**University of Central Florida**
Department of Electrical & Computer Engineering
**EEL4915**

# 120 Page Final Document
# Senior Design 2 Documentation
# Soareboard

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## 1.0 Executive Summary

At the University of Central Florida, we noticed a significant number of students who are passionate about skateboarding and longboarding. In fact, there is even a skate club on campus, which demonstrates the popularity of these activities among students. Being environmentally conscious, we were motivated to use this interest as a basis for our project and incorporate clean and renewable energy into it.

We recognized that skateboarding, by itself, is a form of sustainable transportation that can reduce carbon emissions. However, we wanted to take it one step further and create an electric skateboard that could provide even faster transportation while also reducing carbon emissions. That's why we came up with the idea of using solar power to charge the skateboard's battery.

As college students, we understand the importance of taking care of the environment, and we believe that small actions, such as using an electric skateboard charged with solar power, can have a significant impact. By combining two environmentally friendly activities, skateboarding and solar power, we hope to make a positive contribution towards a more sustainable future.

After considering the potential problems that electric skateboards may face, our group has decided to pursue a solar-powered skateboard. Common issues with electric skateboards include the need for frequent recharging from an outlet, the potential for the battery to run out midday, a bulky design, a lack of a low battery indicator, and a lack of accuracy in measuring speed. We believe that by implementing solar panels and a rechargeable solar battery, our board can operate for extended periods while simultaneously recharging through the sun's energy. While some may worry that the solar panels and battery will make the board heavy and cumbersome, we have found that our design is on par with current electric skateboards on the market in terms of weight and distribution, ensuring that the board remains portable and easy to carry.

As a group, we decided to go with a Bluetooth controlled application to control the board itself. Using the application, a user can increase the power delivered to the motor using PWM in order to speed up the board. Alternatively, a user can undergo the reverse process by decreasing the speed of the board.

Our group is motivated by the idea of sustainable and environmentally-friendly energy sources. We noticed a lack of affordable and accessible solar-powered skateboards on the market, which further fueled our desire to develop this product. By relying solely on solar energy, our board provides a completely sustainable and green way to produce energy, making it an attractive option for those looking to reduce their carbon footprint.

Although we faced many constraints and roadblocks, our group has managed to create a suitable final product to showcase. These difficulties have caused us to rethink a few previous choices, but with our final components we are confident in our design.

## 2.0 Project Description

To fully comprehend the essence and objectives of the project. It was necessary to articulate a comprehensive description that delves into the origins of the motivation driving it, the targets to be achieved, and an evaluation of the design's effectiveness relative to diverse factors. This section systematically presented all of these points and structured the information into its relevant sections for clarity and coherence.

Firstly, the project's motivation will be clearly explained, and we will highlight the factors that prompted its initiation. This involves a thorough examination of the challenges or gaps in the existing situation that led to the need for the project. The description will go on to provide a clear outline of the specific goals that the project aims to achieve. These goals will be described in detail and will cover the specific outcomes that the project is designed to produce, and the impact that it is expected to have.

Moreover, the design of the project will be examined in-depth, with a view to assessing its efficacy. This will involve evaluating the project's design in relation to various factors, such as its suitability to the context, its feasibility, and its potential to produce the desired outcomes. The description will also include an analysis of the potential limitations of the design and how these could be addressed to enhance its effectiveness.

In summary, this section of the project description comprehensively explores the project's motivation, goals, and design, and presents the information in a structured and organized manner. The aim is to provide a clear understanding of the project's rationale, objectives, and potential impact, while also assessing its effectiveness against relative criteria.

### 2.1 Background/ Motivation

In today's fast-paced world, transportation plays a crucial role in our daily lives. Whether it is for commuting to work, school, or simply running errands, having a reliable and efficient means of transportation is essential. This is where the electric skateboard has emerged as an exciting, innovative, and efficient mode of transport. Particularly in large cities, and specifically at UCF, where traffic congestion and lack of parking spaces can make driving a car a nightmare, electric skateboards offer a convenient and eco-friendly alternative.

While traditional skateboards have long been popular for their simplicity and ease of use, they are not always practical for longer distances or for those who may not have the physical stamina to travel long distances on foot. This is where electric skateboards really shine. Providing users with the speed and convenience of a motorized vehicle, while still retaining the fun and excitement of traditional skateboarding.

In addition to their practicality, electric skateboards are also eco-friendly, emitting zero emissions and helping to reduce our carbon footprint. And with the prices for electric skateboards becoming increasingly affordable, they are now more accessible than ever before.

Moreover, electric skateboards are not just a mode of transport for commuters but also appeal to recreational riders looking for a fun and exciting way to explore their surroundings. Whether you are looking to cruise around the city or campus, commute to work, or simply enjoy the thrill of riding, electric skateboards offer a versatile and enjoyable experience for riders of all skills.

Electric skateboards have gained popularity not only because of their convenience and speed but also because of their contribution to a more sustainable future. Unlike cars, which rely on combustible power, electric skateboards use electric power, making them a more eco-friendly alternative. However, the lithium-ion batteries used in most electric skateboards come with a few limitations.

One of the biggest drawbacks of lithium-ion batteries is their limited range, requiring frequent recharging, especially if used daily. Additionally, lithium-ion batteries are made up of dangerous chemicals, which can cause harm to the environment if not disposed of properly. Moreover, the manufacturing of these batteries involves costly casing, making the overall manufacturing cost of electric skateboards expensive.

To address these limitations, our project aims to develop an electric skateboard that runs entirely on solar power. By harnessing energy from the sun, our skateboard will allow riders to travel for extended periods without worrying about running out of charge. This will also provide a more environmentally sustainable alternative to the traditional lithium-ion batteries used in most electric skateboards. By using solar energy to charge the batteries, we can eliminate the harmful chemicals associated with lithium-ion batteries, reducing their impact on the environment.

Not only will our solar-powered skateboard be more environmentally friendly, but it will also reduce the overall cost of production, as solar panels are becoming increasingly affordable. This means that our skateboard will be more accessible and affordable to a wider audience, helping to promote the adoption of more sustainable modes of transportation.

In summary, our solar-powered electric skateboard aims to address the limitations of traditional lithium-ion batteries, making electric skateboards more accessible, affordable, and sustainable. By harnessing the power of the sun, we hope to contribute to a more eco-friendly and efficient future while still providing riders with the same speed and convenience as traditional electric skateboards.

### 2.2 Goals

Our project's main objective is to create an electric skateboard that can operate solely on solar power. This project, which we have named the Soareboard, takes its name from the Romanian word "soare," meaning sun. We believe that this project will revolutionize the world of electric skateboards by allowing riders to enjoy an uninterrupted riding experience without the need for frequent charging.

In addition to the solar-powered aspect, we are incorporating other features to enhance the rider's experience. One such feature is a set of exterior LED lights that will illuminate the surrounding area at night, making the board more visible to both riders and others around them. This feature increases the safety of the rider and allows them to feel more comfortable when riding in low-light conditions.

Overall, our team is dedicated to designing, developing, and testing the Soareboard to ensure that it meets our high standards of functionality and safety. We believe that this project will not only provide a unique and innovative solution to the issue of charging in electric skateboards but will also inspire further advancements in solar-powered transportation.

Our project revolves around achieving three main goals that are crucial in making the Soareboard a successful product. Each goal represents a specific objective that we must strive to achieve in order to make the electric skateboard functional and efficient.

By setting these goals, we have a clear direction and purpose for our project, and we can measure our progress against these objectives. Ultimately, our goal is to produce a high-quality electric skateboard that is not only environmentally friendly but also fun, safe, and comfortable for riders of all ages and skill levels.

Basic goal: The board is controlled using a controller or app

Advanced goal: The battery should get fully charged through the solar cells for the board to move.

Stretch goal: Go from point A to point B just using an app with no one on.

In Senior Design 2, our overall goal was to create an electric skateboard, our basic goal is to charge the battery with the solar cells, our advanced goal is to detect and warn the rider of rain using the rain sensor, and our stretch goal was to enable remote control operation. We achieved all of the goals, but the stretch goal was achieved without the PCB.

Alongside these larger-scale goals, there are a variety of other goals that we are striving to achieve with the design of this board. These include the following:

- Extensive Battery Life: When not exposed to sunlight, or when exposed to low levels, the board's battery life needs to be able to last long enough for any rider to be able to get to their destination without worry.

- High Speeds: In order for riders to fully benefit from the transportation features of the board, it must possess the ability to travel at relatively high speeds. This will be dependent on the motor and the electronic speed controller chosen. A motor with high levels of torque that can handle high weights is the ideal choice here.

- Safe to Ride: Being an electric skateboard, there are risks that a rider takes when hopping on. As the engineers of the project, we want to ensure the safety of all riders when they step foot on the board. This will be made sure of by choosing the appropriate wheels and deck that can handle a rider's weight and roll with ease.

Since we have yet to decide in Senior Design 1 whether we want to use a physical controller or an app to control the speed of our board, we have two design options in that regard.

In Senior Design 2, we decided to go with the app.

### 2.2.1 Controller Design A

The initial design concept, which we decided against in the end, proposed the use of an external handheld controller that would provide the rider with the ability to adjust the speed of the board. This handheld control is easy to use and would allow the rider to change the speed settings of the board to their desired level, ensuring a smooth and comfortable riding experience.

In addition to the speed control, the controller would have a light indicator to show the battery status of the board. This feature is essential as it would enable the rider to know the remaining battery life and plan their ride accordingly, ensuring that they do not run out of battery in the middle of their journey.

To make the riding experience more convenient, an LCD screen is integrated into the deck of the board, which would allow the rider to visually monitor their speed and battery life and plan their ride accordingly, ensuring that they do not run out of battery in the middle of their journey.

To make the riding experience even more convenient, an LCD screen is integrated into the deck of the board, which would allow the rider to visually monitor their speed and battery life at all times. This feature is particularly useful for riders who want to keep track of their riding stats or need to make adjustments to their speed while on the move.

However, despite the benefits of this design, the team decided to move on to the next controller design option after careful consideration and discussion. This decision was made on various factors such as cost, feasibility, or practicality. Regardless of the reason, the team ultimately chose to pursue a different design approach that would better meet our needs and goals.

### 2.2.2 Controller Design B

This proposed design for the controller of the board is an innovative one, utilizing the power of technology to make the riding experience more convenient and customizable. Instead of an external handheld controller, this design opts for a mobile app that the user can download on their phone. The app would provide a variety of information on its interface, such as the speed of the board and the battery life remaining. It also possibly includes an emergency stop button that would allow the user to slow the board down safely to a stop in case of any emergencies. However, this design specification, in the end, didn't make the cut for our project.

Moreover, the app would provide the added convenience of allowing the user to turn the board on and off, conserving battery life when not in use. Additionally, the design includes the ability to control the LED lights of the board through the app, allowing for a more simplistic and customizable riding experience.

The decision to use this controller design was based on the fact that a couple of members in the group were confident in their ability to develop the app, making it a feasible option for the team. It also makes it easier for the rider to use their phone since they would not have to carry an extra device while riding.

Overall, the design is an excellent example of utilizing technology to enhance user experience and provide more control and customization to the rider. By incorporating a mobile app as the controller, this design makes it easier and more convenient for the user to interact with the board while enjoying their ride.

The team chose to implement an app as the primary design for the board, a decision that proved to be both practical and advantageous. The app offered several inherent benefits, making it a more feasible and efficient option during the coding phase. A key advantage was the abundance of readily available components necessary for the app's functionality, such as the smartphone and the app development tools.

With the widespread use of smartphones and the ubiquity of app development platforms like app inventors, the team found themselves equipped with a vast array of resources at their disposal. These components not only streamlined the coding process but also ensured compatibility with a wide range of devices, making it user-friendly and accessible to a broader audience.

The ease of coding for the app allowed the team to focus more on refining the user interface, enhancing user experience, and adding valuable features to the board's functionality. This enhanced flexibility enabled the team to incorporate innovative elements seamlessly, making the app a more versatile and customizable solution for their project's requirements.

Additionally, the app's dynamic nature allowed for easy updates and improvements, ensuring that the board's performance and features could evolve over time. This scalability proved to be a crucial factor, as the team could continually refine and optimize the app's functionalities based on user feedback and changing project needs.

Moreover, by leveraging the power of smartphones and their extensive capabilities, the team unlocked endless possibilities for future expansions and integrations with other smart devices or technologies. The app acted as a gateway to a connected ecosystem, granting the board the potential to interact with various other smart devices and services, enhancing its overall value and appeal.

All in all, the team's decision to pursue the app as the design for the board was justified by its ease of coding, the availability of essential components, and its potential for seamless scalability. This choice allowed the team to create a well-rounded, adaptable, and user-friendly solution that could evolve and grow with the project, ensuring its success and relevance in the rapidly evolving world of technology.

**2.3 Requirement Specifications**

To guarantee that our Soareboard has a highly functional design, we created two tables of requirements.

The first table, which we call Table 1, identifies the necessary project features that our board must have. These features are crucial to the success of our design. We divided each feature into its respective parts to have a more comprehensive understanding of the specific elements that we need for this project. Additionally, this table served as a guide for us to address important questions and concerns when we were in the initial stages of brainstorming our design.

By breaking down the features into their respective parts, we were able to consider every aspect of the board's design and identify the specific components that we needed to achieve each feature. This approach allowed us to ensure that every necessary component was accounted for, and no important details were overlooked.

| Main Requirement | Features | How many? | Values? | When do events occur? |
|---|---|---|---|---|
| Solar cells are able to charge the battery | Absorb Solar Energy | 5 solar cells | 5 Volts each | Once solar cells are exposed to the sun |
| App able to connect skateboard within 30 seconds | Control Speed | One app that controls all the features together | 12000 RPM Max Speed | Every time the board is used in order to regulate speed |
| Push buttons of smartphone and within 15 seconds see a response | Control Speed | One controller that controls all the features together | Every time | Every time the board is used in order to regulate speed, turn on/off the battery |

| | | | | |
|---|---|---|---|---|
| Motors Drive can carry up to 130 pounds | Generate Mechanical Power | One on the back wheel | Every time the user wants to move forward | When user activates board |

**Table 1: Project Features**

Table 2 is an important aspect of our design process, as it outlines the specific requirements for each feature in Table 1. By breaking down each requirement into its individual specifications, we are able to fine-tune our design to ensure that each component of the Soareboard is optimized for maximum efficiency.

Through this approach, we are able to create a detailed roadmap for our design process, which allows us to clearly identify the key design elements that we need to prioritize in order to achieve our desired outcomes. This approach also enables us to set specific benchmarks and targets that we can measure our progress against, ensuring that we stay on track throughout the development process.

By constantly revising and refining Table 2, we are able to ensure that our design is always evolving and improving, as we take into account new ideas, technologies, and feedback from our testing and simulation results. Ultimately, this enables us to create a product that not only meets our initial requirements, but exceeds them, delivering a board that is reliable, efficient, and enjoyable to ride.

| Component | Parameter | Design Specifications |
|---|---|---|
| Solar Cells | Accuracy | Charge battery 90% |
| App Controller | Response Time | 60 Seconds |
| Motor and Motor Drivers | Weight | Carry 130 pounds within 10 seconds to start moving |
| Rain Sensor | Accuracy | 2% |
| Ultra-Sonic Sensor | Accuracy | Center 2% |
| App connection to board | Response Time | 30 Seconds |
| Motor | Max Speed | < 19 MPH |

**Table 2: Engineering Specifications**

### 2.4 House of Quality

The house of quality is a useful tool in product design and development, and it plays a vital role in ensuring that the final product meets the needs and expectations of the users. The figure shown below, Figure 1, represents the house of quality developed for this particular project. This diagram is a graphical representation of the inter-relationship between the product requirements and the consumer requirements.

The primary goal of the house of quality is to identify critical parameters or specifications that are most important to the users and align them with the production requirements to develop an efficient product. The house of quality helps engineers to prioritize the consumer requirements, which ultimately leads to the development of a product that is more user-friendly and efficient.

The house of quality is a powerful tool as it helps to identify the correlations between different aspects of the product design and how they relate to consumer requirements. This allows engineering to understand which production requirements are most critical to the user’s needs and how to prioritize them in the design process.

The house of quality can help to optimize the product design process by identifying areas that require improvement and highlighting potential trade-offs between different specifications. This enables engineers to make informed decisions and balance the trade-offs between different aspects of the product design to deliver a final product that meets the consumer’s needs and expectations.

In summary, the house of quality is an essential tool in the product design process that allows engineers to develop a better understanding of the consumer’s needs and how they relate to the production requirements. This helps to prioritize the critical specifications and ultimately leads to the development of an efficient and user friendly product that meets the needs of the users.

Consumer requirements are an essential consideration during the design process of any product as they reflect the needs and preferences of end-users. When designing an electric skateboard, one of the primary consumer requirements is safety. It is crucial to prioritize safety as it ensures that riders do not encounter any hazards or risks when using the product.

While it is essential for an electric skateboard to have the ability to reach high speeds, it is equally important to regulate speed to prevent accidents. The speed of the board must be limited to a level that guarantees the rider's safety. This can be achieved through a range of measures such as speed restrictions, braking systems, and stability controls.

Speed restrictions can be implemented through various mechanisms to ensure that riders are not exposed to unsafe speeds. For example, the electric skateboard could be designed to have speed limitations that align with local speed limits to ensure that riders are not riding at excessive speeds. Additionally, speed restrictions can be applied to the board through software that limits the board's speed to a safe level.

In addition to speed limitations, braking systems are also essential in ensuring the rider's safety. The braking system should be responsive and able to bring the board to a quick stop, especially in emergency situations. The braking system must also be reliable and durable to ensure that it functions optimally in all conditions.

Furthermore, stability is crucial in preventing falls and maintaining the rider's balance, especially when riding at high speeds. The electric skateboard should be designed with stability in mind, and the materials used should be of high quality to ensure that the board is stable and able to maintain balance even at high speeds.

In conclusion, designing an electric skateboard that meets consumer safety requirements is crucial in ensuring that the rider is protected from potential hazards. Engineers must prioritize safety features such as speed limitations, braking systems, and stability controls to enhance the rider's overall experience and safety when using the electric skateboard.

When designing an electric skateboard, engineers must consider several crucial consumer requirements to ensure that their product meets the needs of potential buyers. One of these requirements is efficiency, which is paramount to the board's functionality. Engineers must aim to minimize battery consumption while maintaining a reasonable speed to ensure that users can ride for longer without needing to recharge the battery. This not only enhances the overall user experience but also makes the board more practical and convenient for riders.

Another crucial consumer requirement is user-friendliness. A user-friendly device is easy to operate, navigate, and use at any stage of a ride. A product that is easy to use not only enhances the user experience but also contributes to the rider's safety. Therefore, engineers must strive to design an electric skateboard that is intuitive and straightforward to use, even for first-time riders.

In addition to safety and efficiency, the cost of the product is also an essential consumer requirement. Engineers must design the electric skateboard with affordability in mind to ensure that it is accessible to a wide range of consumers. A highly-priced product may be deemed unaffordable to many, resulting in a limited consumer base.

Finally, consumers expect an electric skateboard to have a high power output. Maximizing the board's power output will enhance its efficiency and appeal to potential customers. However, engineers must balance this requirement with safety and efficiency concerns. While increasing the board's power output is desirable, it must not come at the expense of battery life or user safety. Therefore, engineers must optimize the board's power output while ensuring that it still meets the necessary safety and efficiency requirements.

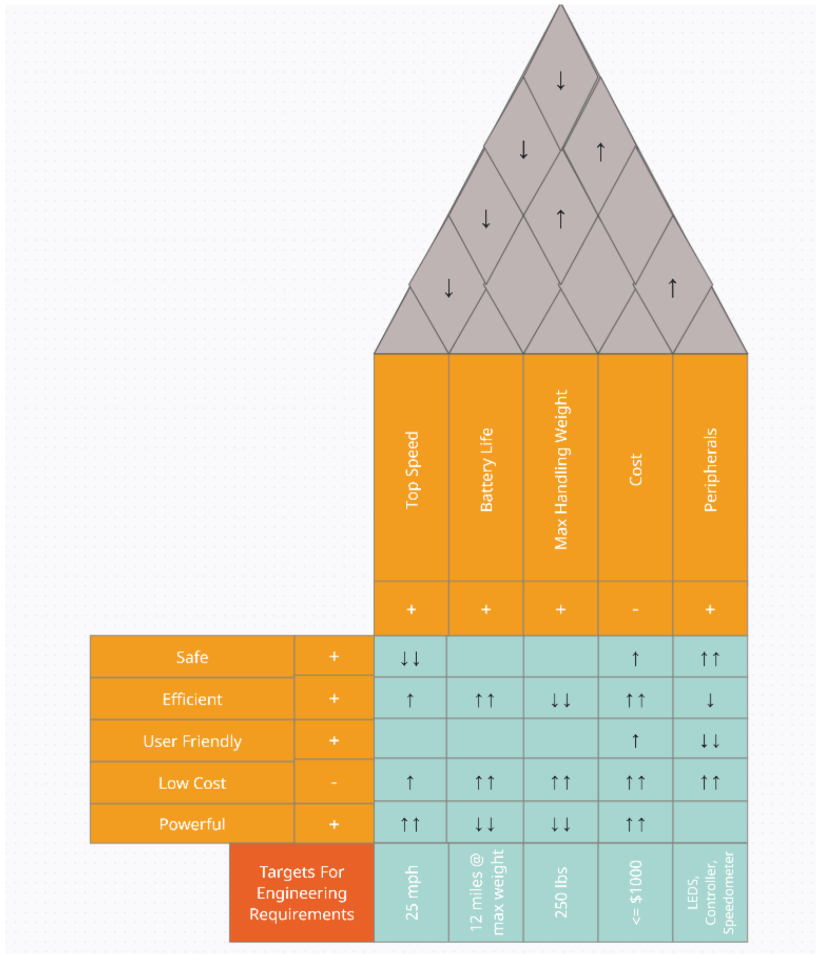


*Figure 1: House of Quality*

The table shown is a tool that helps engineers and designers to identify the most optimal design by analyzing the relationships between different design parameters and determining the best combination of them.

In our case, the house of quality shows that there are trade-offs between various design parameters such as speed, comfort, cost, and efficiency. For instance, when prioritizing safety, the top speed of the board may need to be limited. This is because increasing the speed could compromise the safety of the rider. Similarly, making the board more comfortable and secure to ride may increase the cost of the product and peripherals, as these features may require additional materials and components.

On the other hand, an increase in the efficiency of the board can lead to positive impacts on other design parameters such as top speed, battery life, and cost. This is because an efficient design can utilize the available energy more effectively, allowing the board to travel faster and farther on a single charge. However, it is also important to note that the maximum weight that the board can handle may decrease as efficiency increases, as the additional weight could compromise the energy efficiency of the board.

Overall, the design trade-off helps engineers and designers to identify the most optimal design by considering the trade-offs between different design parameters and determining the best design compensation based on the needs and preferences of the users.

Analyzing the relationship between the user-friendly requirement and cost, it is important to note that a user-friendly device may require additional components or features, such as user manuals or tutorials, which can increase the cost of the Scoreboard. On the other hand, reducing the number of peripherals on the board may make it easier to use, but it could also result in a less user-friendly product. It is essential to find a balance between cost and user-friendliness to ensure that the product is affordable for consumers and still easy to use.

Regarding the relationship between cost and other engineering specifications, it is clear that as more requirements are met, the cost of the board will increase as well. This is because the more expensive components are often required to meet these specifications, such as high-performance motors or advanced battery technology. Therefore, when designing the board, we know that it is important to prioritize the most critical specifications to keep the cost reasonable for consumers.

The power of the board is a critical requirement for electric skateboards. A higher power output translates to a higher top speed and better acceleration. However, it also means that the board will consume more energy and have shorter battery life. Additionally, the weight capacity of the board may decrease as the power output increases since the board needs to be able to handle the added stress that comes with higher speeds and acceleration. Finally, the cost of the board will also increase with higher power output, as more expensive components are required to achieve this specification. We must balance these factors when designing the board to ensure that the board meets the needs of consumers while remaining affordable and safe to use.

