5.1 Hardware Design

The hardware design is essentially putting all the pieces together to make a whole. Initially, we will be using a breadboard design to test each part to ensure they work properly. During the breadboard design, progress will be made to design the PCB. The final stage of the hardware design is ensuring all the components are connected with the correct power and voltage input. This includes attaching all the components, such as Bluetooth module, camera, sensors, power, PCB and any other component that is a part of the project. The design components will be ordered from various websites and will be attached by soldering the parts that can be soldered.

5.1.1 Breadboard Prototype

The breadboard design is a breakdown of the project utilizing surface mounted component, function generator, oscilloscope and other lab equipment to design a prototype of the actual design that will be done once it is confirmed that all the component used will actually work.

Following the successful completion of the breadboard design a record will be taken of all the component that was used to design the PCB.

This process is essential to the completion of our project. Without it, there will be countless amount of assumptions and trial and error which will, in turn, take a lot of time and potentially, cost money. So far, we are in the process of testing each component that will be used in the actual design to ensure they work effectively, and also do what they are required to do. There are no complications. However, we are expecting to have a challenge with finding the actual library for some of these devices in the Eagle software. If that happens, we are prepared to find other alternatives, such as using a different software that may have these libraries, or may not require the use of libraries.

5.1.2 Transmitter and Receiver Circuit

Throughout our research, we found that the process of designing a wireless transmitter (Tx) can be very daunting, time consuming and by extension, frustrating without having a general knowledge of what the needs are, and what needs to be done to meet those needs. Extensive research has been done and enough information is gathered to enable us to move forward with designing the circuit.

There are many options available to design the transmitter circuit. To avoid any confusion, it is important that we find a solution that will work best for our purposes and use it to achieve the goal we desire to achieve. The transmitter circuit requires 12 volts power source that will be supplied from the solar panel. A voltage regulator will be required to reduce the voltage from 12 volts to either 3.3 or 5 volts.

The picaxe 08M2 chip is used in designs for the main purpose of serving as an oscillator that generates the resonant frequency for the transmitter. The output is fed to the gate of a MOSFET power transistor that will drive a coil directly to its drain. To prevent any potential kickback during turning on and off transitions, a snubber capacitor from the drain side of the MOSFET will be connected to ground.

For this to function effectively, it is necessary to program the picaxe to generate the resonant frequency. In addition, resistors are needed to aid the circuit in generating a 12 kHz output.

5.1.3 Transmitting and Receiving Coils

The preparation in creating the coils for the inductive charge comes with experimenting with diverse types of coils of varying diameters, geometries and size of wire. There is a potential for this to become the most difficult part of the project, but it can be done. The coil used for inductive charging is an old principle known as inductive coupling. In recent years, it was discovered that when two resonant circuits resonate at the same frequency, due to the evanescent wave coupling the energy that is being transferred from the transmitter to the receiver is at a high efficiency.

The frequency of both the transmitter and the receiver is required to be the same for maximum efficiency. This is because if the frequency is not the same, there could be associated parts that may not work effectively. Another factor to be mindful of is having the coils placed in the right position to minimize losses by ensuring the size of the area is appropriate and the coupling factor is ideal. The coupling is mainly used to compensate for misalignment and it is important that the coils are designed with high quality coupling factors.

The skin effect is another factor to consider as this depends on the frequency of the alternating current. Since we are somewhat restricting ourselves to direct current, this application may not be application to our design. However, there are other effects such as proximity effect that influences the energy losses in the coils. The current constriction and displacement in closely spaced conductors is caused by this effect because of the magnetic flux leakage in each of the conductors.

To optimize the efficiency of the transmitter and receiver coils it is necessary to minimize the parasitic resistances in the coils by using high quality materials, designing efficient wire strand insulations and optimizing winding technologies. Doing this will provide better performance of the wireless energy transmission and is essential in the overall efficiency of the system.

5.1.4 Coil Enclosures

The options for coil enclosure vary on a number of factors. The first few considerations had to do with the ability to achieve maximum efficiency. We discovered that some enclosures limit the flow of signals from one component to the next, and especially as it relates to Bluetooth and Wi-Fi signals.

The coils can be enclosed in prefabricated acrylic blocks. The advantage to using this type of block is the ability to withstand pressure. This is essential because of the pushing and pulling forces that will be used, moving things around in different areas. The disadvantage to using this block is the lack of variety with dimensions. Most of the blocks are made in standard sizes which makes it difficult if there is a need to manipulate depending on the size of the project.

Two sets of blocks are needed. One for the transmitter coil and the other for the receiver coil. The coils will be winded inside the blocks with a few inches left on the end to prevent unraveling of the coil.

5.2 Solar Power Installation

In this section, we had the opportunity to design and implement how the solar power would be connected to the design to charge the skateboard battery, especially incorporating it wirelessly. One setback we anticipate to encounter is the risk of power loss due to voltage drop since the voltage from the solar panel is unstable. To fix that problem, we will be using a solar charge controller which stabilized the voltage coming from the panel, making it a consistent 18 volts supply.

Because this is a temporary system, we will be ignoring the use of storage batteries which we believe will be more beneficial for permanent designs. This means that the power from the solar will be going directly to the charge controller and from there, to the inductive charge transmitter.

5.2.1 Solar Panel Mounting Options

In many cases, mounting a solar panel is ideal for the security and safety the panel itself, and for any individual who might be in contact with that panel. Generally, mounting a solar panel using ground mount can cost exponentially more than other methods. This is partly because of the process of digging into the earth deep enough to secure the parts, in addition to the cost for approval and permitting if necessary. Although this option can give more flexibility in terms of direction and placement, it is the decision of the end user to finalize placement of these panels.

For buildings, rooftop solar has its advantages and its disadvantages. It is recommended that the solar panels be placed at the south most location and a good angle for the most effective operation. If there are any obstacle preventing the placement in this direction, such as chimneys, trees or any kind of shade, the solar will be less productive.

For our project, we will be utilizing the standard ground mounting option. This is solely due to the flexibility to mount the panels at different angles and the ability to adjust position if necessary. This will be beneficial because it will generate more electricity over time depending on the placement.

5.2.1 Protection

Safety is a major part of any project. This is simply having the ability to discontinue the power flowing between devices and ensuring that there is no exposed wires and circuits that can cause an electric shock or short circuit. Since we are using 36 volts battery to supply power to the skateboard, it is important that we have the option to cut supply. In doing this, we will be installing a 12-volt DC switch at a point before the solar charge controller. This will allow us to be able to control the flow of electricity in the system and also prevent any problems associated with the power distribution.

Another point of protection that is of vital importance is having a fuse installed at other points that will serve as overcurrent protection for added safety. This fuse will be installed at a point between the receiver circuit and the boost converter which will account for any protection needed at the input of the converter.

For added safety and protection we’ve chosen to have a sensor on the board itself that will engage once the user steps on the skateboard. This will release the functionality and features of the board and allow the user to be able to operate the equipment. If something should happen while riding, the user will be able to release the sensor that will disengage the all the board’s features. We believe this is an important feature to add in case of an emergency and the user may not be able to stop in time. This will allow them to stop the ride without the board running away and cause injury to pedestrian or property.

5.2.1.1 Power Switch

The final safety feature for the board is a power switch. This will have the main task of powering the board on and off before and after each use and will contribute to saving on battery usage. It is only natural for individuals to leave equipment on when not in use, especially if there is no way to disconnect the power going to the device. With our design, a power switch will be very useful in helping us to conserve energy and save battery life for more ride time.

There are multiple power switches on the market today, and it gets overwhelming going back and forth between which one is better, or even one that will suit the purpose more effectively and efficiently. Currently, we are looking at a latching push-to-make push-to-break 12 volts power switch that will be able to turn the board on and off. Before riding, the user will engage in opening the mobile application on an android or phone which will give them access to the features and the ability to operate the board effectively. The user will then access the power switch on the board to turn the power on which will in turn open the features on the board, including the Bluetooth which is needed for communication.

Once this is done the user will be able to connect the phone to the board via the Bluetooth connectivity and they are ready to ride, providing that all the requirements are met. To power down the board, the user will be required to utilize the power switch to turn the power off which will shut down the board and disconnect from the mobile application. One feature that we will consider for future enhancement is having the board going into sleep mode after idle for a certain time frame, after which the board will turn the power off by itself. Some of the switches on the market have indicator lights that will turn on when the switch is turned on and turned off when the switch is turned off. This will add to extending the life of the battery, and also allow user to know when the power is on or off.

For additional safety and to ensure there is no disturbance with the power or any of its components, it is important to have either an enclosure to house the switch, or have a switch that is either waterproof, or housed in a waterproof casing that will aid in protection from water and moisture.

5.2.1.2 Fuse

For our design, protection from electric shock and any form of short circuit is essential to the successful launch of our final design. To ensure this protection is active, we've decided to add fuses to protect ourselves and the circuit. The fuse we used is a Bussmann inline fuse that has a capacity of up to 250 volts, but handling 32 volts with up to 30 amps more precisely.

One fuse will be placed on the transmitter circuit and the other will be placed on the skateboard, directly after the battery to protect the circuit.

5.3 Software Design

The two frameworks used for software design were React Native for mobile application development and the Arduino IDE for embedded system development on our microcontroller and associated PCBs/components.

5.3.1 Mobile App Prototype

In this section we will be further explaining our initial goals and plans for the mobile app that will be paired with our board. The development of this app will be paramount in the success of this project as we are striving to provide the user as much control over their riding experience as the leading companies in this market, if not more.

The core idea of implementing an app that gives the user control over their ride is first and foremost to eliminate the need for a secondary device as most companies and hobbyists use now. Although there have been improvements in the overall quality of these devices it can still seem troublesome to users to carry another device on them. With our design, we are taking a device that most people already carry on them anyways in order to deal with this and by looking at what other products have to offer, we are also looking to build on top of some pre-established features while adding our own ideas as well. And although the initial mockups were for iOS devices, we are in fact striving to make this accessible to Android users as well.

The React Native framework relies on several existing libraries and frameworks to function. We elected to start with installing React Native under the assumption of full native app development from scratch rather than integrating React Native into an existing application. As such we needed Node.js, Python2 and an existing Java JDK of at least version 8 (our implementation used 10.0.2).

To facilitate package installation, we utilized the Chocolatey package manager for Windows. This package manager is easily installable via the command line and allows for package installation similar to the Linux operating system. From here, Node.js 11.14 and Python 2.7.16 are installed. Afterwards, we use Node's built-in package manager, npm, to install the React Native command line interface.

In order to develop on the Windows platform with React Native, Android Studio is needed. The most recent version was installed along with the Android's SDK interface to ensure the most recent version of Android (Android 9 (pie)) along with its dependencies and relevant system images are installed. From here, two additional system variables needed to be created, ANDROID_HOME and JAVA_HOME, pointing to the Android sdk and Java jdk files, respectively.

With all of the required software and dependencies installed, React Native is ready for development. React Native projects contain an app.js file which is where the bulk of the code for the app is done. They in turn, when properly compiled, feed into either a currently running Android Virtual Device (a software emulator that allows for any number of Android devices to be simulated) or directly into an Android phone, if one is connected to the development machine.

5.3.1.1 Status Bar

This is a common feature across all Smart Phones and gives the user a quick look at their phone's signal, battery life, and time. There are various apps that choose to remove this from the screen while running although there isn't a clear and set reason as to why. We are choosing to include this feature because we believe it would be useful to riders who may sometimes be trying to beat the clock to get somewhere, or may be trying to monitor their phone's battery consumption more closely. Figure 18 below shows how the screen will look in the end.

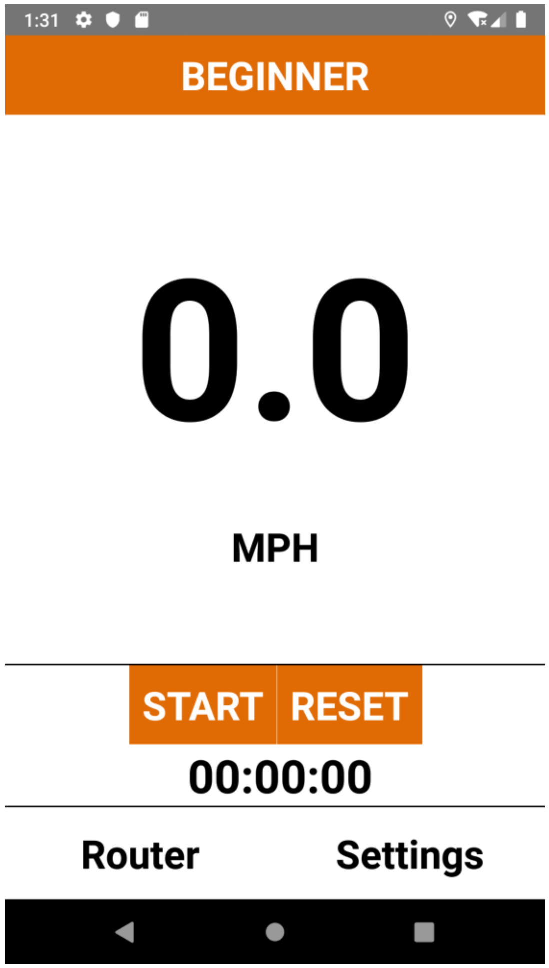

Figure 18: Mobile App Home Screen

5.3.1.2 LED/Night Mode

In order to further allow our users to give their riding experience a unique factor we are including a strip of LED lighting on our board. This will serve two primary purposes. The first will be based on safety. For various reasons, a user may be required to operate their board during times of low light and visibility, which can be quite hazardous. In the case of a late night or early morning ride, the LEDs will function as a light source in order to increase the visibility of the rider but since this will be on the board and not the rider themselves, we still recommend the use of reflective or high visibility gear.

The second feature is to add a bit of customization to the board, as we will give the user the ability to change the color of the LED strip in order to add their own personal touch. The toggling of the LED feature will be on the main screen in order to allow users to quickly turn this on or off without having to distract themselves from operating the board and keeping an eye out for any potential hazards in their path. The functionality for changing the LED colors will be in the settings of the app, discussed in more detail shortly.

After making this feature operational and doing some testing with our LED strip, we figure out that due to the PWM of the LEDs and the amperage needed to make them work we would have to limit the customization options. Originally, the user was provided with a color wheel which would allow them to select virtually any color and transmit this to our strip. Due to the load this would put on the strip, our LEDs would get out of sync, transmit data incorrectly and flicker with instability. After some configuring, we found 8 different configurations for the LEDs in terms of RGB values and limited the options to these which we knew were stable. Along with that, there is also a message that is sent before each color change that clears out the LEDs so that no residual data in the line pollutes the data being sent in.

5.3.1.3 Analog vs. Digital Speed Controls

A key feature in the controls for the other products we evaluated in our research was that they only allowed the user to control their speed in one way, most commonly analog. The most common implementations involve a dial or an analog stick that allows the user to accelerate or decelerate and depending on the remote controller, the actual speed may display digitally or not at all. An example of the latter is Boosted's controller, seen in Figure 19, which also includes a button to engage the controller but no indicator of real-time speed. Our version of the analog dial involves a long strip composed of multiple smaller bars and an arrow indicator that the rider would slide up and down in order to increase or decrease their speed. This bar would be multi-colored, transition from green to red in order to convey in a simple way the added inherent risks with the increase in speed.