### 2.5 Overview of Responsibilities

Assigning responsibilities to team members is an essential component of any successful project. Our project requires the collaboration and coordination of each team member to ensure its success. Creating a list of responsibilities and assigning them to specific team members helps to ensure that everyone is working towards a common goal and is held accountable for their work.

Assigning responsibilities also helps to ensure that each team member is utilizing their strengths and expertise to contribute to the project's success. This allows for more efficient and effective use of time and resources. Furthermore, it fosters a sense of ownership and commitment to the project, which can increase motivation and productivity.

Communication is key when working on group projects and assigning responsibilities helps to facilitate this communication. Each team member will have a specific task to complete and will need to communicate with others to ensure their task is completed successfully. This helps to prevent confusion and duplication of efforts and ensures that everyone is on the same page.

The block diagram that we have created not only shows the hardware components of our electric skateboard but also the different aspects of the project that need to be worked on. By dividing the project into smaller, more manageable parts, we can assign specific tasks to each team member, ensuring that everyone has a clear understanding of their responsibilities and what they need to do to contribute to the project's success. In addition to providing a clear understanding of each team member's responsibilities, the block diagram also allows us to identify potential issues or bottlenecks in the project's development. The block diagram is an essential tool for keeping everyone on the same page and ensuring that the project is completed efficiently and effectively. It allows us to break down the project into manageable parts, assign specific responsibilities, and identify potential issues or bottlenecks that need to be addressed.

Collaboration and assigning specific responsibilities to each team member are crucial for the successful completion of any project. When each member of the team knows their responsibilities, it helps to create accountability and ensure everyone is working together towards a common goal. Effective communication and coordination are also fostered when each member knows their role and tasks.

In our Soareboard project, we have divided responsibilities amongst the team members to maximize efficiency and productivity. Each team member brings a unique set of skills and expertise to the table, which will enable us to create an innovative and high-quality final product.

Here is a breakdown of each team member's responsibilities:

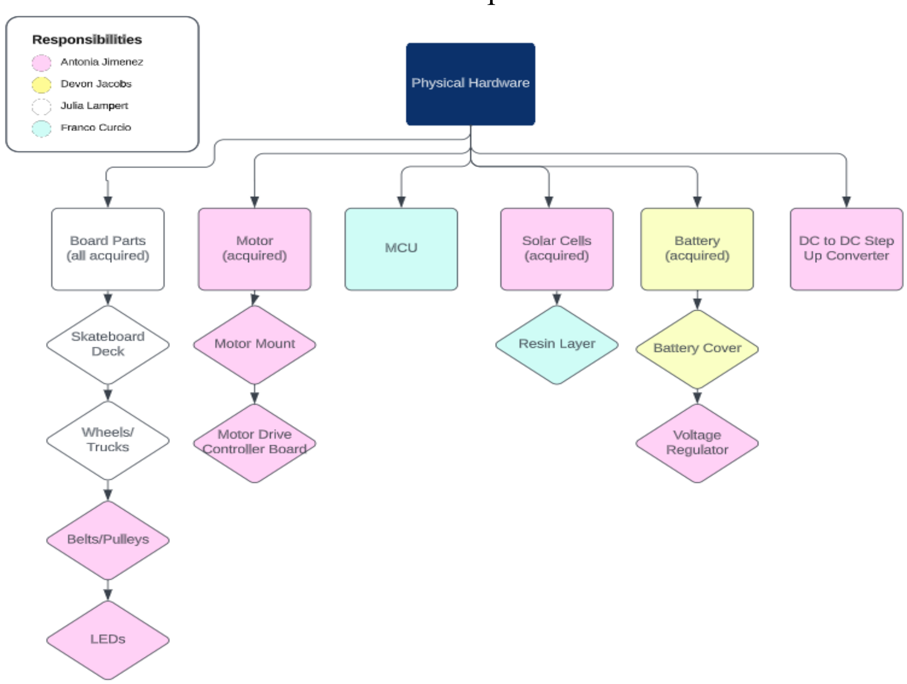


*Figure 2: Hardware Block Diagram*

**Board Parts:**
The board parts are essential components of the electric skateboard, and they need to be carefully designed and selected to ensure the board's efficiency and performance. Julia Lampert and Franco Curcio are responsible for this block, and they aim to acquire the necessary parts to build a high-quality electric skateboard. Currently, the block status is "to be acquired."

**Motor:**
The motor is a critical component of the electric skateboard, and it plays a vital role in determining the board's speed and power output. Franco Curcio and Devon Jacobs are responsible for researching the best motor for the board. The input for the motor is the battery and PCB, and the output is the PCB and wheels. In the motor section, there will be a lot of parts, like the MPPT, the motor driver, etc..

**PCB:**
The Printed Circuit Board (PCB) is responsible for controlling the electric skateboard's functions, including the motor, LEDs, and speedometer. Franco Curcio, Julia Lampert, and Devon Jacobs are responsible for researching the best PCB for the electric skateboard. The input for the PCB is battery power, motor, and controller/app, and the output is the motor, controller, LEDs, and speedometer.

**Solar Cells:**
Solar cells are a sustainable energy source that can be used to power the electric skateboard. Devon Jacobs and Franco Curcio are responsible for researching the best solar cells for the board. The input for the solar cells is solar energy, and the output is the battery.

**Battery:**
The battery is responsible for storing energy and powering the electric skateboard. Antonia Jimenez and Julia Lampert are responsible for acquiring the battery for the board. The input for the battery is solar cells, and the output is the PCB.

**App:**
The app is responsible for enabling the rider to control the electric skateboard. Antonia Jimenez and Franco Curcio are responsible for researching the best app for the board. The input for the app is the user, and the output is the PCB. The app should be user-friendly and easy to operate to enhance the rider's experience.

## 3.0 Research

Research is an indispensable aspect of any successful project or commercial product. It is the driving force that informs the development and ultimate completion of any project. For this particular project, extensive research is required to determine the best features to incorporate and the most suitable product versions to use in building the electric skateboard.

In this section, we will provide an overview of similar commercial products in the market, as well as examine other senior design projects that share similar characteristics with our project. We will also explore the history of relevant technologies and provide an in-depth analysis of how they operate and are traditionally used.

Furthermore, we will delve into the essential components of the electric skateboard, such as the motor, battery and solar cells, among others. This detailed examination will enable us to determine the best products to use in constructing the skateboard, considering their capabilities and limitations. Not only will we talk about the components we decided on in Senior Design 1, but we will be explaining why some of the parts we chose did not work, and what component we ultimately put onto the board.

Additionally, we will include vital theoretical concepts, such as pulse width modulation, which forms the backbone of this project. This comprehensive approach to research will ensure that we have a thorough understanding of the products and technologies involved, enabling us to create a top-quality electric skateboard that meets and exceeds our expectations.

### 3.1 Similar Commercial Products

The Soareboard is a unique concept that aims to combine the efficiency of an electric skateboard with the renewable energy of solar power. Electric skateboards have been in existence since 1997, and since then, they have undergone significant technological advancements. Electric skateboards are now widely available in the market, and the WowGo Pioneer X4 is considered the best electric skateboard currently available, with a top speed of 28 miles per hour and a price tag of $700. Tesla is also in the process of designing the Hunter Board, which is expected to be a game-changer in electric skateboard technology, boasting a 3600-watt motor and a top speed of 34 miles per hour.

The Soareboard seeks to take the electric skateboard to the next level by incorporating solar power, thereby making it more sustainable and efficient. Jackson Hedden, an industrial designer, has already designed the Particle Board, which incorporates solar panels on the top to create power from direct sunlight. The energy generated is stored in a battery and used to power the motors, propelling the skateboard forward. This design is similar to the Soareboard's concept, which aims to utilize solar power to reduce the charging time and provide a reliable mode of transportation.

The concept of a solar-powered skateboard is not new, but the Soareboard is an improvement on this design. With the Soareboard, a multimeter is used to verify that each solar cell has at least three volts, which is the amount of power needed to use the DC to DC step-up converter without burning or damaging any of the other electronic components. Wires are then soldered to the step-up converter to connect it to the battery, which is located on the other face of the board. The solar cells are clipped to the converter, and two other wires are soldered to the out poles on the other side of the converter to ensure that the voltage required by the battery is supplied by the solar cells.

In summary, the Soareboard is an innovative concept that seeks to combine the efficiency of an electric skateboard with the renewable energy of solar power. While the idea of a solar-powered skateboard is not new, the Soareboard seeks to improve on this design by utilizing solar power to reduce charging time and provide a more reliable mode of transportation. With electric skateboards already widely available in the market and the Tesla Hunter Board in the works, the Soareboard is poised to be a game-changer in electric skateboard technology.

### 3.2 Similar Senior Design Projects

The idea of an electric powered skateboard is very attractive. Having a battery powered skateboard, propelled forward by a motor appealed to our group, and has similarly appealed to many groups in the past. One of the major issues addressed in these senior design projects is to make these electric skateboards more efficient. Soareboard's answer is to use solar cells, which receive power from the sun, which is then stored in the battery to run the motors, being overall more efficient using a renewable source of power. One such senior design project is "E-Skate" from UCF spring to fall two thousand eleven. The design of E-skate is fairly traditional as far as electric skateboards go. E-Skate require charging through a power outlet similar to most electric skateboards, while Soareboard will use a more efficient and renewable sense of power in solar powered cells. E-skate includes a microcontroller designed to operate the board, which is also fairly traditional. Comparatively, Soareboard will have a smartphone app created designed to control the board, increasing efficiency and replacing the extra production that would go into making a physical controller. A main distinction is that this project was created over a decade ago, so it was likely rather impressive for the time. Electric skateboard technology has progressed significantly since then, meaning a traditional design would not be a significant senior design project. Soareboard aims to further progress the technology and innovate in the production of an electric skateboard. Another project based around the Electric skateboard from the University of Illinois, "Safety Suite for Electric Longboards". This project differs from the one discussed earlier and the Soareboard, Safety Suite focuses on improving the safety features typically found in Electric skateboards. There are a few features that highlight their improvements in the area of safety, one such feature is that the CPU of the board is designed to sense when wheel slip occurs and will compensate by reading the power to the motors, improving stability. Another feature detects when the user has fallen off the board, and signals the motor to stop. The last major feature is designed to provide an auditory warning of upcoming obstacles. The Soareboard does not have significant focus on safety design, with the only major feature being the dead man switch, as is common in electric skateboards. The dead man switch works by stopping the motor as the user indicates by no longer pushing forward on the controller. The existence of this project shows the versatility of the electric skateboard, that you can have projects that are on a similar topic, yet take an entirely different approach to it. The Safety Suite focuses on Safety efficiency, while Soareboard focuses on power efficiency.

### 3.3 Relevant Technologies

Soareboard serves as the culmination of thousands of years of human development. Technologies ranging from motors, solar panels, and the skateboard itself. The creation of the skateboard is commonly associated with California in the nineteen fifties, but the roots of the invention go back as far as the component necessary for its creation, the wheel itself. The first use of the wheel was found to be six thousand years ago. The wheel is one of the most famous and impactful inventions in human history. The wheel was primarily used for chariots and as a way to conveniently transport goods. This opened the door for numerous inventions that used the wheel, including the car, bike, wheelbarrow, and the skateboard itself. Another essential component to the Soareboard is the motor that propels the board forward. This invention dates back to the industrial revolution. The first electric motor was created by British scientist William Sturgeon in eighteen thirty two. One of the first major uses of the electric motor was in a small scale printing press. In the modern day, motors are used in a number of power tools and appliances. Soareboard includes LEDs as a way to display the board and light it up. The use of LEDs goes back to the nineteen fifties, originally used to light up circuit boards. The technology used in the LED dates back to Thomas Edison and the invention of the lightbulb in eighteen seventy nine. They are much more common today, being used in many products. The most powerful object in our solar system is the sun, so, it would make sense to use the suns' energy to power technology. People have been using sunlight as an energy source for thousands of years, used to create fires, using mirrors to harness the power of the sun. A major step forward in the use of the sun as an energy was in the creation of the Solar Panel in eighteen eighty one. Solar Panels have photovoltaic modules consisting of photons that are used to generate power. These panels operate off the Photovoltaic effect, which is a chemical phenomenon that generates voltage and electric current. Soareboard also uses a Resin coating to protect the Solar Panels and prevent erosion. The electric skateboard will be controlled through a smartphone app. This is a revolutionary technology that will allow Soareboard to not use a physical controller. Smartphones are one of the most influential inventions of the twenty-first century. A major breakthrough in this technology was created with the original Apple iphone. There are a number of technological inventions that allow for the creation of apps, which we will use to create an app designed to control Soareboard.

### 3.4 Board Design

Choosing the right board is one of the most crucial decisions in building an electric skateboard. The board serves as the foundation for the rest of the components, and it is important to select one that is strong and sturdy enough to handle the weight of the rider, the battery, and the motor. In the case of the Soareboard project, the team recognized the importance of selecting a board that was well-suited for their needs.

Initially, the team considered the possibility of building a skateboard from scratch. While this would have given them complete control over the design and functionality of the board, the team quickly realized that none of them had any prior experience in woodworking or skateboard building. This meant that building a board from scratch would be a complex and time-consuming process, requiring a significant amount of trial and error.

After exploring various options, the team identified two alternatives: either to build a board from scratch or to purchase a pre-made one and modify it to suit their needs. In weighing the pros and cons of these two options, the team ultimately decided that purchasing a pre-made board was the best course of action. This allowed them to focus on building the other components of the skateboard, such as the motor and the battery, while ensuring that the board itself was sturdy and capable of handling the weight and stress of the rider.

By selecting a pre-made board, the team was able to save time and resources while ensuring that the skateboard would be built on a strong and reliable foundation. They were able to select a board that met their specifications and modify it as necessary to fit their needs, while avoiding the potential pitfalls and complexities of building a board from scratch. This decision allowed the team to focus their efforts on the other components of the skateboard, ultimately resulting in a more efficient and effective development process.

One option that was considered in senior design 1 for the project was the Pwigs Pretty&Popular skateboard, which is available on Amazon. This board has several qualities that make it a suitable option for the project. Firstly, it is relatively cheap, with a price tag of just thirty dollars, making it a cost-effective choice. Secondly, it is designed to support weight up to three hundred and thirty pounds, making it a sturdy and reliable option for riders of various sizes. With these qualities in mind, the team decided to select the Pwigs Pretty&Popular skateboard as the base for their project.

While there were other available options for skateboards, the team ultimately decided that the Pwigs Pretty&Popular skateboard would suit their needs just as well as the other alternatives, such as the highly-rated Penny Australia 27 Inch Caps Penny Board. In a project as extensive as Soareboard, cost-saving measures must be taken into consideration, and the cheaper option was favored over other alternatives. By selecting the Pwigs Pretty&Popular skateboard, the team was able to focus their efforts on building and modifying the other components of the project while still ensuring that the skateboard was of sufficient quality and durability to support the weight of the rider and the other components.

In Senior Design 2, after careful evaluation and consideration, the team unanimously settled on the "Bamboo Skateboards Hard Good Blank Long Board" as the ideal choice for their project. This board not only met but exceeded their expectations in various critical aspects, making it the perfect canvas for their innovative creation.

One of the standout qualities of the chosen board was its exceptional capacity to accommodate all the required components seamlessly. This remarkable attribute streamlined the assembly process, ensuring that the board's design remained sleek, compact, and visually appealing. The well-thought-out layout allowed for efficient placement of all the necessary elements, contributing to a more efficient and functional end product.

In addition to accommodating the components, the "Bamboo Skateboards Hard Good Blank Long Board" demonstrated remarkable weight-bearing capabilities. It not only supported the intended load but also proved to be resilient enough to handle additional weight beyond the team's initial estimations. This versatility in load-bearing capacity granted the team the freedom to incorporate additional features and enhancements without compromising the board's structural integrity.

Despite the board's ability to flex, particularly due to bamboo's inherent properties, the team found that this characteristic was not a hindrance but rather a beneficial attribute. Bamboo's natural flexibility provided the board with a unique dynamic that actually enhanced its performance. The team recognized that this flexibility contributed to a smoother and more responsive ride, resulting in improved maneuverability and control, which were valuable traits for their project's goals.

Moreover, the board's sturdiness and durability were well-appreciated attributes. Despite the indentation made for the solar cells, the "Bamboo Skateboards Hard Good Blank Long Board" remained impressively robust, withstanding various stresses and impacts. This durability ensured that the board could withstand the rigors of real-world usage and maintain its integrity throughout extended periods of operation.

In conclusion, the team's decision to opt for the "Bamboo Skateboards Hard Good Blank Long Board" proved to be a masterful choice. Its capacity to accommodate components efficiently, impressive weight-bearing capabilities, and the advantageous flexibility of bamboo made it an ideal platform for their project. The board's sturdiness and durability further solidified its suitability for the application, providing the team with the confidence that their creation would not only perform exceptionally but also endure the test of time and usage.

### 3.4.1 Motor

The motor is crucial in making a successful electric skateboard. The main function of a motor in an electric skateboard is to provide propulsion. The motor is most often connected to the back set of wheels and is connected to the axil to make them spin, forcing the board to move forward.

When it comes to motors, there are a variety of different types of motors that exist. For this paper, we will be focusing on DC motors and the various types of sub-motors that fall under that category. In order to understand the different types of DC motors, we must first dive into what a DC motor even is. A DC motor is a type of electrical machine that converts electrical energy into mechanical energy. The term "DC" stands for direct current, which means that the electrical current within the motor flows in one direction. DC motors use a magnetic field produced by the flow of electrical current through the motor’s coils to generate rotational motion. This rotational motion is then used to drive the mechanical loads: gears, wheels, pumps, etc. These types of motors are incredibly common in a variety of applications such as electric vehicles, industrial machinery, household appliances, children's toys, and robotics due to their simplicity, high reliability, and precise speed control. Throughout this section, we will discuss a few different types of DC motors and some options that we considered purchasing for the board itself.

One of the key components in the electric skateboard is the DC motor, and for our design, we have decided to explore the compound DC motor. This type of motor is specially designed with both series and shunt windings connected to the armatures, which makes it a versatile option with a wide range of applications. In particular, the compound DC motor is known for its high starting torque and speed regulation capabilities, which makes it an ideal choice for our electric skateboard.

Since our goal is to create a skateboard that is both fast and efficient, high torque is a crucial factor in achieving this. By selecting a compound DC motor, we can ensure that the skateboard will have the necessary starting torque to accelerate quickly, even on steep hills or rough terrain. Additionally, the speed regulation capabilities of the motor will enable us to fine-tune the speed and ensure that the skateboard operates smoothly and efficiently, providing the rider with a comfortable and enjoyable experience. Overall, the compound DC motor is an excellent choice for our electric skateboard and will play a critical role in its performance and success.

However, compound DC motors tend to be more complex and expensive than standard series or shunt motors, which are more commonly used in various applications. Compound DC motors are typically utilized in applications that require both high torque and precise speed control, such as conveyor systems and printing presses.

The schematic of a compound DC motor is illustrated in the figure below, which shows the series and shunt connections. By combining both series and shunt windings, the compound DC motor is able to produce the desired combination of torque and speed for our specific application.

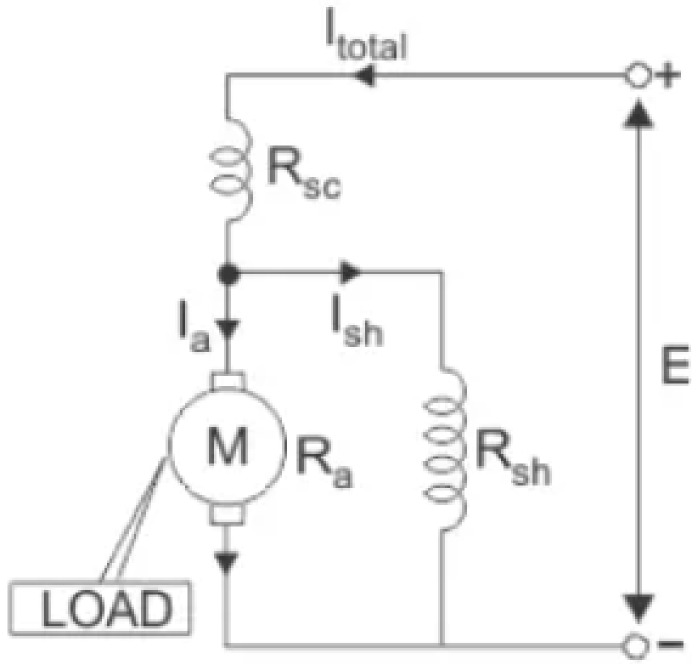


*Figure 3:Compound DC Motor Schematic*

In addition to compound DC motors, another commonly used type of DC motor is the series DC motor. These motors have their field windings connected in series with the armature, providing them with high starting torque and speed regulation capabilities similar to compound DC motors. However, one of the advantages of series DC motors is their ability to regulate speed under different loads. The motor's windings have a changing resistance as the load on the motor increases, causing the speed to decrease, and vice versa. This self-regulating property makes it well-suited for applications where a constant speed is not necessary.

One way to address the challenges of series DC motors is to incorporate a speed controller, which allows for more precise regulation of the motor's speed. The controller can adjust the amount of current flowing through the motor, thereby controlling its speed and torque output. This can be especially useful in electric vehicles, where precise control over the motor's speed and torque is necessary for optimal performance and efficiency.

Another advantage of series DC motors is their high power-to-weight ratio, which makes them well-suited for applications where weight and size are important factors. They also have a simple design, which makes them easy to manufacture and repair. Despite their simplicity, however, series DC motors can still be highly efficient, especially when compared to other types of motors.

Overall, while series DC motors may have some limitations, their unique characteristics make them a valuable option for many applications. Their high starting torque, self-regulating speed, and high power-to-weight ratio make them ideal for use in electric vehicles, industrial machinery, and power tools. With the proper monitoring and control mechanisms in place, series DC motors can provide reliable and efficient performance in a variety of settings. The schematic is below:

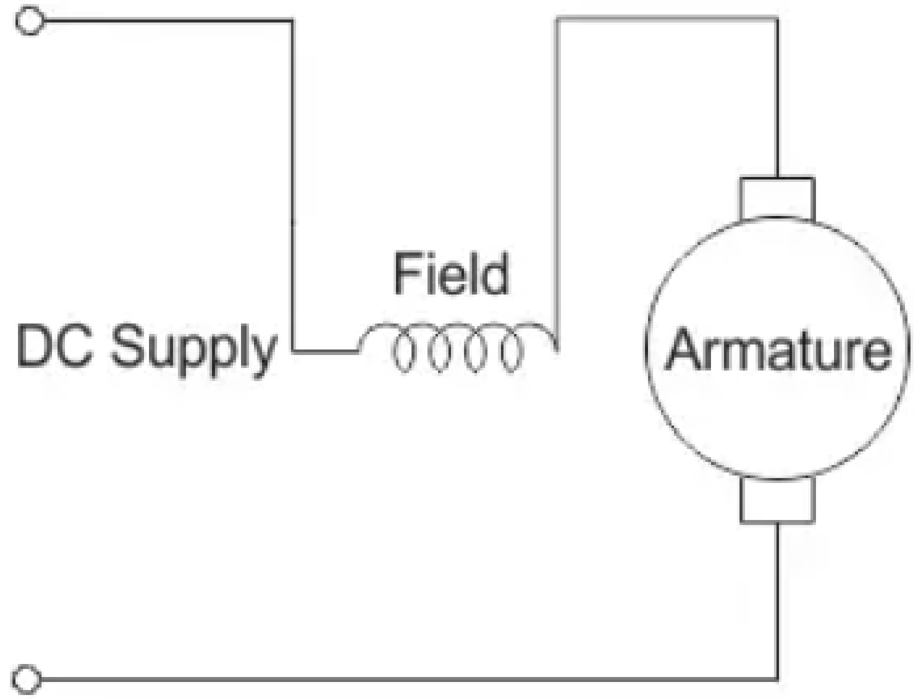


*Figure 4:Series DC Motor Schematic*

Brushed DC motors are the most common type of DC motors due to their simplicity and affordability. They rely on brushes and commutators to change the direction of the magnetic field within the motor. The brushes make physical contact with the commutator, which is a rotating metal ring with multiple segments. As the commutator rotates, the brushes switch the current flow in the motor’s windings, generating a magnetic field that drives the motor’s rotation. This mechanism offers good speed control and makes them well-suited for driving small appliances, toys, and power tools. Despite these advantages, brushed DC motors require regular maintenance as the brushes and commutators wear out over time and need to be replaced. Furthermore, they can generate a significant amount of electrical noise due to the mechanical contact between the brushes and the commutator. This electrical noise can interfere with electronic circuits and cause electromagnetic interference. Despite these limitations, brushed DC motors are still widely used in various applications such as automotive power windows, HVAC blowers, and pumps. The simplicity of their design, coupled with their ability to provide high torque at low speeds, makes them an attractive choice for many applications. The figure below shows the schematic of a brushed DC motor.