The digital version of this is comprised of two large buttons, one of which will have a plus sign and the other a minus to signify an increase or decrease in speed, respectively. This is yet another feature that we will allow users to change freely in the settings in order to provide them with their preferred method. Along with these features for controlling the speed, our app will display the actual speed at which the board is going at a given time in large, visible numbers to take any guesswork out of the equation. This display will be available in both miles per hour and kilometers per hour so the user can choose whichever system is more familiar to them and would only require a small conversion on the programming end in order to be achieved.

Another possibility would be to use the volume up/down buttons on the phone to control the speed. This could also have an "analog vs. digital" mode depending on the implementation. If the speed increases linearly when the button is held down, this would essentially do the job of the analog slider and would allow for us to remove another component from the screen, allowing more space for everything else. If the buttons worked more like clicks and each click was representative of a uniform step up or down in speed it would work more like the digital buttons, we were thinking of implementing.

This could be an extra feature or it might end up being the core method for changing speed and might be the safest method as well. By using the volume up/down buttons, the rider would not really have to look down at their phone unless they wanted to actually verify what speed they were going. Changes in speed would become easier, requiring the rider just feel around for these buttons on their phone before increasing or decreasing their speed. Ultimately, this is something that will have to undergo further testing to verify the validity and usefulness of the method but it may prove very useful and might even be applicable to other controls on the board.

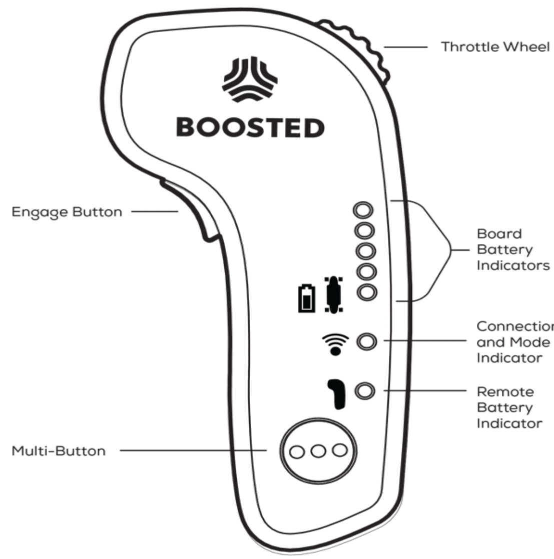

Figure 19: Boosted Board Remote Controller

Once we started developing our app, we realized that in order to maximize safety, the controls for the app's speed would be the volume buttons. The application takes priority over the normal use of the buttons, so the volume will not be affected while in the app. Upon detecting a change in speed, the app will write to the PCB via Bluetooth which takes in the speed and converts it to an appropriate number of RPMs for the motors which is then sent to the ESCs via UART. Implementing this allows for the user to feel for the buttons instead of taking their eyes away from where their board is going. The speed increases in half steps of either miles or kilometers depending on the unit selected and is displayed in a larger font in the center of the main screen of the app.

5.3.1.4 Board Battery Life Display

This is a feature that seemed rather intuitive to add since we understood as a group how important it would be for us during testing and others once the project was finished to be able to quickly glance down and quickly ascertain what our remaining battery life was. Although at this time, we have not finalized the design for this, the basic premise of how we want to design this portion of the app is as follows. We will display a battery symbol like the one in our mockup which will be composed of four or more bars. The number of bars will depend on how precisely we wish to show the battery life, meaning if we have four bars, they each will be comprised of 25% of the battery life as opposed to five bars that would show 20% each or 10 bars that show 10% each. We will also be making slight changes to the color of the symbol as the battery drains so that even without looking at the exact number of bars the rider will know more or less where they stand by that alone. Another option we were considering was to show the actual percentage somewhere around the battery symbol to further increase the accuracy but this is something we will have to experiment with as we do not want to oversaturate the screen with information.

In order to reduce the amount of information being sent back and forth between our app and PCB we decided to remove this feature. For information on the amount of battery left we still have the battery display meter on the bottom of the board and we feel this will be a sufficient source for checking the amount of battery left and is most highly recommended before the start of a ride.

5.3.1.5 Max Distance Left on Charge

This portion of the app ties in to the previous one as both are used to relay information to the rider as to how much longer and how much further they can ride. Although we have not entirely worked out how this will be calculated, as it may require extensive testing once we have built the board and have it running, the goal of this feature is simple. We want to indicate to the user a rough estimate of how much farther they can go until the battery gives out and they have to revert to a push-kick method in order to travel on their board.

The reason this may take extensive testing is because of various aspects that could potentially factor into this calculation. These factors include, but are not limited to, the ride mode the rider is using which will affect how much load can be put on the motor and therefore the battery; the weight of the rider as this again puts a load on the board and at heavier weights could result in shorter distances that can be attained; the terrain that is being ridden on as well as if this terrain is level or if there is an incline to account for; the use of peripheral devices such as LEDs or the ultrasonic sensor. All of these variables will need to be accounted for in order to make this feature viable and accurate to a certain degree.

Due to a limit in time we were unable to add this feature. Due to the tight schedule we had we were unable to perform enough testing to implement this feature and to do so in an accurate manner. In order to correctly be able to output this number we would have to take into account far too many variables than is possible, especially given our amount of testing so we decided to remove this feature.

5.3.1.6 Map / Ride Tracking

A unique part of our project that we have not seen implemented elsewhere is the ability to track your rides. In order to do this, we will be using location tracking and mapping API files from our chosen framework, as all of the ones researched for this project do in fact provide this for us. This feature, unlike the Battery Life Display and the Max Distance Left on Charge can be clicked and will lead to a secondary screen as seen in Figure 18. On this secondary screen, the main display will be a large map that will display the start and end locations of the user's ride. Below this will be multiple bits of data having to do with the ride itself.

As of this time, we are leaning towards three data points here which will be the average speed for the ride, the distance traveled and the time it took to do so. A notable feature on this screen, as well as others that will be discussed shortly, is that we still want the user to be able to control their speed while on this screen. This means that regardless of whether the speed is controlled through the digital or analog method, the controls will remain accessible to the user so that will still be in complete control of the ride. This is something we wanted to include so that even when they are checking these stats or checking their route, they can speed up or slowdown in accordance with what is in front of them, which ideally means they will still be experiencing as safe a ride as possible.

At the time of implementation, this feature worked out extremely well with only some minor changes. The application uses Google Maps API in order to display a high-quality map which also displays points of interest. The location tracker waits for a change in position and once that is received it will update an array that keeps track of all positions and creates a path out of them, updates the distance and also updates the average speed. The average speed is also calculated but the timer that aides in that calculation is not displayed.

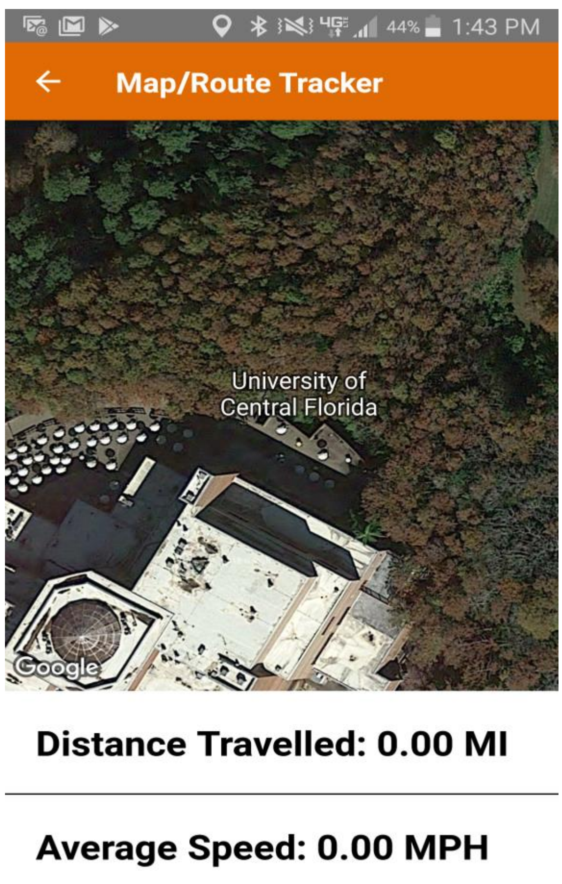

Figure 20: Map/Ride Tracking Screen

5.3.1.7 User Settings

This is another essential portion of our app, seen in Figure 20, as it will provide the users the means by which to customize their experience. The first notable feature on this screen will once again be the speed controls. As mentioned previously, we want the rider to be able to seamlessly be able to navigate the app while still maintaining full control of their ride, and although we do not recommend the app be focused on too heavily during rides at higher speeds, we do understand that sometimes it is simply required. Although the first tab of the settings page will be for the rider to select their ride mode, this will be discussed in more detail further in the report since it involves a lengthy explanation.

Next, we will discuss the two easiest functions to toggle, which will be the changes between analog/digital speed controls and the unit in which the speed appears on the main screen, both of which will be done through the use of switches much like the LED control is toggled. The LED customization will also be found here and this is where we will have different preset colors for the rider to choose from in order to give their ride a personal touch. At this point in time we are still deciding on whether or not to add additional LED functions such as automated color transition patterns or the ability to make the lights flash.

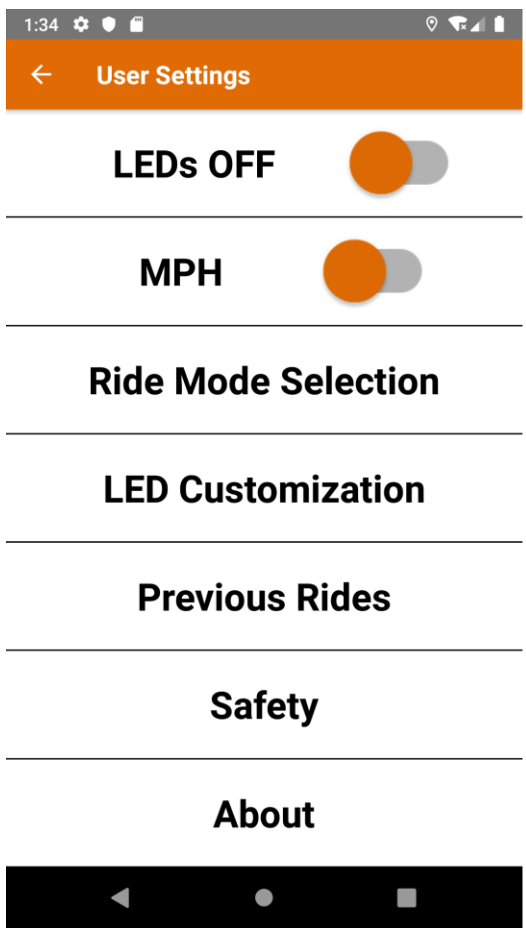

Figure 21: Settings Screen

While these could further ensure the rider is visible at night, they could also put an extra strain on the battery life which may ultimately not be worth it. The settings page, as shown in figure 21 will also feature a Safety tab, explaining some safe practices for the user and also pointing out the assumed risks that come with traveling at higher speeds. The final tab will be an “About” page which will contain a small summary of the purpose of this board and its relation to this project along with some technical details.

5.3.1.8 Ride Modes

The ability to provide different “ride modes”, based on the proficiency of the rider, is something that was seen across the board when we looked at similar products, the only noticeable difference being the number of modes available. This is a feature we believe will help users operate the board with their mind relatively at ease as each mode will offer a different speed cap in order to allow users to progress and speed up as they see fit while mitigating their risks. Presently, we are looking to have four standard ride modes although the exact details of each one has yet to be decided upon and probably will not be finalized until we can actually test them out. These four modes will be divided into Beginner, Intermediate, Advanced and Economic, or ECO, although these names are subject to change.

5.3.1.8.1 Beginner Mode

This mode, as its name implies, is for riders with little to no experience. Beginner mode, shown in figure 22, will be the one that is impacted most heavily besides ECO, as we will look to limit some of the functionality of the board in order to ensure the rider can still feel safe and can gradually improve without the fear of losing control. This mode will have the slowest acceleration out of the four and will also have the lowest top speed since it will be targeted at users who still need to learn some of the basics of skateboarding before going faster and putting themselves at risk. We are currently theorizing a top speed of 20 mph and thus would want to cap the Beginner mode at around one-third of that, meaning the top speed would be 7 mph which is 35% of the max.

5.3.1.8.2 Intermediate / ECO Mode(s)

The Intermediate and ECO modes are for those who already have some riding experience under their belt and better understand what they can or cannot handle. With a theoretical max speed of 14 mph this mode would reach roughly 70% of the top speed that the board could handle. These modes are the two we see being utilized most often as they may feel like a good balance for the greatest number of people, allowing them to kick the speed up when they really need to but take it easy at other times. The main difference between these would be the other limitations the ECO mode would put on the board. The purpose of this mode would be to extend the battery life of the board as much as possible, which would be done by turning off or disabling some of the peripheral devices and focusing all power into the motor and mobile communications. This mode would require the most testing in order to truly maximize the potential of the board while figuring out which peripherals to disable.

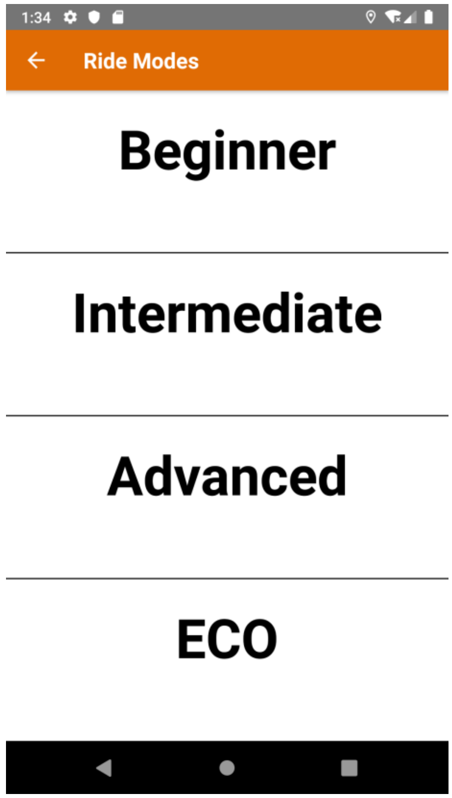

Figure 22: Ride Modes Screen

5.3.1.8.3 Advanced Mode

For the Advanced mode, there would essentially be no speed cap, allowing riders to reach the top speed that the motor could withstand. Understandably, this mode would be the most dangerous as a collision or unexpected dismount from the board could lead to serious injuries at max speed. This mode would also be the one that drains the battery the fastest as it would require the most power to reach those higher speeds and maintain them. With this mode we do want to give the user a faster acceleration to go with their increased speed as an experienced rider will have more knowledge and understanding of how their movements should be in order to keep up with these speeds but we don't want to increase it too much where it could lead to the board suddenly flying out from underneath the rider's feet. Testing will be required to find the correct balance for this.