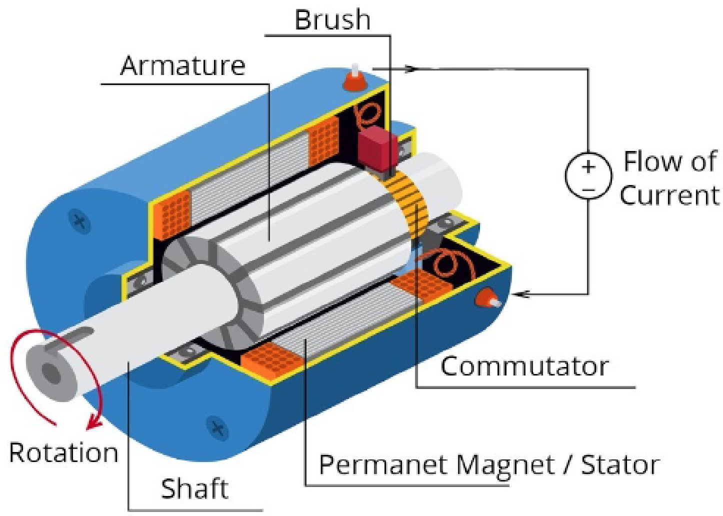


*Figure 5:Brushed DC Motor Breakdown*

The final type of DC motor that we will be discussing is the brushless DC motor. This type of motor is the one that will be discussed throughout the entire paper as it is the type we have decided to go with for our board design. A brushless DC motor is a type of DC motor that replaces the use of brushes and a commutator with an electronic commutation. This electronic commutation is used to control the motor's speed and direction and consists of a controller, a set of sensors, and a set of electromagnets. The controller uses feedback from the sensors to determine the position and speed of the motor's rotor and then applies power to the appropriate electromagnets to generate a magnetic field that drives the rotor's rotation. Since there are no brushes or commutators, brushless DC motors are generally more reliable and efficient than brushed DC motors, with reduced electrical noise and lower maintenance requirements. One of the primary advantages of these types of motors is their high efficiency, which is due to the absence of mechanical friction and the ability to optimize the magnetic field using the electronic commutation system. Additionally, brushless DC motors can provide precise speed and torque control, perfect in our situation since it allows us to give our board increased torque and precise speed controls. These motors also tend to be more compact and lighter weight than brushed DC motors, making them easier to integrate into a wide range of products. Aside from all of its advantages, the brushless DC motor does come with disadvantages as well. One prominent disadvantage is that brushless DC motors can be more expensive and complex than brushed DC motors due to the additional components required for the electronic commutation system. However, as the cost of electronic components continues to decrease, this disadvantage becomes less significant. Overall, brushless DC motors offer far more advantages than brushed DC motors, which is why in the end we narrowed down our search to these types of motors. A comparison table, seen below, was created to map out the advantages and disadvantages of each type of DC motor which allowed us to narrow down our choices.

| Type of DC Motor | Design | Applications | Advantages | Disadvantages |
|---|---|---|---|---|
| Brushed DC Motor | Uses brushes and commutators | Small appliances, toys, power tools | Inexpensive, easy to control | Require regular maintenance due to brushes and commutators |
| Brushless DC Motor | Uses electronic controllers | Industrial automation, electric vehicles, computer cooling fans | More efficient, durable, quieter than brushed DC motors | More expensive and complex |
| Series DC Motor | Field windings connecting in series with the armature | Heavy-duty applications: electric locomotives, cranes, and elevators | High starting torque and speed regulation | Difficult to control, speed varies with load |
| Compound DC Motor | Series and shunt windings connected to the armature | Conveyor systems, printing presses | High starting torque and precise speed control | More complex and expensive than series or shunt motors |

**Table 3: DC Motor Comparisons**

Since we have now narrowed down the type of DC motor we will be using, we can now go on to selecting the best brushless DC motor we can find, while also being cost effective. In order to do this, we compared a few different options that we found. Although we looked through many different brushless motor options, we narrowed it down to 4 possible options, each described in detail throughout this section.

The first brushless DC motor we considered was the “Dual 6354 190KV Brushless Outrunner Motor Set”. This motor set was found to be a relatively popular choice for electric skateboards due to its high power output, reliability, and ease of use. In the set, it includes two 6354 motors with a 190KV rating, which provides high torque and speed. The motors are advertised to be easy to mount, coming with a variety of mounting options, making them suitable for a wide range of skateboard designs. They also are noted to have a low noise output and good efficiency, making them an ideal choice for commuters who desire a quiet ride.

The second brushless DC motor we considered was the “C6374 Efficiency Brushless Belt Sensored Motor". This brushless DC motor was designed specifically for electric skateboards and longboards, featuring a KV rating of 170, which means it has a relatively low RPM per volt, making it suitable for applications that require high torque. This motor is also sensored, meaning it includes Hall Effect sensors that provide feedback to the motor controller and help it control the motor’s speed and position more accurately. The sensor arrangement can also help to reduce cogging, which is a jerky movement caused by the interaction between the magnets and the stator of the motor. This motor is designed to work best with a belt-driven system, which can provide better torque and reduce wear and tear on the motor and wheels compared to a direct drive system. The C6374 has a maximum power output of 3250 watts and an efficiency rating of 85-90%, which means it can provide a lot of power while still maintaining a good range. On top of all of this, it has a relatively low weight of 720 grams, making it a good choice to keep the weight of our board as light as possible.

The third brushless DC motor we considered was the “Maytech 6355 190KV Brushless Outrunner Motor”. This product was advertised to be popular due to its high power output and reliability. It has a 190KV rating and can deliver up to 2600W of power, making it suitable for heavy-duty applications. The motor is said to be easy to mount and has a quite compact design, which makes it a good option for smaller skateboard designs too. The efficiency rating on this motor is 85-90% and runs at a low noise level.

The fourth and final brushless DC motor we considered was the “Alien Power System 6374 170KV Brushless Outrunner Motor”. This motor features a KV rating of 170 and can deliver up to 3000W of power. Just as with the previous C6374, this motor is also censored, which helps control the motor’s speed and position more accurately. The efficiency rating of this motor is a little lower than the previous one, with a rating of 80-85%, and has a weight of about 820 grams. In order to create a solid comparison between each motor, a table was built that organized the information for each brushless DC motor within it.

| Motor | KV Rating | Max Power Output (Watts) | Weight (grams) | Noise Output (dB) | Sensor Type | Efficiency (%) | Price (USD) |
|---|---|---|---|---|---|---|---|
| Dual 6354 190KV Brushless Outrunner Motor Set | 190KV | 4400W (Combined) | 1220g (Combined) | Low | Sensorless | 85-90% | 179.99 |
| C6374 Efficiency Brushless Belt Sensored Motor | 170KV | 2700W | 700g | Low | Sensored | 85-90% | 52.99 |
| Maytech 6355 190KV Brushless Outrunner Motor | 190KV | 2600W | 448g | Low | Sensored | 85-90% | 109.99 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Alien Power System 6374 170KV Brushless Outrunner Motor | 170KV | 3000W | 820g | Low | Sensored | 80-85% | 145.00 |

**Table 4: Brushless DC Motor Product Comparisons**

The selection of the appropriate motor is one of the crucial steps in designing an electric skateboard. After considering various options and comparing the features of each, we have decided to go with the C6374 Efficiency Brushless Belt Sensored Motor. One of the key reasons behind choosing this particular motor is its efficiency in terms of cost, reliability, and high-performance. The brushless DC motor is an excellent choice for an electric skateboard as it provides better performance, improved speed control, and a longer lifespan compared to the brushed motors. Additionally, the use of a sensored motor ensures that there is better synchronization between the motor and the ESC (Electronic Speed Controller), resulting in smoother acceleration and braking.

Choosing the right motor is an important decision as it determines the power output, speed, and overall performance of the electric skateboard. The C6374 motor is a powerful and reliable motor that can generate high torque and speed, making it an ideal choice for our project. Furthermore, it is designed to handle a range of voltages and currents, making it versatile and suitable for different types of batteries and ESCs.

It is important to note that the selection of the motor is not set in stone and may change in the future based on the performance of the prototype. However, based on our initial research and analysis, we are confident that the C6374 motor is the best option for our electric skateboard and we will be designing the rest of the project around this choice.

This new table represents the final options that the group selected, keeping in mind price, efficiency, and the one that will be delivered in less time to start testing with. Another important aspect that was considered was the amount of current that the motor would require. Since the battery was already chosen, the team chose a motor that was able to work accordingly without being damaged.

| Motor | KV Rating | Max Power Output (Watts) | Weight (grams) | Noise Output (dB) | Efficiency (%) | Price (USD) |
|---|---|---|---|---|---|---|
| 775 Motor | 10,000 - 20,000 RPM/V | Up to 200 W | 200 | Low | 50-80% | $30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RS-550 Motor | 18,000 RPM/V | Up to 200 W | 170 | Moderate | 50-80% | $20 |
| 540 Motor | 12,000 - 15,000 RPM/V | Up to 100 W | 180 | Moderate | 50-80% | $20 |
| 360 Motor | 5,000 - 7,000 RPM/V | Up to 20 W | 60 | Low | 50-80% | $15 |

**Table 5: Final Brushless DC Motor Product Comparisons**

**3.4.1.1 Motor Driver**

In order for our motor to be programmed properly and operate exactly as we want it to, we require the use of a motor driver. A motor driver is essentially an IC chip, typically bought separate from the motor, which is commonly used in autonomous projects and embedded circuits. It allows us to send instructions to the motor and have it move accordingly. In addition, a motor driver can also provide safety features to ensure that the motor receives the correct amount of voltage and current to operate as effectively as possible.

When it comes to the types of motor drivers, these can be classified into three different motor driver types. The first of these types is an Integrated Motor Driver. Integrated motor drivers are compact devices that consolidate all the necessary motor driver circuitry into a single integrated circuit (IC) or module. This integration offers a space-efficient and convenient solution for motor control. Integrated motor drivers are available in various configurations to support different motor types, such as brushed DC motors, brushless DC motors (BLDC), and stepper motors. They often come with additional features like current sensing, protection mechanisms, and control interfaces. These drivers are commonly used in applications where space is limited, such as portable electronics and small robotics.

The second type of motor drivers is the H-Bridge Motor Driver. H-bridge motor drivers are extensively used for controlling the direction and speed of DC motors. They consist of four switches (transistors or MOSFETs) arranged in an H configuration. This arrangement allows bidirectional current flow through the motor. By controlling the switches, the motor can be driven forward, reverse, or stopped. H-bridge drivers provide versatility and precise control over motor operation. They find applications in robotics, electric vehicles, home automation, and other systems that require bidirectional motor control. It's important to ensure proper control of the switches to prevent simultaneous activation, which can lead to damaging the motor or the driver. This type of motor driver is what we primarily focused on in our design.

The third and final type of motor driver that we looked at was the Stepper Motor Driver. Stepper motor drivers are designed specifically for the precise control of stepper motors, which move in discrete steps rather than continuous rotation. These drivers deliver the necessary signals and power to accurately position the motor. Stepper motor drivers are available in both unipolar and bipolar configurations, depending on the motor type. They receive step and direction commands and adjust the motor accordingly. Stepper motor drivers are commonly employed in applications that require precise positioning and control, such as 3D printers, CNC machines, and robotics. They offer excellent control over motor movement and can maintain position even when power is removed. However, it's worth noting that stepper motors may produce more vibration and have lower maximum speeds compared to other motor types.

A table comparison between the three different types of motor drivers can be seen below:

| Motor Driver Type | Design | Control Method | Efficiency | Cost | Applications |
|---|---|---|---|---|---|
| Integrated Motor Driver | Combines functionality of motor driver & microcontroller in one integrated circuit | Offers flexible control methods including: PWM, serial communication, & sensor based control | 85%-95% | $10-$100 | Small consumer, electronics, drones |
| H-Bridge Motor Driver | Controls direction & speed of a DC motor using four switches | Bi-directional control & speed control using PWM | 75%-90% | $5-$50 | Robotics, hobby projects |
| Stepper Motor Driver | Controls motion of stepper motor by sending electrical pulses to motor windings | Precise position control through precise pulse sequences | 80%-90% | $10-$80 | 3D printers, CNC machines |

**Table 6: Motor Driver Comparisons**

Once we narrowed down the type of motor driver we needed, we compared three different H-Bridge motor drivers. These three motor drivers consisted of the L298N Motor Driver, the HiLetgo BTS960 43A Motor Driver, and the TB6612FNG Dual H-Bridge Motor Driver. The table below created distinct comparisons between each motor driver and their characteristics.

| Motor Driver | Voltage Range | Maximum Current | Motor Channels | Control Interface | Price |
|---|---|---|---|---|---|
| L298N Motor Drive | 4.5V-46V | 2A per channel (4A peak) | Dual | PWM/TTL | $10 |
| HiLetgo BTS7960 43A | 5V-35V | Up to 43A | Dual | PWM, Direction Control, Current Limit | $10 |
| TB6612FNG Dual H-Bridge Motor Driver | 2/7V-5.5V | Up to 1.2 A per channel (3.2A peak) | Dual | PWM, Direction Control | $13.50 |

**Table 7: Motor Driver Product Comparisons**

### 3.4.2 Solar Cells

The crucial difference that separates Soareboard from other available electric skateboards is that Soareboard is solar powered. An important part of solar power is the battery that is used to store the power that is collected, yet you also need something to generate the solar power itself. This is where the Solar Cells come in. They will be placed onto the board, with the aim of generating solar power, which will then be stored in the battery to be used later. One available set of Solar cells is "FellDen Micro Solar Panels Photovoltaic Cells". They are a small and affordable set of solar cells. They are designed to be used for small projects, meaning they should be suitable for our purposes. We might determine that the requirements for our board is significantly higher, then we would have to reconsider our choice of solar cell. In that case, "SUNYIMA" or "AOSHIKE" would be more acceptable. Its higher voltage and current would provide the board more power to help the board go faster.

The placement of the solar cells on the Scoreboard is a crucial aspect of its design. There are several possible ways of setting up solar cells, including placing them on the sides of the board, on the bottom of the board, or even using flexible solar panels that can be rolled up and stored when not in use. However, the most efficient method must be chosen to maximize the board's design and ensure that the solar cells can generate the maximum amount of power possible.

The design we chose for the Soareboard is one that places the solar cells in a matrix form, arranged in rows and columns on the top of the board itself. This setup allows for the maximum surface area of solar cells to be exposed to sunlight, thereby maximizing the amount of power generated by the cells. Additionally, by placing the cells on the top of the board, we can ensure that they are not obstructed by the rider's feet, and are not affected by any debris or obstacles on the ground.

To protect the solar cells from damage or weathering, they will be covered by a protective layer of resin coating. This layering will not only protect the cells but also enhance the rider's grip on the board. The resin coating will be chosen for its durability and weather-resistant properties, ensuring that the solar cells remain protected even in harsh weather conditions.

Overall, the placement of the solar cells on the top of the board in a matrix form, covered by a protective layer of resin coating, is the most efficient and effective method for maximizing the power generated by the solar cells while ensuring the longevity of the board and rider safety.

| Solar Cell | Price | Voltage | Efficiency |
|---|---|---|---|
| AOSHIKE 10Pcs 5V 30mA Mini Solar Panels | $15.99 | 5 V | High Efficiency |
| SUNYIMA 10Pcs 5V 60mA Mini Polycrystalline Solar Panels Cells 68mmx37mm/2.67" x1.45" | $16.95 | 5 V | High Efficiency |
| 10Pcs 2V 100mAh 0.2W 40X40mm Micro Mini Power Small Solar Cell Panel Module | $12.99 | 2 V | High Efficiency |

**Table 8: Solar Cell Technology Comparison**

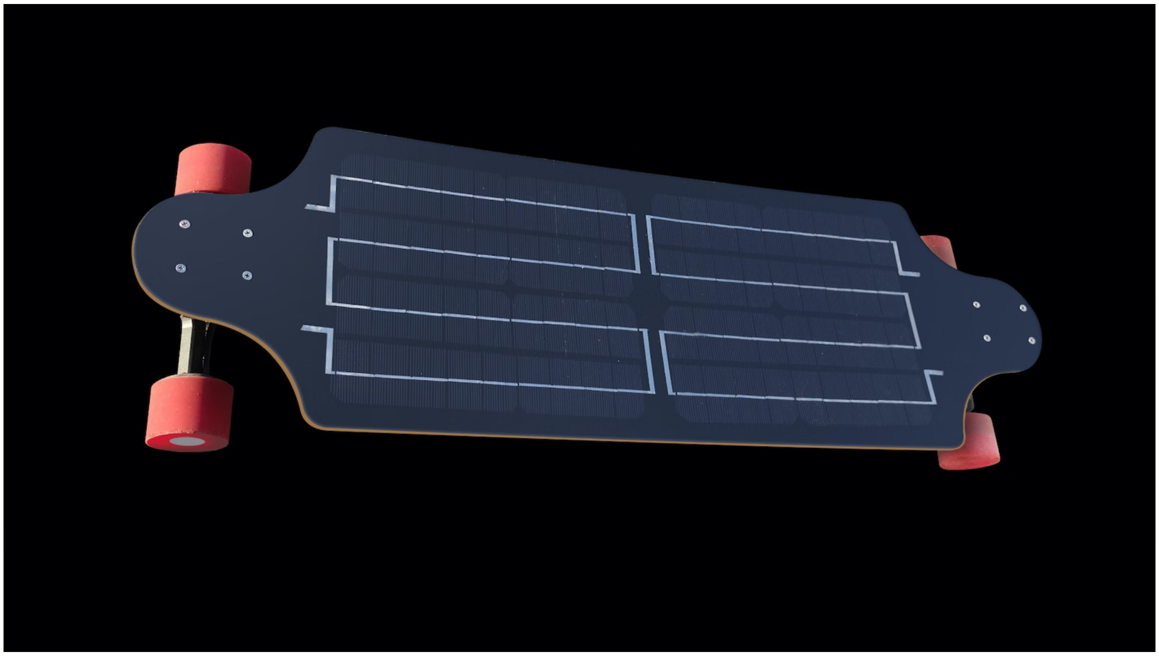

*Figure 6: Existing Design for Solar Powered Skateboard*

Figure 3 depicts a design variation that our project team is considering implementing. The design features solar cells arranged in clusters throughout the board, leaving some space in the center. The reason for this design is to account for the user's body and the possible shadow it may cast over the solar cells. The use of solar cells is an eco-friendly approach to powering the board and reduces reliance on traditional power sources.

By carefully analyzing the design, it can be noted that the clusters of solar cells are arranged in a way that maximizes exposure to sunlight. The space left in the center of the board ensures that a user's body does not obstruct the solar cells from receiving sunlight, which is essential for efficient power generation. In addition, the arrangement of the clusters ensures that the solar cells are evenly distributed throughout the board.

This design variation is a great example of how solar cells can be incorporated into a board's design, and how careful consideration of a user's movements and positioning can be taken into account when arranging the solar cells. The design ensures that the board can operate efficiently and sustainably, while still being practical and comfortable for the user to ride.

### 3.4.3 Solar Battery

The most essential component to this project is the Solar Battery. The function of the Solar Battery is to collect the energy created from the Solar Panels, which is protected by the Resin coating, and sent to the battery for storage. The battery is used to power the movement of the motors. For this project, we will use a lithium ion battery, which is a popular and effective choice for a solar battery. We will use the Miady twelve volts lead acid battery. The dimensions of the battery are relatively small, at 5.94*2.55*3.74 Inches inches, which suits our needs. The cost of the battery is also relatively small, coming in at twenty two dollars. The power of the battery is twelve volts, which lines up with our motor which is also twelve volts, making them a natural choice together. Another option for the battery on our electric skateboard is “2000 Cycles 12V 6Ah Miady Lithium Iron Phosphate Battery” There are many similarities between these two batteries, they are made by the same manufacturer. The second battery discussed, while more expensive, is significantly lighter, 1.65 pounds compared to 4.6 pounds. For this project, cost is an important factor, but weight is also a significant factor, so it could be worth the additional cost. This is the batter we used in Senior Design 2 as well.

| Battery | Price | Composition | Voltage |
|---|---|---|---|
| 2000 Cycles 12V 6Ah Miady Lithium Iron Phosphate Battery | $35.99 | Lithium-phosphate | 12.8V |
| ENEGON 12V 6Ah LiFePO4 Battery 2000 Cycles Maintenance-Free Rechargeable Battery | $29.99 | Lithium | 12V |
| NPP NP6-12Ah F1, 6V 12Ah Battery, Rechargeable Sealed Lead Acid 6V 12Ah Battery | $24.99 | Lead-acid | 6V |

**Table 9: Battery Technology Comparison**

Having in mind the voltages that the battery holds and the solar cells that we will be ordering that produce around 5V or a little more, we can see that there is a huge difference between the values. A solution we encountered was to use a DC-to-DC converter, but what is this? And why is it useful?

Well, with this converter, we will be able to convert our voltage to a higher level, enabling the solar cells to charge the battery at a higher rate, in this case at 12 volts. In other words, this component will let the board travel at the fastest rates and at the same time give the user the ability to control the velocity, either by increasing or decreasing it. Please refer to the table below to look at the comparison.

In figure 4, the schematic shows how the DC to DC Step up convertor works. For starters, one of the main advantages of using a boost converter, is its high efficiency. About ninety-nine percent of the energy that works as an input source can be converted to an useful output. There are two main factors in this converter that helps it achieve the main purpose, and these two factors are a MOSFET, and the on-resistance value.

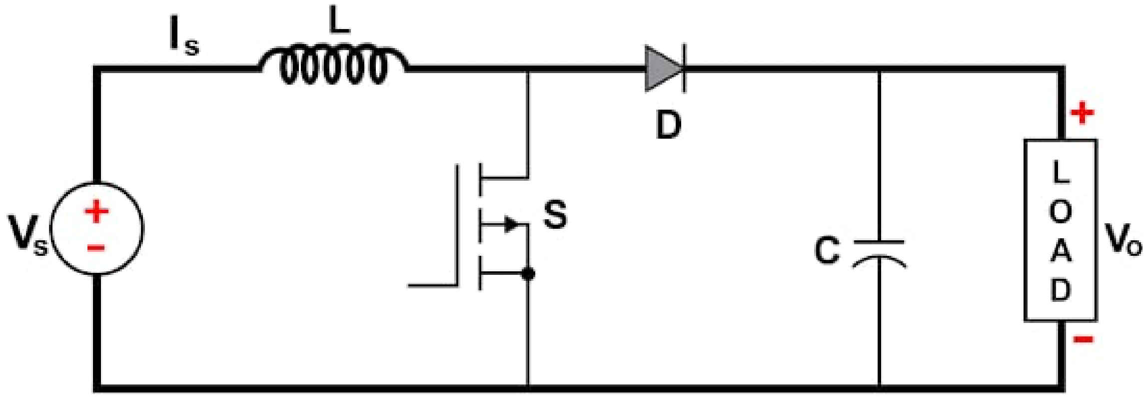


*Figure 7: DC to DC Step Up Converter Schematics*

As represented on this circuit, the relationship between the input voltage and the output voltage can be expressed as Vout being equal to Vin divided by (1-D), D being the duty cycle, meaning the percentage of time that the switch has been on.