5.3.2 Embedded Prototype

For our embedded development, we used the Arduino IDE. We selected this framework due to its ease-of-use with Arduino products. The Arduino IDE is easily installed via Arduino's website. The software is open-source and has no cost. After installation, the correct chipset is selected in the options along with the current COM port that it the Arduino is plugged into. From here, the sketch is ready to be compiled and uploaded. The IDE comes with a series of built-in libraries along with easy to use examples.

On initialization, the embedded software initializes 3 UARTs, one to 9600 baud rate, and two to 115200 baud rates. It clears all of the LEDs, assigns the UARTs to their corresponding VESC and signals that the board is ready to receive data. The main loop runs through several processes

The board will run load-cell code to ensure that rider is actually on the board before allowing for a speed change. If the weight exceeds a threshold of 40 lbs., then a flag will be sent to the app via Bluetooth, signaling that the app is safe to send speed data. From here, if the ride mode is set to Beginner, and the speed is greater than 0, the ultrasonic sensor will check for obstacles. If an obstacle is detected at less than 12 feet, the PCB will initiate and emergency slow-down for the motors, throttling the speed until coming to a halt. Simultaneously, it will transmit a flag to the app, signaling the app to reset it’s speedometer to 0 and lock out any further speed changes until the PCB signals again that the board has come to a stop and is ready to receive again.

Lastly, the PCB is reading the serial input and looking for one of three inputs. These can be a ride mode update which updates the PCBs ride mode, an LED update, which updates the LED strip on the outside of the enclosure, and lastly a speed change, which updates the current RPM count for the motor. At the end of the entire loop, the UARTs transmit whatever the current rpm is to the motors. As a precaution, the VESCs are configured to come to a stop if no setRPM () is received for one second.

5.4 UML Diagrams

The following section details our UML diagrams which provide a visualized look at our software along with a summarized breakdown of software functionality and intended implementation.

5.4.1 Use Case UML Diagram

Figure 23 details Use Case Diagram for the Phoenix Board. It illustrates the different use case potentially at play throughout the entire Phoenix Board system, including all relevant actors. The rider’s basic actions include turning on the board and opening the app. The board has its power management subsystem and sensor suites interacting with each other and with the rider, depending on the rider’s selected actions.

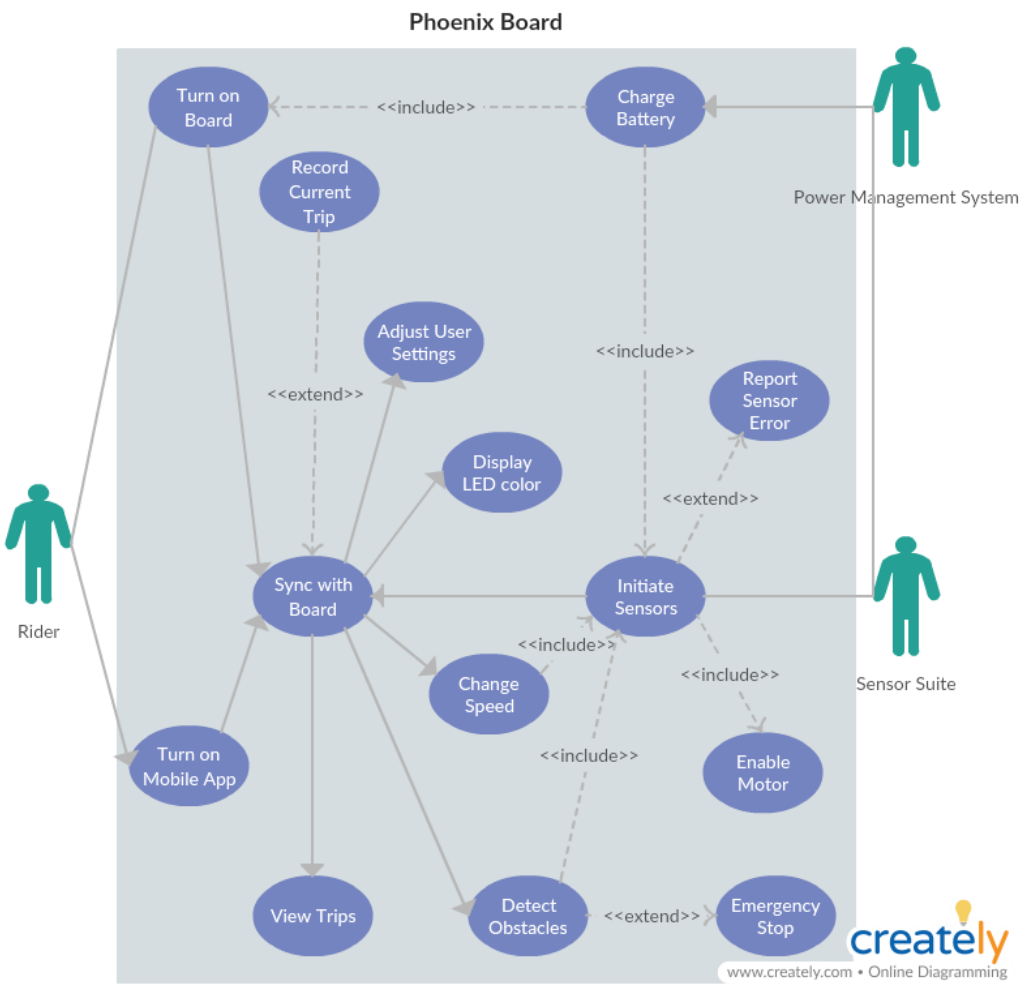

Figure 23: Use Case UML Diagram

5.4.1 Breakdown of Use Cases

The following is a detailed breakdown the various Use Cases along with their various triggers, prerequisites, main success scenarios, and post conditions.

Use Case 1: Turn on Board

Pre-Conditions

- Sufficient Battery Power

Triggers

- Rider switches on the board

Main Success Scenario

- Sensor Suite initiates
- Motor is enabled

Post-Conditions

- Sensor suite is live and ready to receive/transmit
- Board is ready to sync with mobile app

Use Case 2: Turn on Mobile App

Pre-Conditions

- Rider phone battery has sufficient power
- App is correctly installed

Triggers

- Rider opens app on their phone

Main Success Scenario

- App home screen opens
- App loads existing user settings

Post-Conditions

- App is ready and looking to sync with the board

Use Case 3: Sync with Board

Pre-Conditions

- Board must be turned on
- App must be on
- Board must have sufficient battery
- App Bluetooth must be enabled

Triggers

- Board and app are on and looking for a sync

Main Success Scenario

- Board and app successfully pair via Bluetooth connection
- App signals board ready for use

Post-Conditions

- Board is now ready for user input

Use Case 4: Record Current Trip

Pre-Conditions

- Platform running app must have a valid data connection to run on-board GPS

Triggers

- Rider elects to record current trip

Main Success Scenario

- Google Maps API is activated via app, location data via GPS begins to be tracked

Post-Conditions

- Once rider elects to end ride, map of ride along with relevant statistics is stored in the app

Use Case 5: View Trips

Pre-Conditions

- Sufficient memory on phone running app

Triggers

- Rider elects to view trip history

Main Success Scenario

- Phone storage is accessed, list of existing rides is on screen

Post-Conditions

- Rider has full list of previous trips, detailing route taken and relevant statistics

Use Case 6: Adjust User Settings

Pre-Conditions

- Phone app is currently running

Triggers

- ·Rider selects user settings to edit current app settings

Main Success Scenario

- App opens user settings page and loads existing settings from memory

Post-Conditions

- Rider is able to see, edit, and save desired operation settings for app.

Use Case 7: Change Speed

Pre-Conditions

- App is connected to the board

Triggers

- Rider uses volume buttons to change desired board speed
- Speed is transmitted via Bluetooth

Main Success Scenario

- App checks current user proficiency settings to determine maximum allowed speed and caps user input accordingly
- App sends speed to board via Bluetooth connection
- On-board PCB adjusts motor settings to increase/decrease speed accordingly

Post-Conditions

- Rider is now riding at the desired speed.

Use Case 8: Initiate Sensors

Pre-Conditions

- Sufficient board battery power remaining

Triggers

- Board is switched on by rider

Main Success Scenario

- All on board sensors are checked
- Flow of sensor data begins

Post-Conditions

- On-board sensors are currently active and recording relevant data

Use Case 9: Enable Motor

Pre-Conditions

- Sensor suite has initiated properly
- Battery check has successfully completed

Triggers

- Board has been turned on

Main Success Scenario

- Power is now being delivered to the motor.

Post-Conditions

- Motor is waiting for user input

Use Case 10: Report Sensor Error

Pre-Conditions

- Board has been turned on

Triggers

- Failure when testing any board component, including battery and any member of the sensor suite.

Main Success Scenario

- Send error diagnostic via Bluetooth to app
- App opens an error window displaying error message

Post-Conditions

- Board is outputting an error message and rider has successfully received it

Use Case 11: Charge Battery

Pre-Conditions

- Battery is physically connected to Booster
- Solar charger is in sufficient lighting conditions

Triggers

- Battery is connected from the receiver to the booster

Main Success Scenario

- Solar Panel generates electricity
- Electricity is passed to charge controller
- Charge controller passes electricity onto the transmitter
- Power is transmitted

Post-Conditions

- Receiver accepts power
- Boost converter takes that power and boost to meet specification
- Battery is charging

Use Case 12: Detect Obstacles

Pre-Conditions

- Ultrasonic Sensor is on and capturing data
- Bluetooth connection is on and transmitting data to the app

Triggers

- Phoenix Board is moving

Main Success Scenario

- Bluetooth connection transmits flag to app when obstacle detected

Post-Conditions

- Mobile App is resets speed to 0.0 and waits for all clear flag from PCB.

Use Case 13: Emergency Stop

Pre-Conditions

- Mobile app receiving stop flag from board
- Object detection algorithm is running

Triggers

- Object detected by ultrasonic sensor

Main Success Scenario

- Microcontroller transmits signal to motor to quickly bring it to a stop

Post-Conditions

- Board has successfully and safely come to a stop

Use Case 14: Display LED colors

Pre-Conditions

- Phoenix Board is powered on
- LEDs are receiving power

Triggers

- Turning on the board
- Board not synced with app
- Error condition with board components

Main Success Scenario

- Microcontroller sends signal to LEDs

Post-Conditions

- LEDs correctly display appropriate pattern for current condition
- Rider is able to gain information about the board from the LEDs

5.4.2 UML Class Diagram

Figure 24 illustrates our class diagram which shows our different classes at play within our system at a given time. Board_Main handles all of the PCB's variables and functions. For the app, the HomeScreen class is the bottom of the stack and therefore contains the vast majority of the app's functions and variables. Fromm there, every other class maintains a one-to-one relationship with the HomeScreen. Route Screen is used to track and view the current route being taken. SettingsScreen is used to view the current user settings. The SafetyScreen displays a brief text about the board's safety features, the AboutScreen displays a brief about description relating to the Phoenix Board, the LEDScreen sends a new LED color configuration to the PCB, and lastly the ModesScreen sends and updates the currently selected Ride Mode to the PCB.

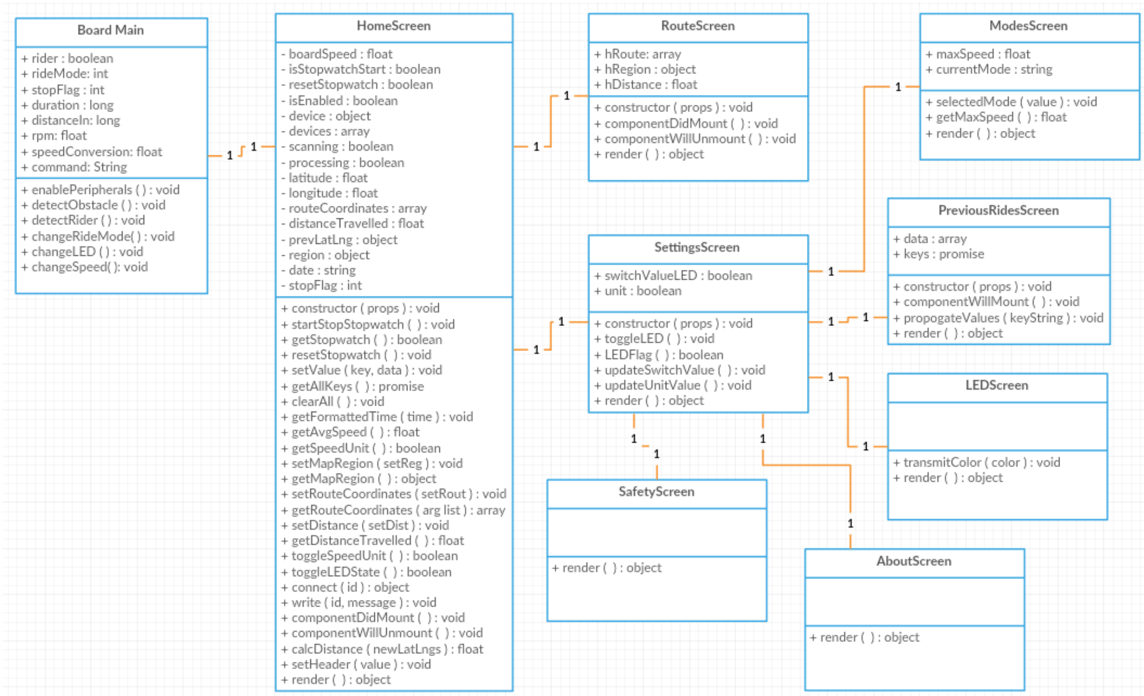

Figure 24: UML Class Diagram

6.0 Prototype Testing

In this section, we will use testing procedures to ensure that all the components that will be used in our design is working effectively. This will allow us to be able to find any broken link, or identify anything that requires changing before the final phase of the project. If this is not done, we may find ourselves having a situation where parts are defective and we may or may not have enough time to add replacement. So, to eliminate this problem, everything will be tested.

First, we will utilize surface mounted components on a breadboard to test each part to ensure proper working condition. In doing this, we will also test all the moving parts like the motor and make any corrections necessary to achieve the results we need. We will also be testing each component, sensors, camera, LED and any other component that will be used in the project. This process is expected to be time consuming and will require some dedication and commitment which attributes of each team member.

6.1 Battery Testing

In this section, we will be assembling the battery to the system to ensure that the battery itself is in proper working condition, and that it is accepting and dissipating charge effectively. This is crucial for the design as the battery is the main power source for the board and all its functionalities. The battery requires 36 volts which will be provided through a boost converter that will be installed to boost the 12 volts coming from the receiver to that 36 volts. We will test for proper power transfer, heating issues and any other problems that might be associated with the operation of the battery.