Moreover, we thought that it was really important that this converter help us reach the output voltage needed, but another key aspect is its weight. The board by itself needs to be everything but heavy because it will require more power to move. So, that is why we also thought about the weight that each component has in order to control the amount of weight that we will be adding to the board.

Now, having the main idea of what a DC to DC step-up converter is and why it is helpful, we went ahead and looked at all of the converters that could possibly help us, having an input of 5 volts and needing an output of 12 volts. Please refer to the table to see the comparisons we made.

| DC to DC Convertor | Price | Output Voltage | Weight |
|---|---|---|---|
| 2V-28V Output 2A DC-DC MT3608 Step Up Boost Power Supply Regulator | $5.19 | 28V | 0.63 ounces |
| HiLetgo XL6009 Boost Module DC-DC Adjustable Module DC3.0-30V | $5.99 | 30V | 0.799 ounces |

| | | | |
|---|---|---|---|
| DC to DC MT3608 Micro USB Step up Boost Converter Power Supply Boost Module 2V-24V to 5V-28V 2A | $4.39 | 28V | 0.63 ounces |

**Table 10: DC to DC Converter Comparisons**

After researching more about the step-up converters, the team decided not to include them in the project since these components are not really efficient. Instead, the team chose to work with the solar cells in series to get the required voltage needed to charge the battery.

### 3.4.3.1 Solar Battery MPPT Charge Controller

To ensure that the solar cells properly deliver the appropriate current and voltage to the battery, an MPPT Charge Controller module was used. An MPPT module is a type of DC to DC converter that regulates the power transfer between solar cells and the battery bank. Essentially these modules take the high voltage and current of the solar cells and bring it down to an acceptable level for the battery to absorb.

Taking a look at the different options we surveyed for our design, a chart was created to compare each.

| Solar Panel Controller | Input Voltage | Output Voltage (DC) | Output Current | Weight | Price |
|---|---|---|---|---|---|
| MPPT Solar Controller Titanate Battery Charger Module | 12-28 DC V | 1.2-11 V | 1 A | 0.35 ounce | $8.83 |
| MPPT Solar Panel Controller | 8-28 DC V | 5-26 V | 2-5 A | 1.65 ounces | $18.92 |
| Waterproof PWM Solar Charge Controller | < 50V | 12V - 24V | 10 A | 2.39 ounces | $20.99 |

**Table 11: MPPT Comparisons**

Analyzing the table above, it can be denoted that we ended up going with the MPPT Solar Panel Controller. This module takes in an input range of 8 to 28 V and outputs 5 to 26 V. In addition, it can output a current range of 2-5 A depending on the type of battery connected to it. Likewise, the module itself is lightweight and compact, allowing for easy installation to the design.

### 3.4.4 Electronic Speed Controller

One of the most important elements of any electric skateboard, the electronic speed controller (ESC) is essentially the brain of the entire skateboard. This element is responsible for controlling the way the motor functions by regulating its speed and direction based on input from a controller.

In order to understand why the electronic speed controller is so crucial, we must break down the process of how it works in relation to the motor.

1) A rider inputs a signal that is relayed from the controller directly to the electronic speed controller in order to select the desired speed.

2) The electronic speed controller receives this signal and uses a built-in microprocessor to analyze the signal and translate it into a new control signal that is established for the motor itself.

3) The electronic speed controller uses pulse width modulation to adjust the amount of power the motor receives.

4) The PWM signal is then sent to the motor and the motor responds to this signal by adjusting the speed and direction in which it spins in reference to the signal.

The electronic speed controller is a critical component in electric vehicle systems. It not only controls the speed and direction of the vehicle but also performs several other essential functions. One of the most important roles of the ESC is that of braking. The ESC can apply a force to slow down or even stop the vehicle if necessary. This is crucial for ensuring the safety of the rider and other people around the vehicle. The braking function of the ESC also helps to prevent accidents and collisions, especially in situations where sudden stops are required.

Another important role of the electronic speed controller is related to the battery of the system. The ESC can monitor the voltage of the battery and ensure that it does not experience overcharging or over-discharging. Overcharging and over-discharging can lead to severe damage to the battery and even cause it to explode. By monitoring the battery voltage, the ESC helps to protect the battery and extend its lifespan. This is particularly important for electric vehicle systems where the battery is a significant investment.

The electronic speed controller also provides safety features to protect the integrity of the entire system. These safety features include over-current protection and temperature monitoring. Over-current protection ensures that the electrical components of the system do not experience excessive current flow, which can lead to overheating and damage. Temperature monitoring is essential, especially in situations where the system is exposed to high temperatures, such as direct sunlight. The ESC can monitor the temperature and prevent damage to the system by reducing the power output or shutting down the system if necessary.

Choosing the right electronic speed controller (ESC) is a crucial aspect of designing a high-performance electric skateboard. An efficient ESC can significantly improve the overall performance of the board, while a subpar one can result in poor acceleration, lower top speeds, and reduced battery life. Therefore, it is important to carefully consider the available options and select an ESC that can meet the specific requirements of the system.

In this scenario, two options have emerged for selecting an ESC: a solid ESC or a VESC. A solid ESC is a standard type of ESC that is widely used in many electric skateboard applications. A VESC, on the other hand, is a more advanced type of ESC that provides greater control and customization options. While a VESC can be more expensive, it offers several advantages over a solid ESC, including improved performance, greater efficiency, and more precise control over the motor.

After researching the available ESC options for this design, a Dual Hub Motor ESC was found to be the best option. This ESC is priced at around $110 and offers several key features that make it a good choice for an electric skateboard. It is capable of handling high current output, up to 120A, which is important for achieving high speeds and accelerating quickly. Additionally, the Dual Hub Motor ESC allows for use with two different motors, which is ideal for a dual-motor setup that can provide improved power and speed.

Another advantage of the Dual Hub Motor ESC is that it comes with a controller that can be easily synced up with the system, minimizing the setup process. This can be particularly beneficial for those who are new to building electric skateboards and want a straightforward and easy-to-use ESC option. Overall, selecting the right ESC is critical to achieving optimal performance and efficiency in an electric skateboard, and the Dual Hub Motor ESC is a strong choice for this design.

Jumping over to VESCs, a VESC is essentially a far more advanced upgrade to the standard ESC. These components are made specifically for electric-powered vehicles and allow for a far greater range of customizability. These components tend to run a little more pricey than a standard ESC but allow for much better results. A big feature the VESCs bring into play is torque control. By adjusting the output current to the motor and the current input from the battery, a VESC can adjust the torque of the board itself. In addition, a VESC can even customize the braking and acceleration curves of the board which allows for it to behave exactly as a user wants it to.

When looking into options for VESCs to purchase, two big names come up: Flipsky and Enertion. These two brands are most popular for these components but run quite pricey. If we were to make the decision of going with a VESC, the most viable choice would be Flipsky's Dual FSECS 4.20 VESC priced at about $179. Seemingly expensive but when it is put in perspective, the importance of a good ESC is so large that the price is worth it. However, the decision has not yet been made on which component to buy but VESC is heavily favored.

After conducting extensive research on the Electric Speed Controller (ESC), the team ultimately opted against its inclusion in the project. This decision arose from our desire to develop a custom ESC solution utilizing a motor driver and an Arduino to directly control the motor's functionality. As a result, we concluded that integrating pre-made ESCs would not align with our project goals and preferred to construct a bespoke system tailored to our specific requirements.

**3.4.4.1 Pulse Width Modulation**

Pulse width modulation (PWM) is a widely used technique for controlling the power output of DC motors. In our electric skateboard design, it is an essential part of the motor control system, which allows us to regulate the speed and torque of the board. PWM works by rapidly turning the power on and off to the motor at a fixed frequency, with the width of the pulses determining the amount of time the power is on versus off.

By controlling the duty cycle of the PWM signal, we can adjust the average voltage and current delivered to the motor, which directly affects its speed and torque. For example, if we increase the duty cycle, the motor will receive a higher average voltage and current, resulting in a faster speed and stronger torque. Conversely, if we decrease the duty cycle, the motor will receive a lower average voltage and current, resulting in a slower speed and weaker torque.

The use of PWM in our electric skateboard design allows us to fine-tune the performance of the motor to meet the specific needs of the rider. By adjusting the duty cycle of the PWM signal, we can achieve the desired speed and torque for different riding conditions, such as uphill or downhill slopes, varying terrain, or the weight of the rider. This makes the electric skateboard more versatile and adaptable to different situations.

PWM is a widely used technique in electronics, and it has several advantages that make it particularly useful in our skateboard design. One of the main benefits of PWM is its efficiency. By switching the power on and off rapidly, we can reduce the average power dissipated in the motor, which helps to improve its efficiency and prolong its lifespan. PWM also allows us to control the motor speed and torque with greater precision and accuracy than other methods, which is essential for achieving the desired performance characteristics in our electric skateboard.

Also, PWM is essential for protecting the battery and the motor from damage. By controlling the amount of power delivered to the motor, we can ensure that it does not exceed its maximum rated current or voltage, which can lead to overheating and damage. PWM also helps to prevent over-discharging of the battery, which can cause irreparable damage and reduce its overall lifespan.

PWM is a critical technique for controlling the power delivered to the motor in our electric skateboard design. By modulating the power supplied to the motor, we can achieve greater efficiency, precision, and protection for the motor and battery. As such, careful consideration and implementation of PWM in our design is necessary to ensure optimal performance and longevity of the board.

The pulse width modulation technique works by adjusting the width of the pulses, which refers to the amount of time the power source is on, while keeping the frequency of the pulses constant. The duty cycle, which is the amount of time the power source is on, can be adjusted to control the amount of power delivered to a load. By adjusting the duty cycle, we can control the speed of the electric skateboard.

In our electric skateboard design, we will be using pulse width modulation to control the speed of the motor. The motor will be powered by a battery, and the amount of power delivered to the motor will be controlled by pulse width modulation. By adjusting the duty cycle of the pulses, we can control the speed of the motor and therefore the speed of the skateboard.

It is important to note that pulse width modulation also has an effect on the efficiency of the motor. By controlling the power delivered to the motor, we can optimize its efficiency and reduce energy waste. This is crucial in our design as we are aiming to create a skateboard that runs solely on solar power.

In addition to controlling the speed and efficiency of the motor, pulse width modulation also plays a role in the safety of the skateboard. By controlling the power delivered to the motor, we can prevent it from overheating and potentially causing harm to the rider.

Overall, pulse width modulation is a crucial technique in our electric skateboard design. It allows us to control the speed and efficiency of the motor while also ensuring the safety of the rider. By implementing this technique, we can create a functional and efficient electric skateboard that runs solely on solar power.

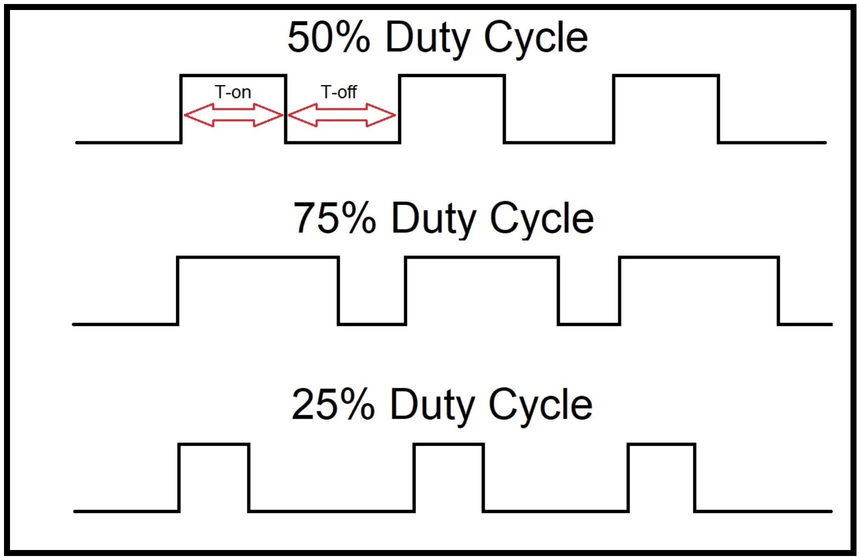


*Figure 8: Pulse Width Modulation Duty Cycles*

Pulse Width Modulation (PWM) plays a critical role in the design of an electric skateboard as it regulates the amount of power delivered to the motor and controls the speed output. The technique achieves this by rapidly turning the power source on and off at different rates to achieve different levels of power. By adjusting the duty cycle of the signal, which is the amount of time the power source is on, the voltage delivered to the motor can be modified, thus affecting the speed output.

In Figure 4, we can observe the effect of changing the duty cycle of a signal. Increasing the duty cycle ratio, which is the signal's ON time versus the OFF time, increases the signal's ON time, meaning it will be on for a longer time than it is off. This causes the motor to receive a higher voltage, resulting in an increased speed output. Conversely, decreasing the duty cycle reduces the ON time, resulting in a decrease in the motor's voltage and a subsequent decrease in speed output.

It's worth noting that pulse width modulation is more efficient than using a variable resistor to control voltage, as the latter method generates heat and energy waste due to the resistance. Additionally, PWM is a widely used technique in the field of electronics and is commonly used to control motor speed, regulate power delivered to LEDs, and in audio applications. In conclusion, the implementation of PWM in our electric skateboard design is crucial to control the motor's speed and ensure optimal performance.

**3.4.4.2 Arduino**

An aspect that has been heavily considered for this project was using arduino as the controller for our board. Arduino is known for being highly programmable and having a variety of potential uses. Arduino was founded on being an open source platform that is easy to use. Arduino was originally founded and created in Italy in the year 2003. The original Arduino consisted of a printed circuit board with an ATmega 128 microcontroller. The Arduino was originally designed to be used by people that were otherwise not familiar with programming. That intent is evident in how easy to use the product can be, that someone with no programming experience could easily use the Arduino. Due to the key features that attract users to Arduino, it has become one of the most popular microcontrollers on the market. As of 2023, there are 17 versions of the Arduino board that are commercially available. Products that are available range from the Arduino RS232, the Arduino Micro, and the Arduino Mega. For this project, we have determined that the Arduino Uno  R3 was the best available product and the one that suited our needs the best. This is the most up to date version of the Arduino Uno sub series. The Arduino Uno R3 supports 14 Digit interfaces that can act as both an input as well as an output, while also having 6 analog interfaces that can act as both an input as well as an output. This advanced series of ports, allows the Arduino Uno to serve multiple functions and support a complex hardware design with a series of subsystems such as the Soareboard. The Arduino Uno R3 is designed to operate between 7 to 20 volts, which is perfect for our electric skateboard, as the battery operates at a power output of 12.8 volts. The image below shows a visual demonstration with the design of the Arduino Uno. This board, also uses an ATmega328p which make it easier for the team to work on the code, as well as on the PCB since it can be configured with the Arduino IDE.

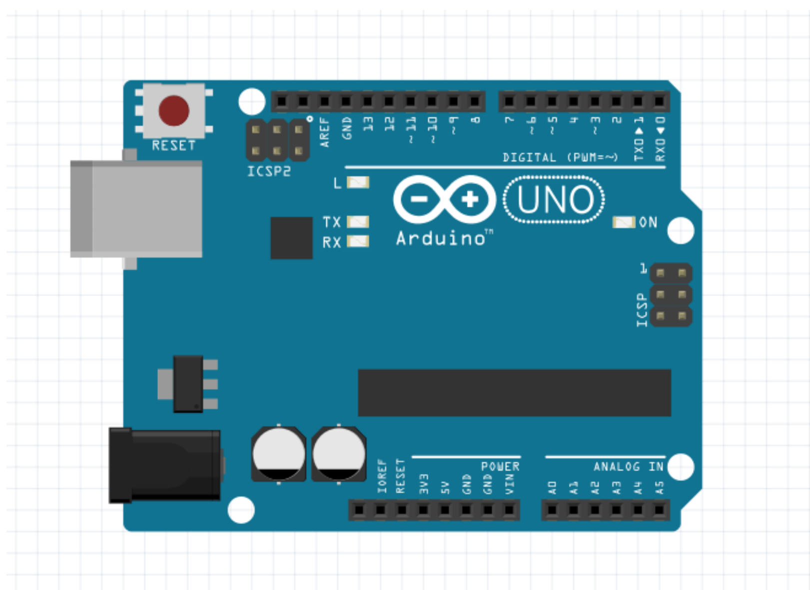


*Figure 9: Arduino Uno Rev3 Design*

**3.4.4.2.1 Arduino MPPT**

For our board to operate independently without the use of a computer to power the arduino, we needed to find a suitable power source and something to regulate the power coming from that battery to the arduino. In order to achieve this, we decided to look for a secondary MPPT that would regulate the voltage and current from a secondary, smaller, battery to the appropriate levels for the Arduino board.

We decided to compare three different options, each listed in the table created below.

| MPPT Module | Input Voltage | Max Input Current | Charging Modes | Efficiency Rating | Output Voltage | Price |
|---|---|---|---|---|---|---|
| DFROBOT MPPT Solar Panel Controller | 5V | 900 mA | Solar & USB | 74% | 5V | $25 |
| BougeRV MPPT Solar Charge Controller | 12-24V | 30 A | Solar | 73% | 12-24V | $37 |
| EPEVER Tracer MPPT Solar Charger | 9-30 V | 10 A | Solar | 75% | 12-24V | $42 |

**Table 12: MPPT Part Comparison**

Taking a look at the table above, we can see that our final selection was the DFROBOT MPPT Solar Panel Controller. The reason we selected this product was due to its low cost, relatively high efficiency, and solid output voltage. We didn't need anything too heavy duty since its intended purpose was simply to power the Arduino which had a voltage input requirement of 5-12V. Another key feature of this MPPT was that it had the ability to take power from both solar elements and DC elements. This meant that we could use a small battery and a single solar cell both in unison to power the Arduino. The solar cell we used was of the same kind previously mentioned in the project.

Once the MPPT was selected, we had to look for a small battery that would work well with the MPPT and the Arduino.

| Battery | Type | Voltage | Capacity | Weight | Price |
|---|---|---|---|---|---|
| AKZYTUE Lipo Battery | LiPo | 3.7V | 500mAh | 12g | $9.99 |
| Tenergy Centura Batteries | NiMH | 1.2V | 2000mAh | 88g | $12.99 |
| Panasonic CR123A Lithium Batteries | Li | 3V | 1550mAh | 17g | $19.99 |

**Table 13: Small Battery Comparison**

In the end we ended up going with the AKZYTUE LiPo battery due to its high voltage output, low price, and minimal weight. In addition, the AKZYTUE had the smallest dimensions out of the three, allowing us to maximize our spatial design.

### 3.4.5 Resin Coating

Protecting the solar cells is a crucial factor to ensure that the board can function optimally and that the user can rely on it for transportation. Solar cells are delicate and can easily be scratched or damaged due to prolonged exposure to humidity and harsh weather conditions. Once the cells are damaged, their ability to convert sunlight into electricity reduces, leading to a decrease in the overall performance of the board.

To prevent such damage, we have decided to apply a protective coating of resin to the cells. The resin coating is an effective way to protect the cells from any potential damage, including scratches, dents, and exposure to humidity. This coating forms a protective layer on top of the cells, shielding them from any external harm.

One of the available products that we have identified for the purpose of the coating is the "EPOXY Resin Crystal Clear 16 oz Kit". This kit is suitable for the needs of Soareboard and will provide an effective barrier against any external elements that could potentially harm the cells. This type of resin is known for its durability and its ability to withstand prolonged exposure to sunlight, making it an ideal choice for protecting the solar cells on the board.

However, it is important to note that the protective resin coating will have to be applied on a routine basis to ensure that the cells are always protected. This is because the coating can wear off over time due to constant use and exposure to external elements. Therefore, a regular maintenance schedule will need to be implemented to ensure that the resin coating is always in good condition and providing adequate protection to the solar cells.

| Resin Coating | Price | Compatible materials | Cure Time |
|---|---|---|---|
| EPOXY Resin Crystal Clear 16 oz Kit | $15.29 | Wood, Glass | 24 Hours |
| 32 OZ Epoxy Resin Clear for Resin Molds, Resin Epoxy Starter Kit | $28.95 | Wood, Rubber | 24 Hours |

| | | | |
|---|---|---|---|
| Artspiration Crystal Clear Epoxy Resin Kit 64 Oz-Art Epoxy Resin, Resin Epoxy Kit | $45.86 | Plastic | 48 Hours |

**Table 14: Resin Coating Technology Comparison**

After researching more about the resin, the team decided not to include it because of time constraints, and it is not necessary for the final version of the board since it will not be a commercial product.

### 3.4.6 Speedometer

A speedometer is a feature that can enhance the overall experience of using an electric skateboard, especially for those who are passionate about tracking their performance. Incorporating a speedometer in the Soareboard could be a unique selling point for the product, as it would give riders real-time information about how fast they are going. This feature is also important from a safety perspective, as it would allow riders to monitor their speed and ensure that they are not exceeding safe limits.

There are various types of speedometers that can be used in electric skateboards, ranging from simple analog gauges to high-tech digital displays. The speedometer could be integrated into the board itself or mounted onto an external controller. Incorporating a digital display could be a more expensive option, but it would allow for additional features such as GPS tracking and the ability to track the distance traveled.

One option for the Soareboard could be to purchase a pre-made speedometer such as the "52mm 2" GPS Speedometer Gauge Waterproof Motorcycle Speedometer". This product is waterproof and designed for use in outdoor environments, making it ideal for an electric skateboard. However, it is also relatively expensive at sixty-five dollars. Alternatively, the team could develop a custom speedometer to match the overall design aesthetic of the board, which would add an additional layer of uniqueness to the product.

While a speedometer is not a necessity for an electric skateboard, it is a feature that many riders would appreciate. By incorporating this stretch goal into the design of the Soareboard, the team would be adding value to the product.

| Speedometer | Price | Speed Range | Minimum Voltage |
|---|---|---|---|
| 52mm 2" GPS Speedometer Gauge Waterproof Motorcycle Speedometer | $64.59 | 0-999 | 9V |

| | | | |
|---|---|---|---|
| KAOLALI Digital GPS Speedometer LCD Speed Gauge Odometer | $60.99 | 0-999 | 9V |
| ARTILAURA GPS Speedometer 0-120MPH with Tachometer 8000 RPM AUTO | $83.99 | 0-120 | 9V |

**Table 15: Speedometer Technology Comparison**

Due to time constraints the team was not able to add the speedometer to the app since some issues were encountered.

**3.4.7 LEDs**

The inclusion of LEDs on the board is a great way to enhance the board's appearance and make it stand out from other electric skateboards in the market. LEDs also serve a functional purpose, as they improve visibility and safety for riders when riding at night or in low-light conditions. The placement of the LEDs on the exterior of the board is a good idea as it will provide a clear and visible indication of the board's presence to others around it.

The chosen product for Senior Design 1, "100 Pieces Clear LED Light Emitting Diodes Bulb LED Lamp", was an excellent choice as it provides a large quantity of LEDs at a reasonable cost. The clear color of the LEDs also makes it easy to integrate them into the design of the board without clashing with any color schemes. Additionally, these LEDs are energy efficient, ensuring that the board's battery life is not significantly impacted by their use.

The ability to change the color of the LEDs and control them through the app is an added bonus that will allow users to personalize their experience with the Soareboard. This feature will also make it possible to coordinate the LEDs with the speedometer, creating an attractive and synchronized display.

The installation of the LEDs onto the board may require additional components, such as resistors or wires, to ensure proper functionality and longevity. It is important to carefully follow the instructions provided with the LEDs to ensure they are installed correctly and securely onto the board.

Overall, the addition of LEDs to the Soareboard is a great stretch goal feature that will improve the board's aesthetic appeal and safety while riding at night. With careful installation and programming, these LEDs will add a unique and exciting element to the overall design of the board.

In Senior Design 2, the team encountered a significant obstacle when the initially selected LEDs proved to be incompatible with the board's design. Determined to find a viable solution, the team meticulously researched and evaluated various LED options. After careful consideration, they made the pivotal decision to switch to the "LOAMLIN WS2812B Individually Addressable RGB LED Strip 16.4FT 5050SMD Smart Flexible Dream Full Color 60Pixels/m Balck PCB Light IP30 Non Waterproof DC5V (Black PCB, 16.4FT 300LEDs IP30)" for their project.

The chosen LEDs came with impressive features, boasting individually addressable RGB lights on a flexible and smart 16.4 feet strip. This strip was perfect for their application as it offered full-color capabilities, with 60 pixels per meter, which allowed for a high level of customization and creative possibilities.

With utmost precision and attention to detail, the team skillfully installed the LED strip onto the bottom of the board, ensuring seamless integration. To enhance functionality and create an interactive experience, they cleverly connected the LEDs with an ultrasonic sensor. This sensor acted as a crucial input device, detecting the proximity of objects in the board's path.

When there was no obstacle in close proximity, the LEDs would automatically light up, illuminating the surroundings with a captivating array of colors. However, the true brilliance of their design manifested when an object came within range of the ultrasonic sensor. In response to the approaching object, the LEDs would intelligently turn off, with the distance from the board determining the level of darkness. This ingenious mechanism served as an intuitive notification system for the rider, instantly alerting them to the presence of an incoming obstacle.

The implementation of the "LOAMLIN WS2812B Individually Addressable RGB LED Strip" not only solved the initial compatibility issue but also elevated the project to new heights, impressing both the team members and their instructors. Through their perseverance, creativity, and resourcefulness, the team had transformed a challenging setback into an opportunity to showcase their engineering prowess, culminating in a truly innovative and functional design.

| LED | Price | Number of LEDs | Max Current |
|---|---|---|---|
| 100 Pieces Clear LED Light Emitting Diodes Bulb LED Lamp | $7.59 | 100 | 20mA |
| DiCUNO 450pcs (5 Colors x 90pcs) 5mm LED Light Emitting | $11.99 | 450 | 20mA |

| | | | |
|---|---|---|---|
| Diode Round Assorted Color | | | |
| 200 Pieces LED Diode Lights, 3mm and 5mm LED Lights Emitting Diodes Assortment Set Kit | $8.98 | 200 | 20mA |
| LOAMLIN WS2812B Individually Addressable RGB LED Strip 16.4FT 5050SMD Smart Flexible Dream Full Color 60Pixels/m Balck PCB Light IP30 Non Waterproof DC5V (Black PCB, 16.4FT 300LEDs IP30) | $20.99 | 300, 16.4 ft | 12A |

**Table 16: LED Technology Comparison**

In order for our LEDs to operate the way we want them to, we required the use of an ultrasonic sensor. For our design, we decided to have our LEDs operate as distance sensors to detect any incoming obstacles in front of the board. This is where the ultrasonic sensor comes into play. The ultrasonic sensor works by scanning the environment in front of the board and relaying that data over to the LEDs. Depending on how far away from the board an object is, the appropriate number of LED nodes will light up. The ultrasonic sensor selected for our project is the HC-SR04 Ultrasonic Sensor. This sensor is a component that we have all worked with, making it an easy and effective choice for our project.

### 3.4.8 Rain Sensor

Nothing spoils a thrilling day of skateboarding more than the unwelcome arrival of rain. Not only does it put the rider's safety at risk, but it also poses a potential threat to the skateboard itself. Determined to tackle this problem head-on, our team embarked on a mission to incorporate a rain sensor into our setup. By doing so, we aimed to reap multiple advantages, primarily enhancing the safety of the entire system and safeguarding the well-being of the rider.

Integrating a rain sensor emerged as a crucial step in our project's design. This intelligent addition acts as a vigilant guardian, constantly monitoring the weather conditions around the skateboard. The moment raindrops are detected, the rain sensor instantly springs into action, alerting the rider through a strategically placed buzzer. This proactive warning mechanism ensures that the user is promptly made aware of the hazardous weather situation in the vicinity, allowing them to take immediate action and seek shelter.

Aside from protecting the rider, the rain sensor also plays a pivotal role in safeguarding the skateboard's well-being. By preventing exposure to water, which could potentially damage sensitive electrical components, we can extend the lifespan and functionality of the board, preserving it for countless future rides.

In summary, the implementation of the rain sensor not only adds an extra layer of security for the skateboarder but also safeguards the integrity of the board itself. Rainy days will no longer dampen our spirits as we confidently carve through the streets, knowing that our innovative rain sensor has our backs.

The rain sensor we decided to go with was the HiLetgo LM393 Rain Sensor Monitor Module. This module was the perfect choice for us as it interfaces well with our Arduino. In addition, this sensor includes a moisture monitor as well which can allow the user to predict that possible dangerous conditions could be happening before they occur. In addition, moisture can lead to damage for our components, so this moisture monitor gives a user time out their board away if this may occur.

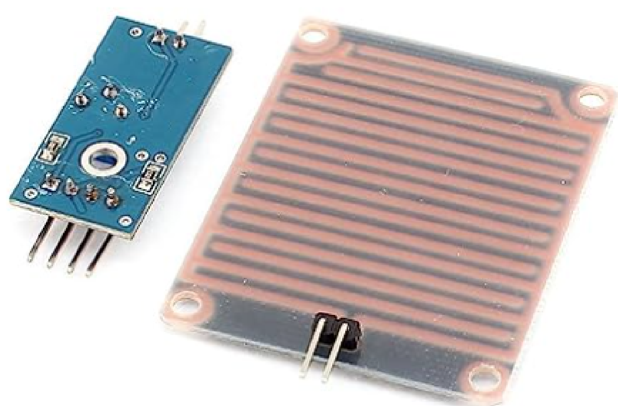

*Figure 10: LM393 Rain Sensor Module*

In order for the rain sensor to alert the user, a buzzer was needed to create a sound loud enough. For this, we used a standard 5V passive buzzer that was compatible with the Arduino we have.

*Figure 11: 5V Passive Buzzer*

**3.4.9 Bluetooth Capabilities**

At the beginning of our project, we envisioned a simple remote control system, similar to those used in RC vehicles, for controlling the speed of our electric skateboard. However, as we delved deeper into our plans and requirements, we realized that a more versatile and portable solution would be more suitable. We decided to explore the option of developing a smartphone application that would act as a central controller for the entire board.

Switching to a smartphone application as our controller offered many benefits, including reduced production costs and improved portability. By connecting the app to the microcontroller on the board, we could seamlessly control the speed of the motor through the application interface. Additionally, the application would also wirelessly control the LED lights, allowing for greater customization and personalization of the board.

To enable Bluetooth connectivity between the microcontroller and the smartphone application, we needed to ensure that the microcontroller was fitted with Bluetooth capabilities. This was a crucial step, as it would allow us to establish a reliable and stable connection between the app and the board, ensuring smooth and responsive control of the skateboard.

So, the decision to switch to a smartphone application as our controller proved to be a wise one. The app provided a more versatile and portable solution, while also offering greater control and customization options. By fitting the microcontroller with Bluetooth capabilities, we were able to establish a stable connection between the app and the board, ensuring seamless control and a smooth riding experience.

In order to fully understand how, and why, Bluetooth ties into this project, we must first discuss its background. The use of Bluetooth technology has been around since about the early 2000s and is responsible for allowing users to wirelessly connect to their devices. As such a useful and powerful technology, it is almost a necessity in most products nowadays seeing as how the tech market is rapidly transitioning to smart products that rely on their wireless capabilities. Bluetooth allows for communication between devices through a wireless medium using radio waves to transmit data between these two devices. Depending on the type of Bluetooth device, the range of data transmission can vary. These Bluetooth devices fall into three different classifications.

| Class Type | Power | Maximum Power Level (mW) | Operating Range | Sample Devices |
|---|---|---|---|---|
| Class 1 | High | 100 (20 dBm) | 100 m (328 ft) | USB Adapters, Access Points |
| Class 2 | Medium | 2.5 (4 dBm) | 10 m (33 ft) | Smart Card Readers, Mobile Devices |
| Class 3 | Low | 1 (0 dBm) | 1 m (3 ft) | Bluetooth Adapters |

**Table 17: Bluetooth Device Class Type Specifications**

These Bluetooth capabilities will allow us to create a wireless connection between our app and the microcontroller and ESC. Luckily, a majority of ESCs and VESCs nowadays come with a Bluetooth transmitter already pre-installed inside the component. The same can be said about microcontrollers. In our case, since we have decided to go with the Arduino UNO microcontroller, there were a few options presented to us for a possible Bluetooth module.

### 3.4.9.1 HC Bluetooth Modules

Looking for options of Bluetooth modules to pair the Arduino UNO with, all signs seemed to point to the HC-05 and the HC-06. These two Bluetooth modules are highly popular with their usage on Arduino products due to their cost-effective nature. Since they are directly compatible with the Arduino UNO microcontroller, these two modules were our initial choice when selecting a proper module.

The HC-05 Bluetooth module is an earlier version of the HC-06. However, this module is still highly effective in its usage. It is denoted as a Bluetooth Serial Port Protocol module.

| Specification | HC-05 | HC-06 |
|---|---|---|
| Class Type | 2 | 2 |
| Bluetooth Version | Bluetooth 2.0 + EDR | Bluetooth 2.0 + EDR |

| | | |
|---|---|---|
| Operation Voltage | 4V to 6V | 3.3V to 6V |
| Communication Interface | UART (Universal Asynchronous Receiver-Transmitter) | UART (Universal Asynchronous Receiver-Transmitter) |
| Communication Range | Up to 10 meters (33 feet) | Up to 10 meters (33 feet) |
| Supported Profiles | Serial Port Profile (SPP) | Serial Port Profile (SPP) |
| Data Transfer Rate | Up to 2.1 Mbps | Up to 2.1 Mbps |
| Operation Modes | Master and Slave | Slave only |
| Security Features | Supports Bluetooth pairing and PIN code authentication | No built-in security features |
| Dimensions | Approximately 45mm x 16mm x 5.6mm | Approximately 28mm x 15mm x 2.35mm |
| Other | Configurable baud rate with AT commands | Configurable baud rate with AT commands |

**Table 18: HC-05 vs HC-06 Specifications**

Breaking down the specifications, we can start by analyzing each module individually, starting with the HC-05.

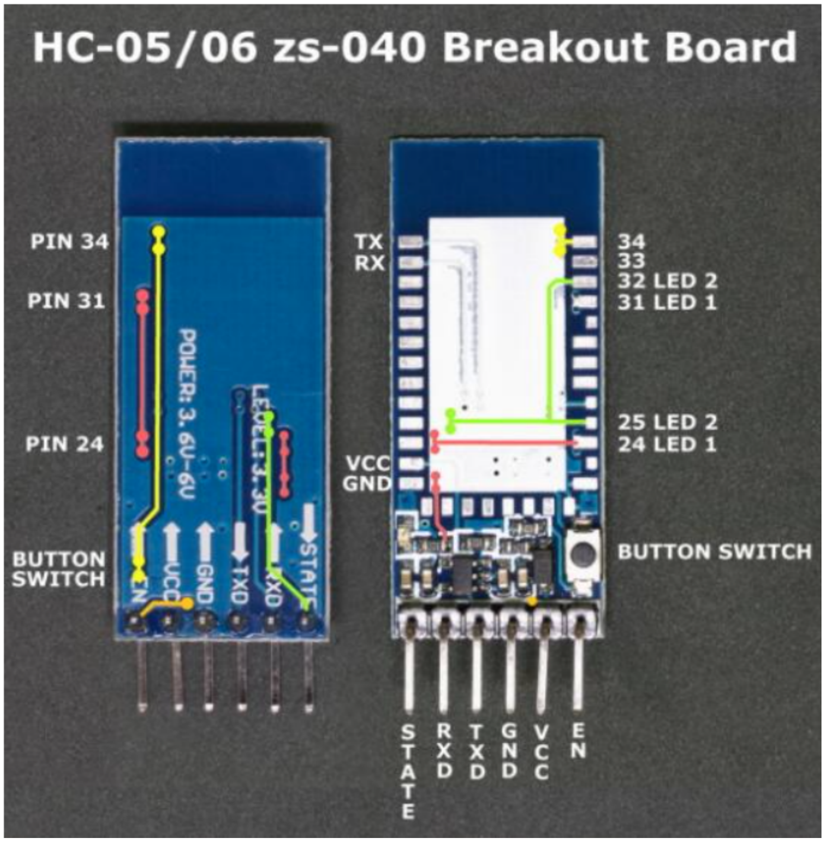


*Figure 12: Pinout of HC-05/HC-06 Bluetooth Modules*

The HC-05 runs on Bluetooth version 2.0 and also supports EDR (Enhanced Data Rate) technology. EDR technology allows for a more reliable and stable connection for data transfer. This module uses a UART communication interface to transmit data, allowing for easy interfacing with microcontrollers or other products with UART capabilities. In our case, this feature is very important as it allows for interfacing with the Arduino UNO microcontroller board. Another important feature that this module possesses is its communication range. With a range of up to 10 meters, the HC-05 supports more than enough range for our purposes. In addition, since it has two modes of operation, master, and slave, it can be programmed to initiate Bluetooth connection (master) or can be told to connect to any device through Bluetooth (slave). Finally, in terms of security, the HC-05 has the ability to implement an authentication when connecting to the device through the use of a PIN that a user can select. This ensures that the connection is as safe and stable as possible

In comparison, the HC-06 contains almost all of the same specifications that the HC-05 has, with two exceptions. The HC-06 can only run in one operation mode, slave mode. As mentioned before, this means that the HC-06 can only be programmed to connect to devices upon request. Likewise, the HC-06 lacks any sort of security feature to protect the stability of a connection. The pinouts of both the HC-05 and the HC-06 are exactly the same and can be seen in Figure 5.

Although the HC-05 and HC-06 are both perfect candidates for what we require, they possess one major downside that affects our project: lack of iOS support. The HC-05 and HC-06 work without issue when dealing with Android smartphones, but since they run on Bluetooth version 2.0, they are not compatible with iOS applications. For iOS applications, only products fitted with Bluetooth version 4.0 or higher can be used. These include BLE (Bluetooth Low Energy) modules which will be discussed in the next section. Although only products fitted with Bluetooth 4.0 or higher can be typically used, there is a way to allow for a non-BLE module to work with an iOS application. In order for these modules to work with an iOS product, they require additional hardware and an MFi (Made For iPhone) certification from Apple themselves. The additional hardware consists of authentication coprocessors that would attach to the microcontroller alongside the Bluetooth modules that allow for the processor to use Apple's iAP protocols. While this part may seem straightforward, getting the MFi certificate is nearly impossible in our case. This is due to the fact that in order to get an MFi certificate, an individual needs to be a part of a large manufacturing company. Due to this, we will have to find an alternative product if we plan on using an iOS application as our board's controller. Solely using Android smartphones to control the board could be an option, but that immediately halves the potential users of the board and would require us to purchase an Android smartphone since we all primarily use iPhones. Since that would drastically increase our budget and create more unnecessary work, we have to turn our sights to a different kind of Bluetooth module that can support both iOS and Android products. As mentioned before, these products are called Bluetooth Low Energy modules.

In the end, since we went with the decision to utilize and Android product instead of an iOS, we decided to go with the HC-05 since it is a product we are familiar with and have used extensively. This product paired perfectly with our Arduino resulting in an ease of use.

**3.4.9.2 Bluetooth Low Energy Modules**

Just like traditional Bluetooth modules, BLEs are compact electronic devices that allow for communication between different devices using Bluetooth technology. Although similar, they are a variation of the traditional modules and are designed to operate under low-power consumption and short-range communication, typically around 100 meters. BLEs operate at a frequency band of 2.4 GHz and can be programmed to transmit and receive a large variety of data formats including text, binary, and even JSON.

BLEs are overall improved versions of standard Bluetooth modules. In addition to supporting iOS and Android applications, these modules far exceed the specifications of modules such as the HC-05 and HC-06. This is due to, as stated previously, their much lower power consumption, enhanced range, low cost, and longer battery life. These modules are quintessential to creating a connection between our application and the microcontroller itself.

When deciding which Bluetooth Low Energy modules to select for our design, we were stuck between 4 different options. The first of these four was the HM-10 BLE module. The HM-10 BLE module supports BLE 4.0 and is compatible with our chosen microcontroller, the Arduino UNO. This BLE can be interfaced through the use of SPI interfacing or UART interfacing. It is classified as a Class 2 Bluetooth device with a range of up to 10 meters. The HM-10 is a convenient device due to the fact that it is able to be controlled easily through the use of AT commands over the serial interface. In addition, just like the HC-05, the HM-10 has two operation modes, allowing it to act as a master or as a slave.

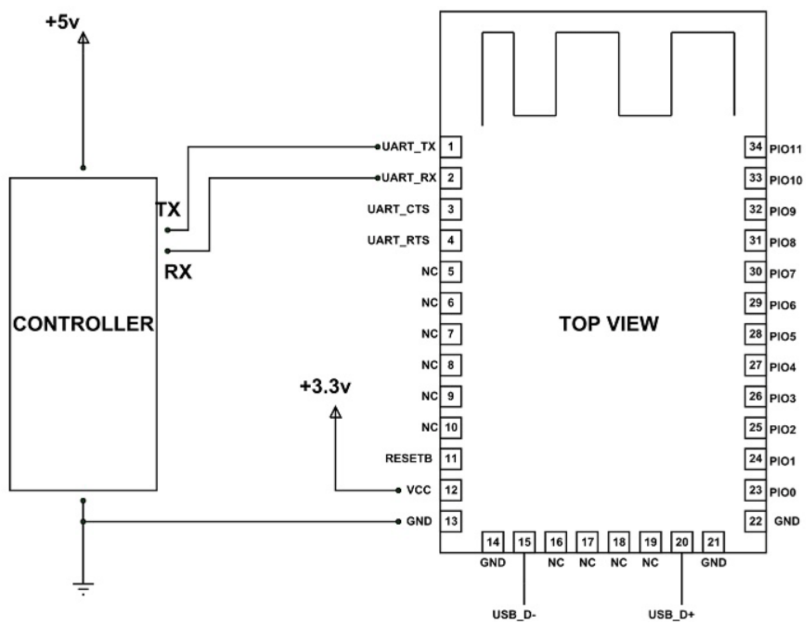


*Figure 13: Schematic of HM-10 BLE Connection to Microcontroller*

One thing to note about BLE Bluetooth 4.0 modules is that they don't have the ability to connect to Bluetooth 2.0 or 2.1 modules unlike the previous choices, HC-05 and HC-06. This denotes that, although it may seem like it, a BLE is not a direct upgrade to the traditional Bluetooth modules and operates in different ways. The figure above, Figure 6, denotes a rough sketch schematic that highlights how the HM-10 would be connected to our microcontroller.

Another option that we looked into when searching for a BLE was the Nordic nRF51822 BLE module. Just as the HM-10 BLE, the Nordic nRF51822 is a class 2 Bluetooth device that can operate within a range of 10 meters. Its device interfacing consists of I2C and SPI connections with other devices that support the same. A notable feature of this module is that its chip is a highly integrated SoC (System-on-Chip). This gives the BLE the ability to be highly configurable, allowing users to optimize and adjust the power consumption of the module for different applications. In addition, the manufacturing company, Nordic Semiconductor, provides users with a comprehensive SDK (Software Development Kit) that gives newcomers the knowledge, and even example code, needed to effectively program the module. This would be incredibly beneficial to us as it will allow us to spend less time figuring out how to program the device and more time with other areas we lack knowledge.

The third option we considered was the Bluefruit LE SPI Friend module. This BLE module works primarily through SPI interfacing, interfacing which the Arduino UNO supports. Likewise, just as the previous two, this module is a class 2 Bluetooth device that has an operational range of up to 10 meters. Just as the nRF51822 BLE, the Bluefruit comes with Arduino example codes and configuration tools to ensure that users have an easy time when setting up the device and modifying it. Another neat feature is its built-in chip antenna which eliminates the need for a separate external antenna. The figure below denotes a schematic of how the Bluefruit LE SPI Friend module would be hooked up to our Arduino UNO board.

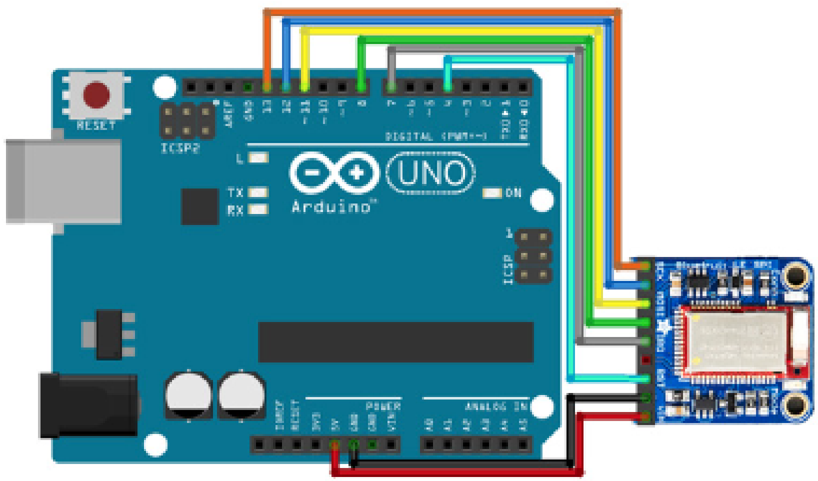


*Figure 14: Bluefruit LE SPI Friend Module Connection with Arduino UNO*

Our fourth and final option that we considered for our BLE was the Bolutek CC2540 BLE module. Starting off, the CC2540 is a class 2 Bluetooth device, just as the previous 3, that has a range of up to 10 meters. The CC2540 operates with a UART interface and interacts only with other devices that have UART interfacing. Unfortunately, this BLE doesn't come with tools that aid users in setting up the device. However, the CC2540, just as the HM-10 BLE, can be easily controlled using AT commands in a firmware that comes pre-programmed onto the module. These AT commands allow for flexibility when it comes to how the module is used. The table below, table 11, denotes the relationships between each BLE considered for the project. Each BLEs important specifications are listed and compared side by side.

| BLE Module | HM-10 | Nordic nRF51822 | Bluefruit LE SPI Friend | Bolutek CC2540 |
|---|---|---|---|---|
| Class Type | 2 | 2 | 2 | 2 |
| Bluetooth Version | BLE 4.0 | BLE 4.0 | BLE 4.0 | BLE 4.0 |

| | | | | |
|---|---|---|---|---|
| Frequency Range | 2.4 GHz | 2.4 GHZ | 2.4 GHz | 2.4 GHz |
| Range | Up to 10 m | Up to 10 m | Up to 10 m | Up to 10 m |
| Interface | SPI, UART | I2C, SPI | SPI | UART |
| Antenna | External | External | Built-in | Built-in |
| Operating Voltage | 2.0-3.3 V | 1.8-3.6 V | 3.3V | 2.0-3.6 V |
| Operating Current | 8-15 mA (max) | 11.3 mA (average) | 12.5 mA (transmit), 9mA (receive) | 15.5 mA (max) |
| Dimensions (mm) | 27 x 13 x 2.2 | 16 x 10 x 2.2 | 27 x 13 x 2.5 | 27 x 13 x 2.2 |
| Price (USD) | $4-$10 | $8-$12 | $17-$20 | $4-$6 |

**Table 19: BLE Module Comparisons**

Analyzing the table, we can see that each BLE module is roughly the same with the exception of their price, interfaces, and antennas. While the Bluefruit LE offers a built-in antenna and higher operating current, its high price completely offsets these slight pros. Due to that, we quickly eliminated this BLE from our selection. With just three left, it was difficult to narrow it down to one since each of them were incredibly similar. In the end however, the HM-10 prevailed as a result of its low price, having both SPI and UART interface, and a relatively good operating voltage.