6.2 Microcontroller Testing

In this section, we have the task of using the MSP430F5529 microcontroller. The process of identifying the pins that will be used in the design is still in progress, as there are a number of items that we need to connect, including sensors, camera and others. We chose to use this microcontroller after a recommendation from our professor, in addition to its ultra-low power consumption. Throughout the design process, it will be used to test all the components that will be used for the project.

Figure 25 shows the connection on the MSP430F5529 REV K chip with additional pins to allow us to be able to connect all our peripheral devices, including those that will be added later. The circuit has been modified, and we will continue to make changes as we put closure to Senior Design I and move into Senior Design II.

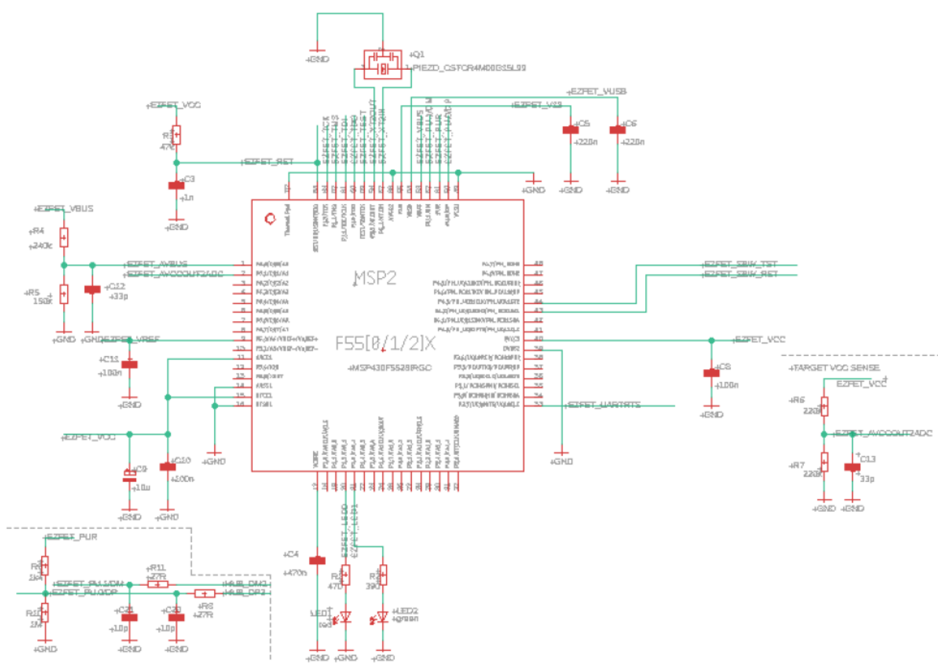

Figure 25: Modified MSP430F5529 REV K Schematic Diagram

Since we are no longer using the MSP430F5529, the project itself became a little easier with less time spent trying to contact personnel for assistance with using the product. The ATmega 2560 was the perfect option, as it has just about everything that was needed for an efficient and effective design. besides, once the PCB design was completed, the components were soldered to the board and then we moved on to the testing phase. The board worked the first time. Figure 26 shows the processor that was incorporated in our design.

6.2.1 Sensor Testing

Utilizing an Arduino MEGA, we individually tested all components, running sample code to ensure that the components were functioning, and slowly incorporating them together in order to troubleshoot how they would work together. Components were connected to our breadboard, powered by the MEGA, and comprehensively tested. The main focus was looking for potential hang-ups and conflicts and organizing in such a way where locking up the board was not an option.

6.2.2 Motor Testing

For motor testing, we used a combination of the Arduino MEGA, a pre-existing VESC UART Arduino library, our 36V battery, and the VESC software suite for Windows. The free version of the software was used. This allows for easy VESC configuration and motor testing. To be safe, whenever a motor was disconnected and then reconnected, the VESC was connected via USB to the software and run to configure the motor. This helped control for possible irregularities in motor operation.

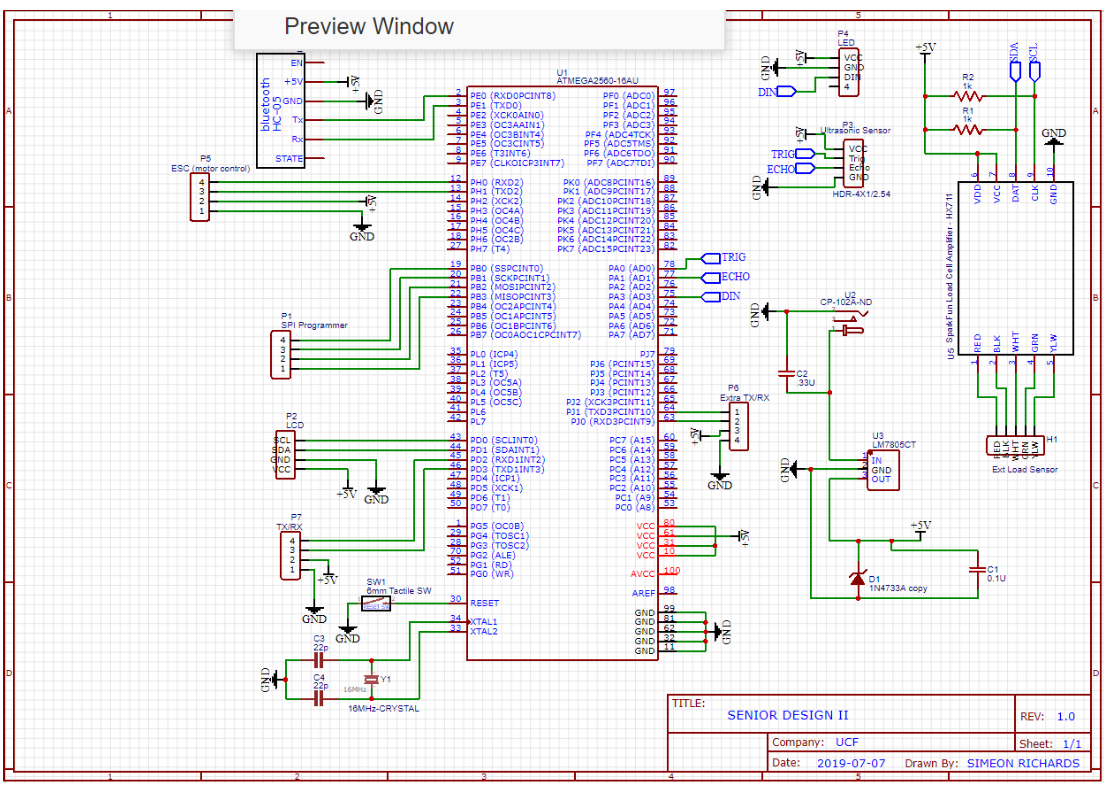

Figure 26: Atmega 2560 Processor/Schematic

6.3 Solar Power Testing

In this section, we will be making connections from the solar panel to the charge controller and then to the transmitter circuit to ensure the power transfer is being done effectively. Although not necessarily in the order described each of these steps will be taken and the installation will be tested to ensure the voltage input and output matches the requirements of the design.

There will be a maximum of 18 volts from the solar panel to the charge controller. The transmitter circuit requires 12 volts. This means that the charge controller should be able to reduce that 18 volts to the 12 volts required. A voltage regulator may be used to aid in this process. The testing of the solar power will be done using multimeter, just to make sure that the voltage going in and coming out is really what we need.

6.4 Mobile Application Testing

In order to properly test out the mobile application we will need to run all or close to all tests on both an Android and iOS device. There are also emulators online that can be used for this purpose and require a lot less risk to anyone's personal property, so in order to make are tests of the app even more comprehensive, we will be testing what we can on an emulator before trying it on an actual device. By doing this, we hope to be able to debug and get our application running properly before ever having it connect to the board, although this is of course easier said than done.