Unfortunately, the final design was made in mind with the fact that the bluetooth module cannot work on it, so the only way for the board to work with bluetooth is to do it without the PCB and just use a breadboard.

### 3.4.10 Skateboard Deck

When it comes to designing an electric skateboard, selecting an appropriate deck is a critical aspect that cannot be overlooked. The deck not only determines the overall look and feel of the skateboard but also affects its performance and durability. There are several options available in the market, ranging from small penny board decks to large longboard decks, as shown in the figure below.

The deck size should be chosen based on the rider's preferences and the intended use of the skateboard. Small decks are suitable for short commutes and cruising around town, while larger decks are ideal for long-distance riding and downhill racing. The deck material is also an important factor to consider, as it affects the overall weight and durability of the board. Traditional decks are made of wood, which offers a good balance of strength and flexibility, while newer decks made of composite materials like carbon fiber or bamboo offer enhanced durability and lighter weight.

Additionally, the shape of the deck can also impact the rider's stability and comfort while riding. Concave decks have a curve in the middle which can provide extra grip and control, while flat decks provide a smoother and more comfortable ride. Ultimately, the selection of the deck is a crucial step in designing an electric skateboard that is both functional and enjoyable to ride.

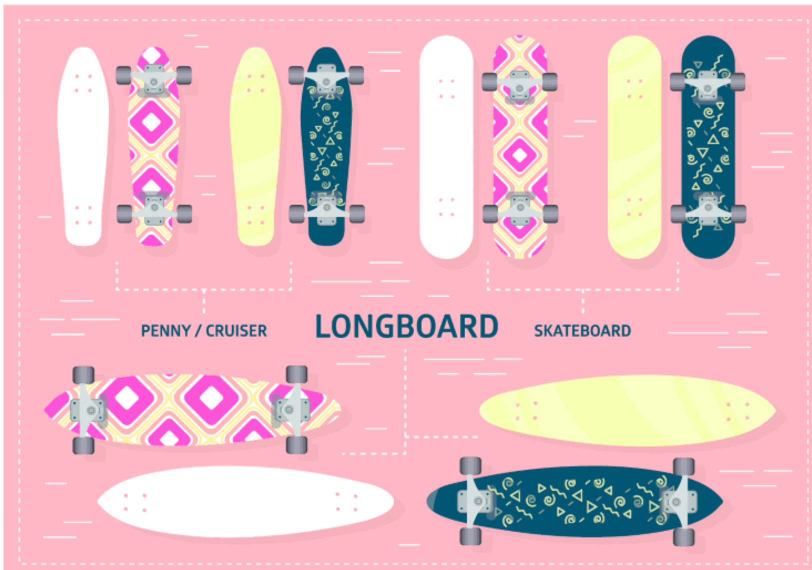


*Figure 15: Skateboard Deck Size Comparisons*

When designing an electric skateboard, it's crucial to prioritize the rider's safety, especially when it comes to high speeds. A stable and sturdy deck is therefore essential. The sturdiness of a skateboard deck depends on its width and length, as these factors determine the evenness of weight distribution. A wider and longer board provides more stability, ensuring a smoother and safer riding experience. This is particularly important for an electric skateboard since the added weight of the motor and battery can affect the board's balance.

Considering these factors, we have chosen a longboard deck for our project. Longboards are typically wider and longer than traditional skateboard decks, which makes them more stable at higher speeds. The added length provides more foot space for the rider, making it easier to balance and shift weight when turning or braking. Additionally, longboard decks often have a more flexible construction, which helps absorb shock and vibrations, resulting in a smoother ride.

When it comes to material, there were a few different options that arose when deciding which to use. The first option is maple wood, which is a popular choice for most longboard decks since it is known for its durability and stiffness. In addition, maple wood has the ability to maintain its shape when riding, which is important for a deck to prevent it from bending. This type of material is most commonly used in downhill or freeride longboards since the boards have exceptional handling at very high speeds.

A secondary option we considered when selecting the material of our electric skateboard deck was bamboo. Bamboo is an interesting option as it is very effective at absorbing shock when riding. Due to this, it offers riders a much smoother experience due to its flexibility. For an electric skateboard, bamboo can be a good material, but it depends on the construction of the skateboard itself. Since bamboo is flexible, it may not be suitable alone for handling high speeds. However, if the bamboo is reinforced with additional layers of materials, such as fiberglass or carbon fiber, the board can maintain stiffness while also being shock absorbent. There are different types of bamboo, higher quality types, which are known to have more strength and better stiffness that can be used as well. In addition to all of that, bamboo is an eco friendly material, something that appeals to us greatly since our board concept revolves around eco friendly options. Due to this, integrating bamboo into our design would be a great choice.

A third option for an electric skateboard material that we looked at was carbon fiber. Carbon fiber is a very strong, high-performance material that is known for its strength and low weight. The low weight stems from the way that it is created. Carbon fiber is made from a large amount of very thin, strong fibers that are woven together into a fabric and then embedded in a resin matrix. The fibers are made from a form of carbon called polyacrylonitrile, which is heated and stretched into long, thin fibers. The resin matrix is what gives the carbon fiber its strength and stiffness. When looking for a material that has a high strength-to-weight ratio, carbon fiber is the best candidate that will result in the lightest and strongest board. However, as amazing as carbon fiber sounds, it is also the most expensive material compared to any other. Carbon fiber is most commonly used in racing and freestyle longboards, typically used by skateboarding professionals.

The fourth and final material that we considered for our electric skateboard deck was fiberglass. Fiberglass decks are a type of longboard deck that is made from layers of fiberglass cloth that are saturated with a polymer resin and then cured to form a solid composite structure. The layers of fiberglass are what provide the deck with high strength and durability, while the resin provides stiffness and helps to bond the layers together. These decks are commonly known for their flexibility and shock absorption, which allows riders to experience a smoother, more comfortable riding experience. Fiberglass also tends to be lighter than most other materials, which is beneficial in our case since we are trying to minimize the weight of the board as much as possible. In addition to being flexible and lightweight, fiberglass also has a natural grip on its surface which can make it easier to maintain control of the board, particularly when riding at higher speeds.

While the type of board deck is an essential aspect of any skateboard project, the specific variations available can be overwhelming. Each variation can have an impact on the overall feel and performance of the board, making it important to choose the right one for the project's goals. The nose and tail of the board, for example, can vary in shape and size, affecting the board's ability to maneuver and perform tricks. Similarly, the overall shape of the board can also impact its performance in various ways.

However, after careful consideration, the Soareboard team has decided to go with a standard longboard deck design, which is both cheap and effective. This decision was made to keep costs low while ensuring that the board is still able to perform at a high level. This type of board can be easily found at a local skate shop, making it a convenient option as well. While it may not have any unique variations, the standard longboard deck design is a reliable choice for a wide range of riders and is well-suited for the Soareboard project.

The board that was selected in senior design 2 was the "Bamboo Skateboards Hard Good Blank Long Board" and it works perfectly for the project.

**3.4.11 Wheels**

When it comes to skateboard wheels, there are quite a few factors that come into play when selecting the best wheels for our board. These factors include the durometer, the diameter, and the width.

Starting with the durometer, the durometer is essentially just a measure of how hard the wheels are. This applies to all material type wheels are made of: polymer, plastics, rubber, etc. Analyzing Figure 9 below, we can see that as the durometer increases, wheels in turn get harder, grip gets loosened, and drag increases. The opposite effect occurs when the durometer decreases.

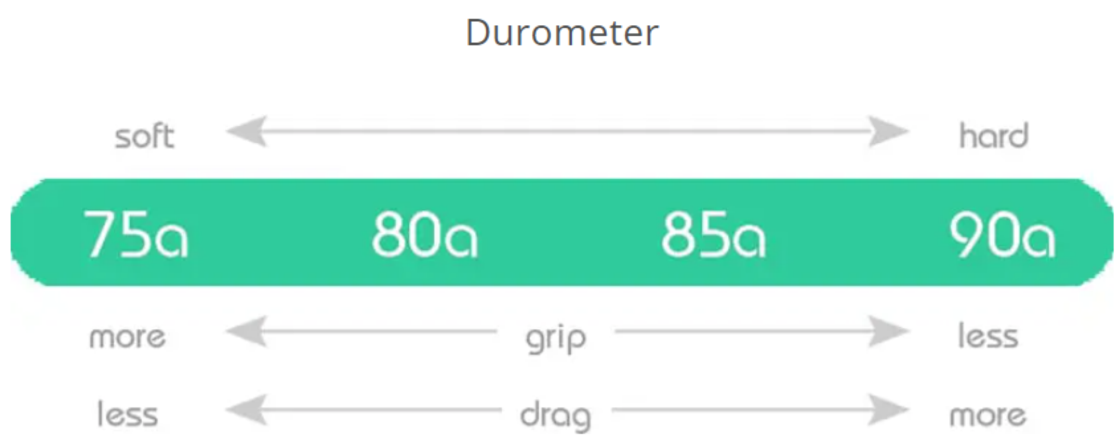


*Figure 16: Durometer Measurements for Wheels*

For our board, we need wheels that are going to be solid for cruising around at high speeds without losing any stability or grip. We found from extensive research that the ideal range of durometer for a smoother ride is roughly 75a-85a. This range results in more grip from the tired, less noise, and a little more drag. With the softer wheels rides will also be smoother over rough terrain as the wheels can absorb more shock.

Moving on to the diameter of the wheels, this measurement affects the speed and handling of the wheels. Looking at Figure 10, we can see that as the diameter of a wheel increases, its speed also increases while its acceleration decreases. In our situation, we need a wheel that fits roughly in the middle, being able to handle high speeds but also having the ability to control itself during high acceleration. Henceforth, wheels in the 75mm+ range are ideal in our case.

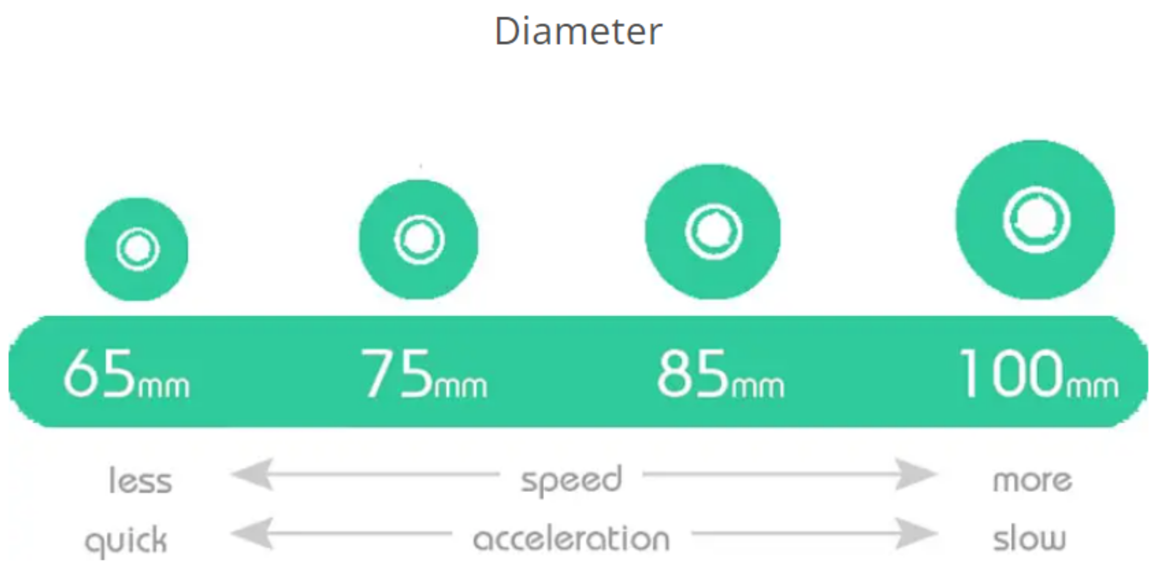


*Figure 17: Diameter Measurements for Wheels*

Understanding the wheel width is a crucial aspect when designing an electric skateboard. The width of a wheel is not simply the measurement from one end to the other, it also involves the concept of the contact patch. The contact patch represents the portion of the wheel that comes into direct contact with the ground. The overall width, on the other hand, refers to the measurement from edge to edge of the wheel. Although the overall width is important for stability, it is the contact patch that has a greater impact on the board's performance as it determines how easy it is to slide.

A larger contact patch means that more of the wheel is in contact with the ground, resulting in increased grip and less sliding. This type of wheel is ideal for cruising and carving, providing a smoother and more stable ride. However, for those looking for more sliding action, a smaller contact patch is the way to go. A smaller contact patch allows the board to slide more easily, making it ideal for freestyle riding, such as performing tricks and slides.

Choosing the appropriate wheel width with the right contact patch is crucial in ensuring that the board is optimized for the rider's intended use. A wider contact patch provides stability, making it a great option for beginner riders, while a narrower contact patch allows for more maneuverability and trick performance for advanced riders. Overall, understanding the relationship between the wheel width and the contact patch is essential in creating an electric skateboard that provides the desired level of grip and maneuverability.

Ultimately, the team decided that the "vanpro DIY Electric Skateboard Longboards Wheel 90MM 9052 pu for Cruising, Carving, Free-Style, Wheels Flywheels 608rs Bearings Cored Classics Wheel" wheels fit perfectly on the board, and work well with the pulley system. The trucks that the team bought were the "vanpro DIY Electric Skateboard Trucks 7.25" Long Skateboard Trucks".

### 3.4.12 Drive System

The drive system is an essential part of the design of the electric skateboard. This is due to the fact that the drive system is responsible for delivering power from the motor to the wheels so that they can properly spin at the desired speed and propel the board forward. Although it seemingly sounds straightforward, the drive system is a bit more complex than it sounds, being composed of several different components. One type of drive system is a belt-driven drive system. These components include a motor mount, pulleys, and a timing belt. Breaking down the system, a toothed timing belt is wrapped around the motor which is hooked up to a motor mount. When the motor starts turning, the belt transfers the torque of the motor to the wheel, which in turn makes the board move forward. The system can be seen broken down into individual parts in Figure 16.

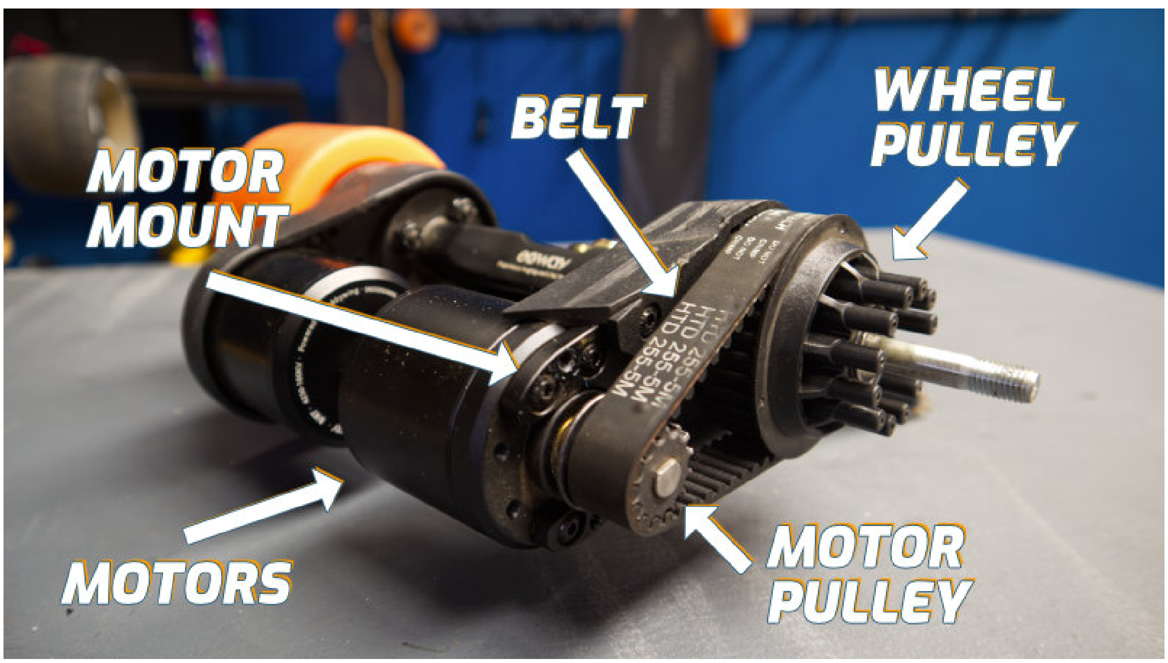


*Figure 18: Driving System Component Breakdown*

Another type of drive system is that of a direct-drive system. Direct-drive systems eliminate the need for belts and pulleys completely. In these drive systems, the motor is directly connected to the skateboard wheel hub instead of being hooked up to a pulley and belt system. This type of drive system allows for a less complex system, and a cleaner look, but may also be more expensive.


*Figure 19: Direct-Drive System Model*

The choice of the drive system is a critical one for any electric skateboard design, as it can significantly impact the overall performance and efficiency of the board. There are several different options available, including direct-drive, belt-drive, and hub motor systems. Each of these options has its own set of advantages and disadvantages, and ultimately, the decision will depend on a variety of factors, including cost, weight, size, and desired performance.

After careful consideration and research, we decided to go with the direct-drive belt system for our design. This system features a motor mounted directly onto the truck of the skateboard, with a belt connecting the motor to the wheel. Compared to other systems, such as the hub motor system, the direct-drive belt offers several key advantages.

First and foremost, the direct-drive belt system is generally considered to be more efficient than other options. This is because there is less friction involved in the transfer of power from the motor to the wheels, resulting in a smoother ride and longer battery life. Additionally, the direct-drive belt system is typically more compact and lightweight than other systems, making it a great choice for a portable electric skateboard.

However, as mentioned earlier, there are also some downsides to the direct-drive belt system. One of the main drawbacks is that it can be more expensive than other options. This is because the system requires a high-quality motor and belt to function effectively. Additionally, the direct-drive belt system can be more challenging to maintain and repair than other systems, as it requires more specialized tools and knowledge.

Another potential drawback of the direct-drive belt system is that it can be heavier than other systems, which can make the skateboard less portable. This may be an issue for riders who want to take their electric skateboard with them on public transportation or store it in a small space.

After careful consideration and analysis of the different options available, we concluded that the direct-drive belt system was the most suitable choice for our electric skateboard design. Although it had some drawbacks such as higher cost and weight compared to other systems, its advantages outweigh them. Although the direct-drive belt system may have cost us more upfront, we believe that it will pay off in the long run. The improved efficiency and performance will result in longer battery life and overall better user experience, which is essential for customer satisfaction.

In conclusion, despite the higher cost and weight, the direct-drive belt system was the best choice for our electric skateboard design due to its sleek design, improved efficiency, and performance, and long-term benefits.

In Senior Design 2, the team decided on the “vanpro DIY Electric Skateboard Brushless Motor Mount Bracket /80MM 90MM 97MM 100MM Pulley Wheel KIT Belt 5M”. It fits well with the motor and on the trucks.

## 4.0 Standards

To start with the description of the project, it is important to understand what the word standard means and why it is important. A standard is a written document that describes each characteristic that a product, process, or service will have. Each of them impacts society, from eating, drinking, communicating, and transporting to industries and their economies, the development of new technologies, and processes, since they work as an important factor when 1 development comes into play.

Moreover, each field has its own importance and useful standards. Communication standards are indispensable for national defense, for example, but not really for child safety, like industry standards that regulate children's toys, strollers, and playgrounds. The two of them are important, each in their own field, but equally important.

Besides, standards are really helpful for determining realistically what the design's solution will cover and, at the same time, supporting the universalization of certain everyday-use elements. Bulbs, for example. Every time they need to be replaced, the standards for each power company are the same, which makes it easier to replace than having a lot of different options. It is important to recall that standards are not mandatory but voluntary and are developed by the government, industry, and through partnerships with local, state, and federal governments. For instance, IEEE, on the one hand, develops standards on many different subjects related to computers and software engineering. On the other hand, the Internet Engineering Task Force (IETF) and the World Wide Web Consortium (W3C) are behind and more related to the development of internet standards.
Having this in mind, the main purpose of standards can be easily summarized as regulations that protect human health and ensure environmental safety. Human health covers many aspects of our daily lives, but let's talk about the most common ones, such as food and drinking water. As is known, food contamination and food processing have always been issues, so here is where the Food and Drug Administration and the U.S. Department of Agriculture come into play since these two entities are in charge of protecting the safety and healthiness of the food that will be later consumed by humans. The FDA is in charge of labeling and letting the consumer know what is inside the food that is out in the supermarkets. The USDA is in charge of developing mandatory standards for primary goods, such as eggs, poultry, and meat, among others. Equally important, the American Society for Testing and Materials (ASTM) International and the National Science Foundation (NSF) International have been in charge of developing the standards that certify safe drinking water and assure that no water contamination has happened, as well as monitoring the technologies, procedures, and testing programs related to water in bottles and purifier devices that have been developed and used to make water contamination impossible. Additionally, for environmental safety, fires are a perfect example. In this case, the National Institute of Standards and Technology (NIST) is responsible for designing practices and codes for tall buildings when a fire is present or about to be present. This involves enhancing guidelines and technologies to improve communication to guide people to get out of the building in case of an emergency. All of these new standards that have been developed will be expected to be referenced at the time of building a new tall building or even a tall part of the house.

As shown above, standards help and regulate human lives, but how do companies benefit from using existing or even creating new standards? Well, companies have many benefits from it since it improves efficiency not only in design but also in development and material acquisition. Companies say that it is really important to make use of standards since it is a way of making sure that what has been developed has already been approved for certain levels of safety and certain requirements that will make the new device work.

In addition, compatibility and interchangeability are part of the standards too. For example, if a company is designing a lamp, the required specifications for a bulb are already given by certain standards that have been approved, so it will be easier to complete this design with the qualified and chosen bulb. Here is where everything clicks: standards not only make the process for the company easier, but they also help increase productivity, competition, and technical efficiency.

The process of companies using common specifications that have already been approved is called standardization, and this can be done internationally. Here, the American National Standards Institute (ANSI) comes into play. As seen in the bulb example, the idea is to establish accepted common specifications for products and services. One of the many advantages that can be seen is the removal of technical barriers, which leads to new markets and economic growth across the world. Currently, the USA receives car parts from different countries, which makes building a car efficient since these parts are already approved. These parts can be used under the same specifications, and they can even be improved to better serve the customer.

After understanding the word "standard" and its importance in every single detail that shapes human life, It was easier to understand every aspect that involves the different technologies and, at the same time, research more about which standards can be possibly used and referenced to make the project work and be functional for use.

It also helped the team to be specific about the many features that will play a role in this project and to know where to do deep research on the different technologies that will be implemented. Starting with the basics, like how to build a skateboard, and moving on to more complex things, like solar energy and how it is stored and later converted to power the skateboard. This is mainly why we have limited our project SOAREBOARD to three different fields, the first one being the skateboard building on its own. The second is solar energy—how to store and use this energy. The third one is the app that will be paired with the skateboard to control speed and turn it on and off.

Most of the information used for this part of the document was sourced from three main sites. Starting with PDHonline Course G150 (2 PDH). From here, all the information about what a standard means, its importance, and what it regulates was taken out. following the Institute of Electrical and Electronic Engineers Standards Association (IEEE SA). This site was referenced specifically for the standards involving solar cells, AC-to-DC converters, and solar energy and its storage. Finally, the American National Standards Institute (ANSI) This site was helpful for understanding deeply how standardization works and how it can be taken to an international level.

## 4.1 Related Standards

This project is based on three main areas: solar power, energy storage, and transportation. During the research on how to implement the different characteristics of the prototype, like solar cells, batteries, speed, and an app to control the different features that the electric board will have.

Two main organizations are part of these transportation standards: The first is the Society of Automotive Engineers (SAE), which oversees the development of vehicles that will be used on land, sea, air, or space. The second is the American Association of State Highway and Transportation Officials (AASHTO), which develops the standards, material specifications, test methods, and recommended practices for every transportation mode. Having this in mind, some companies have their own standards.

Moreover, for the power and renewable parts of the project, two standards were referenced.

The first one is the IEEE Guide for Test and Evaluation of Lead-Acid Batteries Used in Photovoltaic (PV) Hybrid Power Systems. This document is based on the power system, and its main purpose is to measure the battery's capacity by charging and discharging the battery. It is recommended to charge the battery fully and let it rest for a minimum of one hour and a maximum of 72 hours before charging it again since the battery should get fully discharged. The purpose is to measure the battery's capacity by charging and discharging the battery. It is recommended to charge the battery fully and let it rest for a minimum of one hour and a maximum of 72 hours before charging it again since the battery should get fully discharged. Besides, it talks about how to perform a capacity test on the battery and, at the same time, keep a record of the voltage, current, and temperature that it holds. This document also talks about the voltage limit that can be held by a single solar cell and how to make use of the battery (Table 1).

| Cell type | Voltage limit (V/cell) [a] | Minimum duration of constant-voltage regulation at specified voltage limit (h) |
|---|---|---|
| Vented, lead-antimony | 2.45 to 2.55 | 3 |
| Vented, lead-calcium | 2.50 to 2.66 | 3 |
| VRLA, AGM (see manufacturer's specifications) | 2.35 to 2.40 | 6 |
| VRLA, gel (see manufacturer's specifications) | 2.35 to 2.40 | 6 |
| NOTE 1—Voltages specified for battery temperature at 25 °C ±3 °C. | | |
| NOTE 2—V/cell = volts per cell; AGM = absorbed glass mat; gel = gelled electrolyte. | | |

[a]This value should be within the system's operating voltage limits.

**Table 20: Typical system charging parameters(constant voltage)**

The second referenced paper is called IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems (IEEE 1013-2019). This document talks about a method that determines the energy-capacity requirements used in photovoltaic systems. Additionally, this paper talks about the sizing of the batteries, temperature, and the maximum and minimum load voltage that will be required hourly per battery. It also gives the formula to calculate the maximum number of cells that will be allowed to ensure an optimal and safe cell-recharge voltage, in other words, the cell size selection (Figure 5).

$$\text{Maximum number of cells (rounded down)} = \frac{V_{max}}{\text{cell recharge voltage}}$$

*Figure 20: Maximum Number of Cells Formula*

**4.2 Realistic Design Constraints**

When developing any idea, it is crucial to keep in mind the constraints that come with designing a realistic solution. These constraints serve as guidelines to ensure that the proposed design is both functional and feasible. There are several types of constraints that designers must take into account, including social, political, ethical, health and safety, manufacturability, and sustainability factors.

Social constraints may include considerations for cultural differences and societal norms, while political constraints may involve legal regulations or governmental policies that impact the design process. Ethical constraints encompass a wide range of ethical principles and values that must be adhered to, such as the respect for human rights and the protection of the environment. Health and safety constraints are essential to ensure that the design does not pose any risks to the users or the environment. Manufacturability constraints refer to the feasibility of producing the design at a reasonable cost and with available resources, while sustainability constraints relate to the impact of the design on the environment and its ability to meet the needs of future generations.

As our group embarks on a design project, we must keep in mind the various constraints that our project may face. Given that most of us do not have extensive experience in designing, we will need to conduct thorough research and analysis to ensure that our design meets all the necessary constraints. It is essential to approach the design process with a clear understanding of the constraints involved and to develop a solution that is both innovative and practical within those limitations.

**4.2.1 Economic and Time Constraints**

The economic constraint of this project is a budget-limited sum of $800 that is going to be collected from the team members. This money will be mainly divided between solar cells, batteries, printed PCBs, and all the parts that are needed to build a skateboard. An estimated budget has been created by searching the market for each of the elements that will be used to build the prototype, and it came to $600 total. Which is a considerable price for an electric skateboard powered by solar energy.

Moreover, for the time constraints, we need to deliver a final product in less than six months, meaning that by the last two weeks of July, we should have a finalized product. Having this deadline in mind, we should order ahead the parts that will be needed, such as the solar cells, battery, motor, and converter, and start with the PCB design, so in case we decide that it is better to print it outside of the country, there is enough time for it to be delivered. It is important to have the PCB design as soon as possible so we can start testing the solar cells, how to store the energy on the battery, and later on, how to get the energy from the battery to make it available to run the skateboard. A timeline has been defined among the team members to keep everything moving and on track to avoid any delays.

Another time constraint we may have is in the app itself. No one in our group has ever developed an app before, let alone developed one that is used to control anything wirelessly using Bluetooth.

Also in general, the time constraints of having 4 weeks less in the summer for senior design 2 made it very difficult for the entire idea of the Soareboard to be implemented perfectly, so a lot of decisions were made to cut some things off of the design.

### 4.2.2 Environmental and Social Constraints

Since this is a renewable energy approach, all the energy will come from the sun, and later on, it will be converted and divided into the necessary parts of the board to make it move and accelerate at a certain velocity. There is no environmental constraint considered since it will save energy and hopefully reduce $CO_2$ emissions since more people will be using the board to move between short-distance places. An environmental constraint with the board specifically is whether or not we should make it water resistant. Since we live in Florida, we know that it rains often and the weather is sometimes unpredictable, so we need to decide if, and how, we want to make the bottom of the board water resistant. As well as covering the solar cells in to keep them from being damaged. After some research we decided that we would put a resin over them so it will be clear (and possibly add a slight color). Resin is a lightweight and durable material, and it will not make the board unnecessarily heavy, so it will still be easy to carry around.

The impact products have on the environment is a factor that should always be considered. There are regulatory bodies such as the EPA which set standards related to a product's impact on the environment. These regulations and standards are something that needs to be considered when creating a product.

As a social constraint, the idea is to encourage students as well as people around the globe to start using this solar-energy-powered skateboard to travel from one place to another within short distances. Money and energy will be saved since no electricity will be needed to charge the skateboard.

### 4.2.3 Ethical, Health, and Safety Constraints

In designing a product, it is essential to consider the ethical and health constraints that may impact the user's safety. For instance, when designing a board with a battery attached to it, the user must be informed of this feature and be aware that electric loads can potentially harm or even be fatal to a person. Therefore, it is important to incorporate safety measures and provide necessary instructions to mitigate any risks associated with the product.

To ensure the user's safety, it is recommended to wear appropriate safety equipment while using the board. This may include protective clothing, such as a wetsuit or helmet, to prevent any injuries. Additionally, it is advisable to ride the board at a prudent speed to avoid accidents and collisions with other objects or people. Keeping track of the battery's percentage is also crucial to prevent the board from shutting off unexpectedly while in use, which can cause the user to lose control and potentially result in injuries.

There are various safety regulatory bodies that ensure the safety and proper use of customers and operators of these kinds of electrical pieces. One such regulatory body is DOT, which specializes in regulation and safety certification for skateboards and other skateboard accessories such as helmets and other safety items. We aim to produce the Soareboard in a way that it would comply with these regulations and standards. Even though we do not aim to have the Soareboard as a commercial product, it still serves as a decent baseline for our construction

Overall, we must prioritize the safety of the users by incorporating ethical and health constraints into our design. This requires careful consideration of the potential risks associated with the product and taking proactive measures to mitigate them. By doing so, we can create products that not only meet the needs of their users but also ensure their safety and well-being.

### 4.2.4 Manufacturability and Sustainability Constraints

No manufacturability constraints are present at the moment. All of the parts that will be ordered are always in stock. Starting from building the skateboard to the solar cells, battery, motors, converter, and Arduino. The skateboard will be built from scratch, meaning that all the parts will be assembled on our own. Once that is ready to go, we will proceed by pasting the solar cells on the top of the board, and later on, we will adjust the motor, battery, Arduino, and converter. We will use screws and a drill to make sure that every element of this board is adjusted in the right way and that none of them will fall out while riding. Also for the PCB, we will make sure we print it at a certain print shop close by, and if it is otherwise chosen to be printed outside of the country, we will make sure that the print shop has the necessary equipment to conduct this order.

In regards to the sustainability constraint, the main ones are the battery and solar cell life cycles and the maintenance of the skateboard as a whole. Besides the board, which can usually have some scratches within the first months or even years of usage, the wheels are if not the most used part of the skateboard since it is always facing down, and friction mixed with the material of the streets or floors through which the board will be navigating is not always the best. It is said that the skateboard board will last as long as the user wants it to since the wheels can be replaced at certain intervals. Moreover, talking about the battery and solar cells' life cycles On average, solar cells last 25–30 years, and the battery will last as long as the periods of charging and discharging are respected and it is not over burned with the velocity and the amount of voltage that is needed to drive it. On one hand, the battery will have a 3D-printed cap that will protect it from any rocks or possible scenarios that may threaten the battery's life. On the other hand, solar cells will be protected with resin on top of all of them. We chose resin to be the protection factor since it does not enable the cells from getting light, and at the same time, if it rains or something happens to fall into them, there is a hard layer that will stop damage from happening.

In addition to the physical components of the skateboard, the Soareboard team has also decided to incorporate digital technology to enhance the user's experience. Instead of a traditional remote control, the team has opted to develop an iOS app that will allow the rider to control the board through their iPhone. This decision was made after careful consideration of the user experience and the team's desire to provide a more modern and intuitive control system.

The Bluetooth connection between the board and the phone will be facilitated by an Arduino controller. While the use of digital technology may raise concerns about sustainability, the team has taken steps to ensure that the impact on the environment is minimized. The digital controller's life cycle is expected to be relatively long, with the Arduino lasting up to 10-15 years in a cool environment. However, it is ultimately up to the user to ensure that both the phone and the Arduino are properly cared for to ensure their longevity. Despite the addition of these digital components, the team remains committed to creating a sustainable and eco-friendly product.

## 5.0 Project Hardware and Software Design Details

This section went into the design of the Soareboard, both hardware and software. For the hardware, many elements were built into the skateboard, while others were placed onto it. Shown in this section, an initial prototype design was included. An overall plan for the construction of the Soareboard was provided in this section. All of the components were combined to form a cohesive whole. Once the breadboard was received, it was important that it was tested to ensure its usability. The process that was undertaken was detailed in this section. The hardware design of the Soareboard included a collection of subsystems that worked together. The first major subsystem was the collection of power from the solar cells that would be stored in the battery. The second major subsystem was the power stored in the battery being distributed to the Soareboard's other components, including the motor, speedometer, and LEDs. The software design for Soareboard focused on two major sections, the programming of an app designed to control Soareboard, and the programming of the microcontroller. One overall flowchart was provided to detail the logic of the proposed software elements. Visuals regarding the interface and function of the app were included in this section. A chart was shown indicating how the app was designed to interact with the board's MCU.

An initial prototype design of the Soareboard was created and paired with a plan for the construction of the skateboard. The components were designed to work together cohesively to ensure the optimal performance of the Soareboard. It was essential to test the breadboard upon receipt to ensure its usability.

One major subsystem of the Soareboard's hardware design was the collection of power from the solar cells, which would be stored in the battery.

The second major subsystem was the distribution of power stored in the battery to the other components of the Soareboard, including the motor, speedometer, and LEDs.

The third major subsystem related to the controller and its interaction with the rest of the system's components.

The software design of the Soareboard was divided into two major sections, the programming of an app designed to control the Soareboard, and the programming of the microcontroller. An overall flowchart was provided to detail the logic of the proposed software elements.

The app designed to control the Soareboard was programmed to be user-friendly and intuitive. Visuals regarding the interface and function of the app were included in this section. A chart was shown indicating how the app was designed to interact with the board's microcontroller.

### 5.1 Initial Design Architecture and Related Diagrams

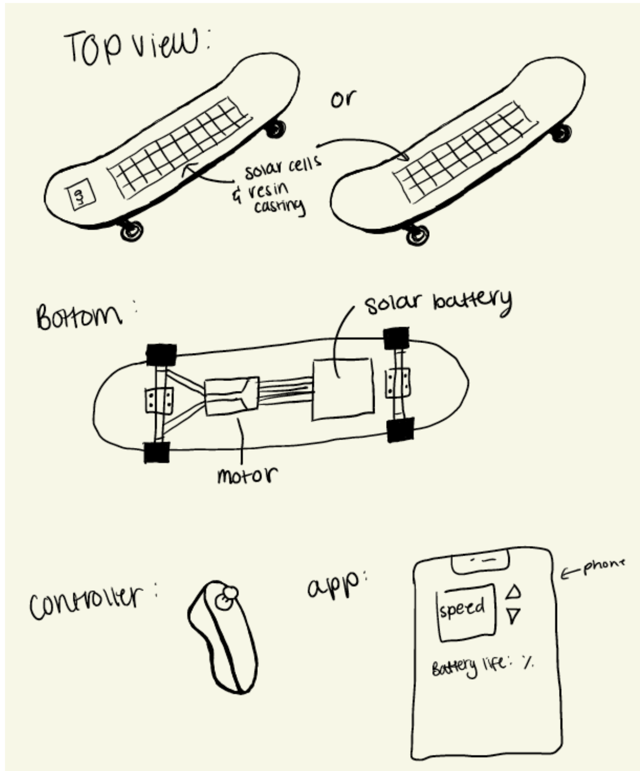


*Figure 21: Prototype Design*

The initial drawings of our electric skateboard design served as a preliminary representation of what the final product might look like. The top and bottom views of the board were presented in Figure 4, with two versions of the top view, one showing the proposed locations for the solar cells, resin, and LCD screen, and the other without the LCD screen. The bottom view highlighted the placement of the motor and solar battery on the board.

The design of the app or controller was also presented in the drawings. We opted to use a Wii controller for the controller, although it might not have been the final choice. The app design was not yet finalized, but we had a basic idea of what it might look like.

However, we still needed to finalize the placement of the solar cells in order to optimize the amount of energy produced from the sun. This might have affected the overall design of the board. We also needed to decide whether to use an app or a controller to control the board. If we chose to use an app, we would no longer need an LCD screen on the top of the board since everything would be displayed on the app. Developing an app might have been challenging, but it would have been a valuable learning experience for our team. Alternatively, using a controller would have allowed us to focus on improving our programming skills, as we did when we learned to use an LCD screen with a microcontroller. Although the initial drawings of the board and the controller/app design provided a basic idea of what we wanted to achieve, the final design was not yet set in stone, and several decisions still needed to be made before the project could be completed.

This image depicted the initial concept and design for the Soareboard, outlining all the components, including discussed features up to the stretch goals. The top of the board featured solar cells, which absorbed solar energy as a source of power. A resin coating was applied to protect the solar cells from erosion and weather damage. As a stretch goal, the top of the board could also feature LEDs and a speedometer. The LEDs could have added an extra design element, allowing the user to customize the color of the board. The speedometer could have displayed the board's speed, providing the user with an easy way to monitor their velocity while in motion.

On the underside of the board, the solar battery and motor were located. The solar battery stored the energy generated by the solar cells. To connect the solar cells to the battery, there had to be a connection through or around the board. The motor powered the wheels to propel the board forward. The motor was usually connected to the axle at the back of the wheels for stability. It required electrical power to function, which it received from the solar battery. As a result, all the significant features of the board were interconnected through a series of subsystems.

An external controller was a separate piece of equipment that played a role in the hardware of the overall system. The controller was designed to control the board, specifically the motor. To connect the controller and motor, a wireless connection, such as Bluetooth, was preferred for convenience.

A smartphone app was also included in the prototype design. The Soareboard team would have used available services to create the app, which would have had several crucial functions. The primary function of the app was to control the speed of the board, allowing the speed to be gradually increased or decreased. The app would not have had a stop function, as it could have been dangerous for the board to stop suddenly. Another function of the app was to control the LEDs. The app would have allowed the user to change the color of the LEDs, providing an easy way to customize the board's appearance.

However, the prototype design had some potential downsides. For example, the direct-drive belt system used in the motor could have been expensive, and maintenance and repairs might have required specialized knowledge and tools. Additionally, the solar cells had to be placed in an efficient matrix form to maximize the board's design, and the resin coating had to be carefully applied to ensure a strong grip for the rider. Despite these challenges, the use of pulse width modulation was essential in controlling the speed and efficiency of the motor while ensuring rider safety. Overall, the Soareboard represented a functional and efficient electric skateboard that ran solely on solar power.

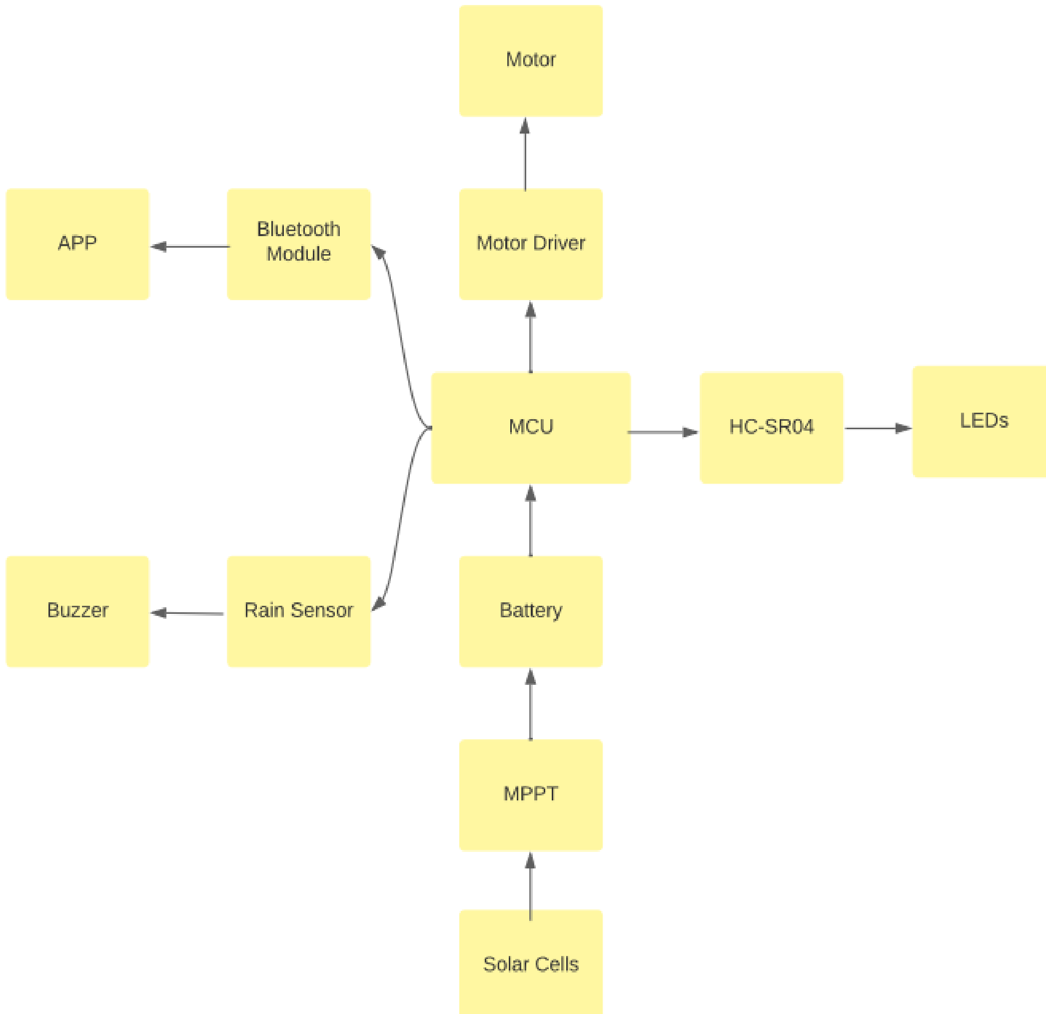


*Figure 22: Hardware block diagram*

The flow of power is an essential point of understanding how our design works. Through the use of solar cells, our entire board is powered sufficiently through the use of clean, renewable energy from the sun. Following the path, it starts from the solar cells receiving energy from the sun and transferring the power to the central battery we have connected to the rest of the elements. The battery then transfers its energy to the PCB which is held as the controller for the entire board. The PCB sends signals to each element: the motor, LEDs, speedometer, and even the controller/app that receives the user inputs. These separate elements are all powered by the PCB and programmed through it. While the LEDs are more of an extra accessory, the speedometer, motor, and controller are all quintessential elements that allow for the board to work as intended. This flow of power dictates the order at which each element will be designed as well. We must make sure that each element works as intended before building the proceeding one. Once each element is constructed, the controller is the last thing needed to connect the entire project together, allowing the board to move as instructed.

This image represents the overall logic of the Soareboard and how each of the individual features of the hardware design all come together to form one cohesive whole. The system starts at the solar cells, which provide the power for the system to operate. The power generated by the solar cells are stored in the battery. The MCU is an overall software design that operates the logic of the board. The MCU decides where the power collected by the battery is directed. There are four subsystems that will be powered by the battery as directed by the MCU; including the motor, controller/app, LEDs, and speedometer. Some of the features such as the controller/app and the speedometer interact with the MCU by both giving and receiving information, which affects how the MCU will operate and direct power.


*Figure 23: LIFE Rechargeable Battery*

This image represents the battery that was chosen in relation to our initial design and preliminary hardware testing section. The battery that was chosen was the "2000 Cycles 12V 6Ah Miady Lithium Iron Phosphate Battery". This battery was chosen for its voltage output, coming in at 12.8 volts, which should suit the needs of our system. The lithium ion nature of the battery should pair well with our solar cells. One of the key features of the battery was that it was rechargeable. It should be able to be charged by our solar cells, while also distributing the power it receives to our electric skateboards and other major components. The second major component that was ordered and received was the battery.

There were a number of factors that contributed to the selection of a battery. Some of the factors that were considered in the decision to choose a battery were price, composition of the battery, and overall voltage. Considering these factors, we decided that “2000 cycles 12V 6Ah Miady Lithium Iron Phosphate Battery”. In spite of its higher price point compared to the other batteries that were researched and discussed, it was determined to have a better voltage of 12.8 total volts. It also had a composition of a lithium iron phosphate battery, which was considered more ideal and was determined to pair better with our solar cells, which was a key factor as to why it was chosen for this project.

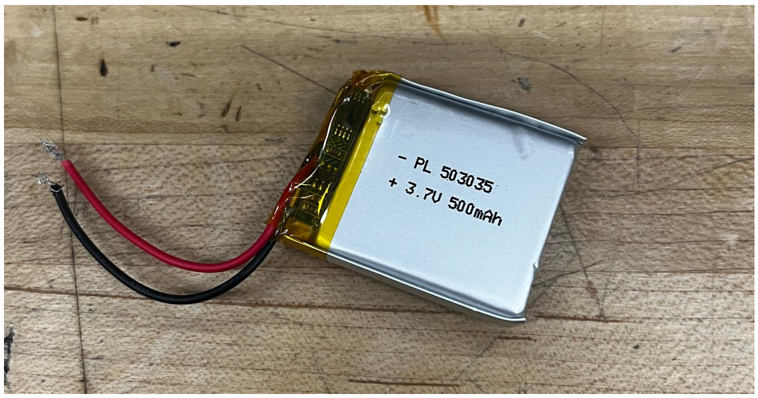


*Figure 24: PL 503035 Battery*

The purpose for this battery is to power the Arduino. The Arduino requires five volts, for this reason a smaller battery is needed. To satisfy this need we choose the “AKZYTUE 3.7V 500mAh 503035 Lipo Battery Rechargeable Lithium Polymer ion Battery Pack”. This battery is rechargeable, therefore it will be connected to MPPT and a single solar cell which can hold up to five volts, so that the battery can charge. Through this the Arduino and the MCU will be powered and can operate, allowing our device to function and perform as expected.