The testing of the mobile application will inevitably go hand-in-hand with the testing of the actual board as some features, such as the mapping/tracking of routes, will require the actual scenarios in order to be properly tested. An example of that applies specifically to the mapping/tracking is that the application must accurately track the location along with the three data points we wish to display on the screen, the average speed, the distance and the length of time of the ride. More of these kinds of events that require numerous trails with the board will become apparent once we begin the actual testing and find any flaws in our implementation.

Once we got into actual development, we ran into some issues with the mobile application testing. One of the first issues was setting up an emulator with Android Studio so that we could continue to develop the application even without a physical Android device present. Although this was successful, it also made the testing process extremely slow due to the load the emulator put on the computer we were developing on. As testing continued however, our engineers became more and more familiar with the emulator and how React Native's errors worked, which smoothed out the process quite a bit. Practically all of the functionality was tested using the emulator with the exception of the location tracking and the Bluetooth communications. Emulators do not have a Bluetooth adaptor and therefore this functionality would not work. As for the location tracking, we were able to show the user's location and region within the emulator but since the tracking was dependent on changes in position and the phone was tethered to simulated location, we could not do more than show that initial location.

Along with the emulator we were also able to test on a physical Android device as one of our engineers had one readily on hand and was able to set it to development mode so we could load in our app at free will to it. Some issues did occur with this however, as when the app is being loaded into the phone a development server is created on the developing computer and disconnecting the phone from it would sometimes cause the app to crash. Even at the end of testing this is some of the more bizarre behavior that we do not fully understand as it still happens but now with a lot less frequency.

6.5 Assembly Testing

Assembly testing is something we will be doing later on in this project once we have individually tested most or all of our parts and have verified, they work. Once we begin assembling our board and all of its components, we will be testing them in conjunction as they are added to make sure all additions work properly and everything that was already added continues to work. We are sure we will run into trouble here as there will be some subsystems that may be incorrectly assembled on our first attempt and will subsequently cause other systems to behave erratically but we are hoping to run through this in the early stages of testing so that more complex and thorough tests may be performed later on.

Assembly testing was done in a piecemeal fashion, with components being thoroughly tested individually before any assimilation was done. This method was very effective for us but we still ended up running into a major issue when we tried to assemble our final product. When trying to assemble our entire project we connected all of our peripherals and secured everything in the position it would be mounted in. We initialized the board and all peripherals and everything started up fine but when we tried to send a speed increase signal to our motors, everything shorted out. We disconnected everything, tried to ensure our connections were good and then plugged our battery back in but this resulted in a very loud pop as well as smoke. We believe that this damaged the battery, the PCB and the single ESC, setting us back significantly at a late and crucial point of development.

Upon further review, we are still not fully certain what it was that caused this malfunction but we believe the fault may have been on either the battery, the PCB or both. Due to this we did have to replace a number of our components and begin the assembly process again. Figure 27 shows our finalized internal assembly.

Figure 27: Internal Assembly for Testing

7.0 Summary and Conclusions

Originally, our group set out to select a project with just three requirements: that it includes some form of wireless communication, that it incorporates robot vision and that it operates on solar power. From this we arrived at multiple ideas to create “smart” objects, such as a shopping cart or a door with a security system, but ultimately, we decided on a Smart electric longboard, the Phoenix Board. The bulk of this project ultimately fell into two systems, power management and a mobile app, but within these two systems are various other subsystems that will aide in producing a smooth and fun riding experience for any and all. For these subsystems we have power management between the board and the solar panel, power management of the peripherals on the board, communication between the board and a mobile device and communication within the app itself. With these various elements all working in tandem, we were able to produce a new and innovative product, the likes of which have not been seen before.

After extensive research, time spent designing, and testing the Phoenix Board, we were able to successfully complete the project. Our testing and research led us to discover a multitude of new knowledge, a lot of which was learned from setbacks and missed core components. An example of this includes realizing halfway into Senior Design 2 that an ESC was needed to control the motors and that direct operation via the PCB was not possible. However, these ultimately contributed to a much greater understanding of the entire board itself, and ultimately allowed for us to control the motors more accurately and to a much more efficient degree.

In conclusion, we have worked quite strenuously to finish this entire project in time. We have researched many topics very meticulously and are thoroughly satisfied with the

Phoenix Board, a Smart longboard that will give riders a pleasing ride and many features to interact with. This board is controlled via an app of our own design which removes the need for a remote controller, allowing riders to minimize the number of devices they need to have on their person at a time when we are already being overwhelmed by the number of devices we carry. This aspect of our project is particularly innovative because at the time of completion, there is not a single commercial electric longboard that has the speed controls directly in a mobile app, instead the majority use some kind of pistol grip controller or nunchuck.

This app is able to track the location of the rider along with other various metrics, including average speed and distance traveled. Along with that it will also include ways in which the rider may customize their experience and their board, such as the LED strip mounted on the outside of the enclosure. These are mainly for night-time visibility but also double to add some uniqueness to the board since they are programmable. Although some of our initial ideas were ultimately scrapped due to time and/or resources restrictions, the Phoenix Board itself is in a position where it can be further expanded upon in the future to increase its functionality.

As it relates to the power system, we were able to come up with a green and efficient solution, albeit somewhat slow. This system fits our initial design goals of a clean, efficient power system and although it’s not as fast as we had hoped it would be, it still succeeds in providing the wireless, solar-powered charging solution we set out to create.

Appendix A: Permission Requests

Evolve Skateboards USA
to me

Hi Hanser,

Our brand name is Evolve, not Boosted Board. But if you wish to use our name and photo in the project, we would be stoked.

Have a great day,

Evolve Skateboards USA

www.evolveskateboardsusa.com

evolve SKATEBOARDS USA!

Evolve Skateboards Permission (Approved)

Hank (Boosted)
Apr 11, 8:58 AM PDT

Thanks for reaching out.

Please use the Plus images form the link here.

Let me know if you need anything else.

Hank
Customer Support-Stoke Team

Boosted Boards Permission (Approved)

Hanserg45
Apr 12, 6:15 AM PDT

Hello,

I am currently working on a senior design project concerning electric boards. In the report for this project my group and I have listed Boosted Boards as one of the main companies in this market and we were wondering if we had permission to include a screenshot of your Halo Board 2nd Edition and its controller in our report.

Thank you,
Hanser Gonzalez

Submitted from: https://www.haloboard.com/pages/contact-us

Halo Boards Permission (Approved)

Contact Us

If you need to contact us or make a suggestion of a longboard to add to the best longboards page, use the contact form below. We'll do our best to response to your queries.

Comments or questions are welcome.

Thanks for contacting us! We will get in touch with you shortly.
Shop Related Products

Longboard Sizes Chart (Approved)

Orders <Orders@digikey.com> Apr 21 at 1:33 PM
To: Simeon Richards

Hello Simeon Richards,

Thank you for your email!

All parts information from our site is free to use; we received it from the manufacturer, so please go ahead and use it as you need. We don't require you to reference us as your source (though certainly we would appreciate it if you did).

Best wishes for your project!

Please let us know if you need anything else.

Thank you,

Amanda Pearson
Global Sales Representative
DIGI-KEY ELECTRONICS
701 Brooks Ave South
Thief River Falls, MN 56701 USA
Orders@DigiKey.com
Domestic: +1 800 344 4539 x2772
International: +218 681 7979 x2772

Battery Fuel Gauge (Permission request granted)

Appendix B: Figures and Tables

Appendix C: References

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