*Figure 23: Arduino Uno Rev2*

The controller is a crucial component of the Soareboard design, as it is responsible for determining the overall logic and functionality of the board. Therefore, it was one of the first components selected for the initial group of part selections and was included in the overall demo video. The selected controller for the Soareboard project is the Arduino, which is a dynamic and heavily programmable piece of hardware. Its capabilities make it an ideal choice for this project.

Given the importance of the controller, it was purchased first, and the rest of the project will be built around it. After conducting some research, it was found that the Arduino UNO wifi Rev 2 has a Bluetooth chip inside, which will enable the board to be controlled wirelessly. It is believed that there will be no need for the HC-05 Wireless Bluetooth, but this decision will be based on the results of testing the wireless communication. Overall, the controller is a vital part of the Soareboard design, and its proper function is crucial to the success of the project.

After a few considerations and more research, the team decided to work with the Arduino UNO board R3. This board was perfect to work with all of the other chosen components as the motor driver BTS7960 and the bluetooth module HC-05. Besides, the MCU that this board uses, we can take it out and by the hand of a crystal oscillator and two capacitors so the bootloader can be burned on the MCU. Burning the MCU enables the project to have some sketches stored, so the code keeps running forever until disconnected or turned off.

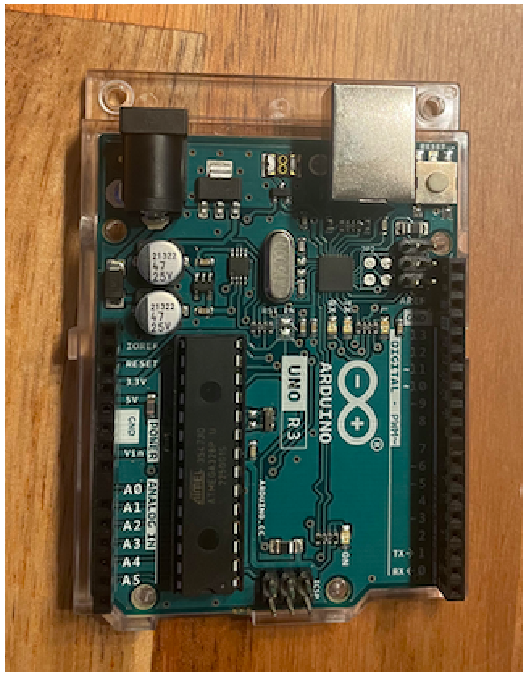


*Figure 25: Arduino Uno Rev2*

*Figure 26: Boosted Board Motor*

The key concept of this project, as with any similar design effort focuses on the concept of a propulsion-based skateboard. The motor is a key component in this project, as it is with other projects of this type. The motor is the most essential component for any electric skateboard, which is why it was one of the first components that was procured for this project. The motor was included in our initial design, and our first major component demo. The decision for the motor was a difficult one, but we ultimately decided on the "IWONDER Original Boosted Board V3 Motor". This motor was designed for the Boosted board, and is an essential component of that board's design. This motor was specifically designed for use in electric skateboards, which should allow for efficiency and ease of use. The Boosted Board motor should allow for a high-functioning and high-speed motor, ensuring Soareboard will be a quality product. The first major component that we received was our board's motor. We had a number of priorities that were considered when selecting a motor for this project. Some of the factors that were considered were price, rpm, weight, and voltage. Upon this criteria, we determined the "IWONDER Original Boosted Board V3 Motor" was the motor that best fit our unique criteria.

After doing some testing with the "IWONDER Original Boosted Board V3 Motor", we realized that it is not the motor we need. We found out that this specific motor is only used for that specific board. It is only able to be connected to the Original Boosted Board, which means that we are not able to connect it to our board. After doing a bit more research, we decided on a different motor. The one we decided on is C6374 170KV Efficience Brushless Belt Sensored Motor for Electric Skateboard Longboarding (C6374, 170KV) and is shown below:

*Figure 27: C6374 170KV Efficience Brushless Belt Sensored Motor for Electric Skateboard Longboarding (C6374, 170KV)*

In Senior Design 2, we found that the motor above also did not work for our project, so we went with the "Motor 775 Power DC Motor".

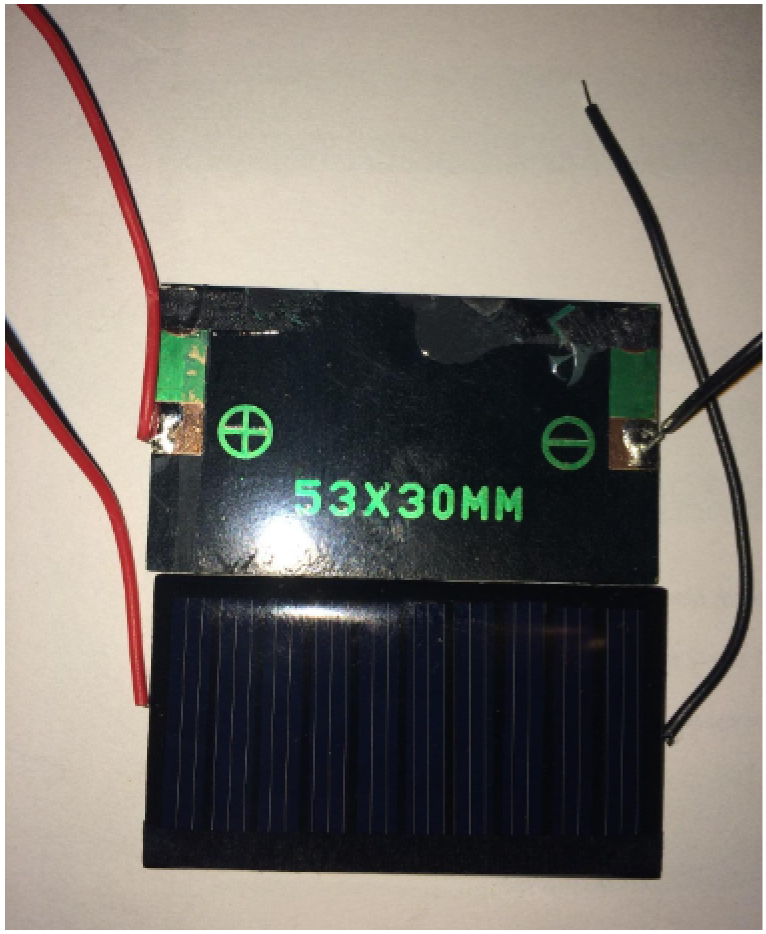


*Figure 28: AOSHIKE Solar Panels*

The final major component that was selected for the first group of parts that were bought regarding this project was the Solar Cells. The Solar cells serve as an essential part of the design of the Soareboard. They are part of the Soareboard's first notable subsystem, which is the power generation subsystem. The Solar cells, when exposed to direct sunlight, will generate power, which will be stored in the battery. Due to this reason, it was important that the solar cells be one of the first components that were selected for this project. There were several criteria that were considered in the selection of the Solar cells. Among the factors considered were price, voltage, and overall efficiency. With these factors in mind, we decided on "AOSHIKE 10Pcs 5V 30mA Mini Solar Panels' ' as our choice in Solar cells. The decision to use Micro Solar cells in our design was a crucial one, but our limitations in space required that our solar cells had less total surface area, which necessitated finding some way to have the cells take up less space. That requirement led to the compromise of Solar Cells.

In addition to solar cells, a DC to DC step-up converter is also a crucial component that must be implemented to make the entire system work. As previously mentioned in the board design section, the converter will help increase the voltage output from the solar cells to meet the required amount needed to charge the battery. Specifically, while the solar cells generate a voltage output of only 5 volts, the battery requires a 12.8-volt input to charge effectively. By utilizing a DC to DC converter, we can efficiently increase the input voltage from 5 volts to 12.8 volts, allowing us to charge the battery and keep the system running seamlessly.

Without this converter, the system would not be able to effectively charge the battery, which could result in power shortages and system failures. Furthermore, this converter ensures that the battery is charged at a consistent rate, which is important for the longevity of the battery and the overall system performance. Therefore, the DC to DC step-up converter is an essential component in this project, ensuring that the solar cells can be fully utilized and the battery is charged optimally.

When selecting hardware components for the Soareboard, one of the main considerations was the input voltage required by each component. It was important to ensure that the minimum input voltage required by the components was the one available. This meant that we had to carefully consider the specifications of each component before making a decision. In addition to input voltage, we also had to take into account the weight of each component. Although the weight difference between the components may seem negligible, it was important to keep the overall weight of the board as low as possible. This was not only important for the board's maneuverability but also for its overall performance. If the board is too heavy, it will require more voltage and power to travel at any speed, leading to potential electrical issues. Therefore, we carefully considered the weight of each component to ensure that the board would be as lightweight and efficient as possible.

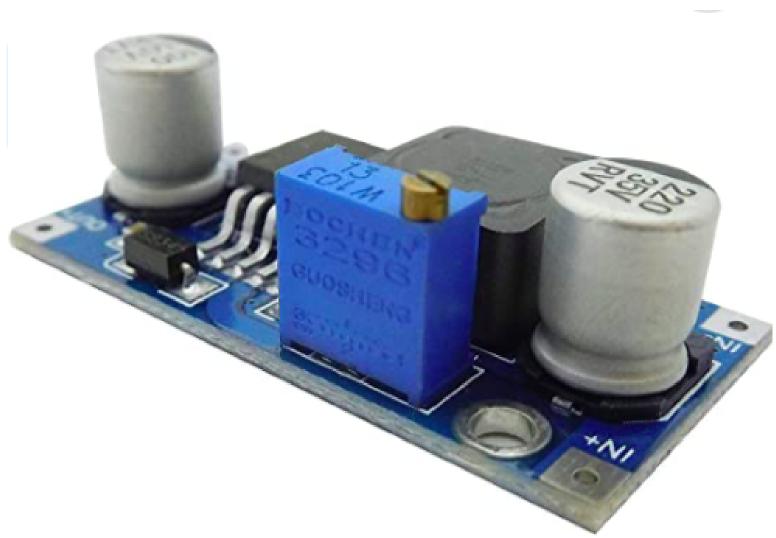

*Figure 29: HiLetgo XL6009 DC to DC*

Hence, having this included in our board will enable our green energy board to work properly and really reduce $CO_2$ emissions since the battery will be automatically charged from the solar light gathered by the solar cells.

### 5.1.2 Final Design Architecture

In the final version of the design, significant changes were made from the initial plans for the design. This section was created to showcase the final version of the design, highlighting areas that differentiate from the initial design.

For the final version of the design, we used the same battery as was detailed in the initial design section. The battery selected in Senior Design 1, was the “2000 cycles 12V 6Ah Miady Lithium Iron Phosphate Battery”. This battery was determined to be sufficient for our needs in senior design 2. Both its voltage and current output paired well with our chosen motor.

The motor selected for the final design differed from what was planned in our initial design. We found a motor that would pair well with the output from our battery and could be installed on our mount. The motor that was selected for the final design was the “775 DC Motor DC 12V - 24V Max 12000 RPM”. This motor worked well and performed the desired function.

*Figure 30: 775 Motor*

With the motor, we determined it was essential to have a motor driver as well. For this reason, we have selected the “HiLetgo BTS7960 43A High Power Motor Driver”. This motor driver worked well and performed its function, both indicating and controlling the motor’s function.

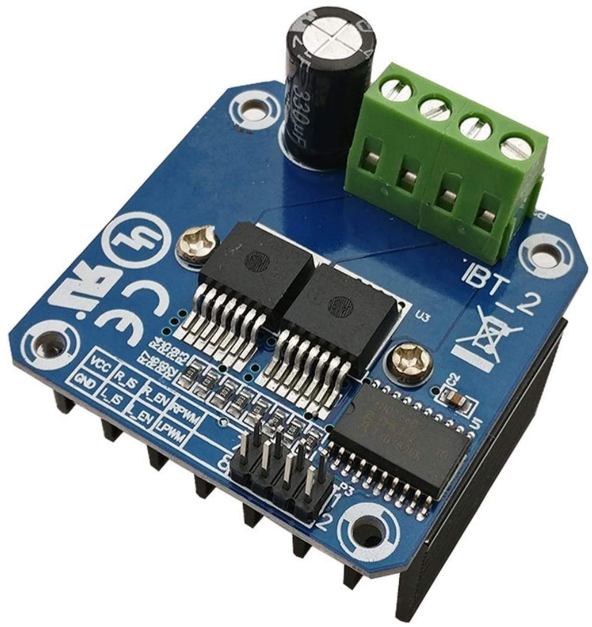

*Figure 31: BTS 7690 Motor Driver*

In our final design, we used the same solar cells as detailed in our initial design. The SUNYIMA Solar Cells were determined to work well for their intended purpose. In our final design we used five solar cells in series to charge our bigger battery that is used to power the motor, then there would be one separate solar cell used to charge the smaller battery that is used to power the Arduino.

In addition to the solar panels, it was determined that a Solar Charger was required. The role of the solar charger would be similar to that of a proposed DC to DC converter. The Charger takes in the voltage from the cells, then releases the appropriate amount for the batteries to receive. The inclusion of the Solar charger was determined to be superior to the initially planned DC to DC converter. The solar charger that was used for this project was the “MPPT Solar Panel Controller, Universe 5A Solar Charge Controller”.

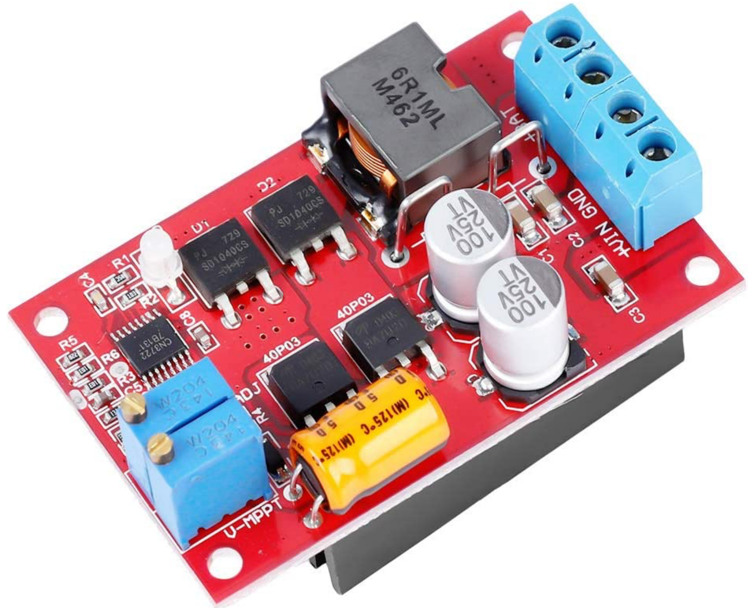

*Figure 32: MPPT Solar Charger*

The Arduino was used in the final design as specified in the original design. The Arduino was an efficient microcontroller that aided us in the design and the construction of the Soareboard.

### 5.2 First Subsystem, Breadboard Test, and Schematics

The hardware design of a board involves several fundamental aspects, including the interaction between various subsystems. To ensure that the board operates efficiently and effectively, designers must consider how different components interact with one another and design the system accordingly.

As part of the design process, it is essential to test the board's hardware design using a breadboard, which allows for easy prototyping and debugging. This enables designers to identify and fix any potential issues with the hardware design before moving on to the final product.

Another critical aspect of the hardware design is the overall schematic that illustrates the electric logic under which the board operates. This schematic provides a comprehensive view of how the various components of the board work together to achieve the desired functionality. It is essential to understand the board's function and how the hardware design supports that function to ensure that the product meets the user's needs.

In summary, the hardware design of a board plays a crucial role in ensuring its functionality and efficiency. The design process must consider various subsystems' interactions and test the design using a breadboard to identify and fix any potential issues. Additionally, we must provide a comprehensive schematic that illustrates the electric logic under which the board operates to ensure that it functions as intended. By prioritizing these aspects of the hardware design, we can create a product that meets the user's needs and expectations.

### 5.2.1 Breadboard Test

An important step in manufacturing a product was the process of testing that the components were functional. One such component that required testing was the breadboard itself. For this project, the breadboard used was a printed circuit board, designed through Autodesk Eagle, and then manufactured through a third-party developer. It was noted that the printed circuit board was a requirement for this project, as a pre-built circuit couldn't be used. Once our printed circuit board was received, we went through the process of testing it. A breadboard test could be undertaken by inserting wires into the breadboard, fraying them at the ends so that they were exposed. We used a multimeter and connected either end to each of the exposed wires. If the multimeter didn't register a response, then the breadboard failed the test. If there was an audible response and the multimeter measured voltage, then the breadboard passed the test. This test could be repeated to measure different sections of the breadboard.

The breadboard wasn't the only component that required testing. Upon receiving our first wave of components, it was incumbent upon us to test them to ensure their proper use and that they would fit their desired application in our project. The first group of components procured for use in this project was the motor, the battery, and the controller. Once these components were initially received, it was a priority that we tested and reviewed them to ensure that they would be sufficient for the purposes for which they were bought.

### 5.2.2 Schematics

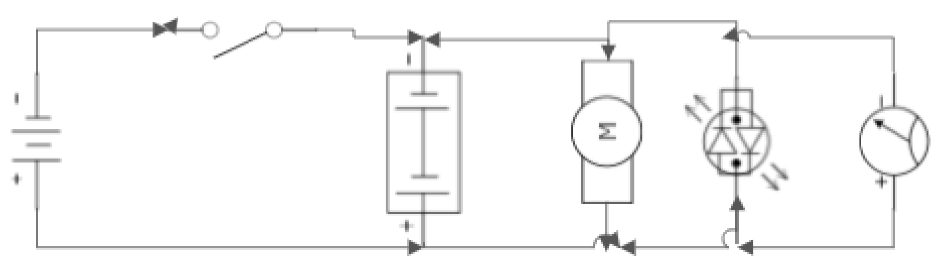

*Figure 33: Schematic*

This image served as an idea for the schematic. The schematic acted as a collection of subsystems, which is why it was portrayed as a series of parallel circuits. The solar cells interacted with the battery. The on/off switch was shown, which created this connection. When it was on, power flowed from the cells to the battery. Notably, the cells did not directly interact with the other components; instead, they indirectly interacted through the battery. The motor, LEDs, and speedometer were connected to the battery through parallel connections. Each component was directly connected to the battery and powered through it. The battery indicated through the MCU which of these subsystems would take power, as shown through this parallel design.

The solar cells interacted with the battery, which was the primary source of power for the other components of the Soareboard. The on/off switch was shown, creating a connection between the cells and the battery. When the switch was on, power flowed from the cells to the battery. It was important to note that the cells did not directly interact with the other components of the Soareboard, but rather indirectly through the battery.

The motor, LEDs, and speedometer were connected to the battery through parallel connections. Each of these components was directly connected to the battery and powered through it. The battery indicated through the MCU which of these subsystems would receive power, as shown in this parallel design.

The schematic was designed to be clear and concise, making it easy to understand how each of the subsystems interacted with one another. It was an essential component of the Soareboard design, ensuring that each subsystem worked correctly and efficiently.

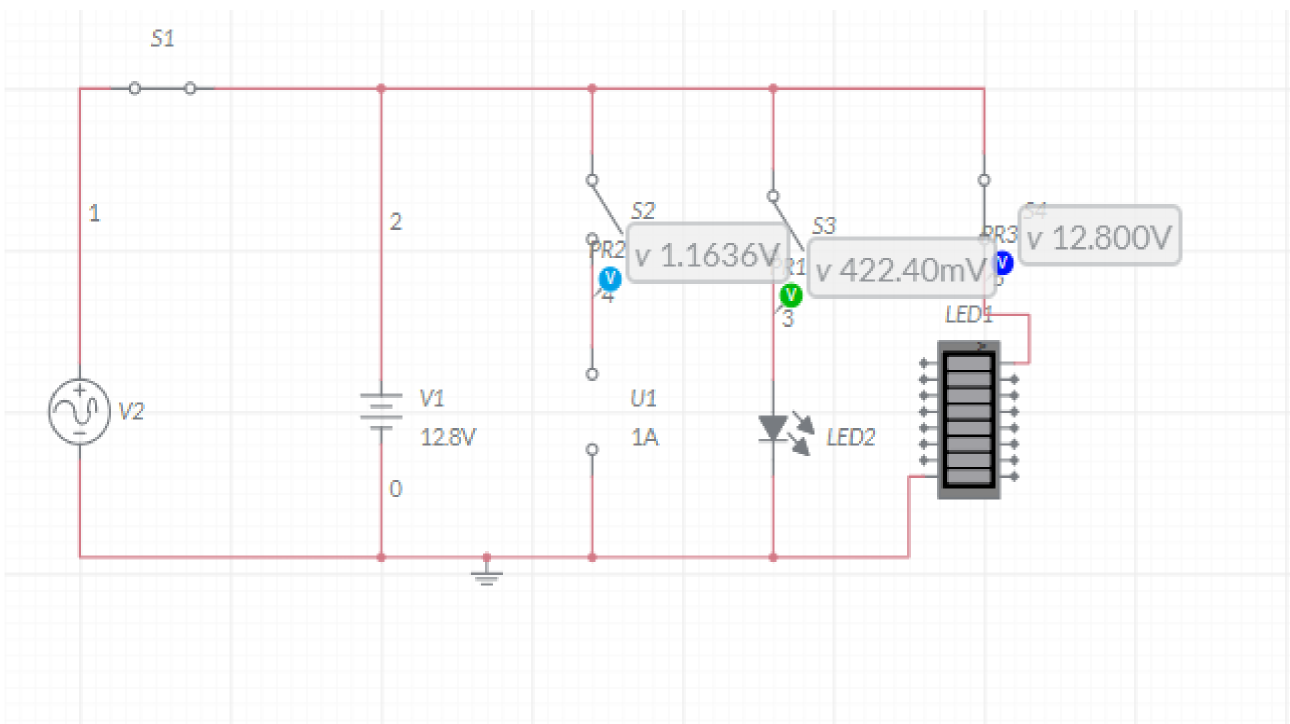


*Figure 34: Schematic Simulation*

The above image provided an overview of the complete schematic for the proposed system. It included a combination of different subsystems that worked together in harmony. The primary subsystem highlighted in this circuit was the power collection subsystem, which included two main components, namely the Solar Cells and the Battery. The Solar Cells were responsible for collecting the energy from the sun, which was then stored in the Battery for later use. The second major component illustrated in this schematic was the power distribution subsystem. The Battery supplied power to the different components of the system, including the motor, the LEDs, and the speedometer.

This multisim simulation was designed to showcase how the proposed system would function in real-life situations. It was important to understand how each of these subsystems worked and how they worked in tandem to achieve the desired outcome. The simulation provided a clear understanding of the entire system and its components, allowing for easier troubleshooting and maintenance. Additionally, it provided an opportunity to test and optimize the system before implementation, reducing potential risks and ensuring that the final product functioned as intended.

### 5.2.3 First Subsystem

*Figure 35: First Subsystem*

The first subsystem shown in the prototype started with the solar cells. The cells interacted with sunlight, creating power. The power generated by the solar cells was then taken and stored in the battery. This crucial interaction was marked as the first subsystem within Soareboard. The solar cells generated the power that would later pass through the DC to DC step-up converter, which would help the remaining subsystems operate. The inclusion of solar cells differed from the traditional power source of electric skateboards. Most electric skateboards were powered directly with electricity through a charger that could be plugged into an outlet. That was undeniably a simpler method for obtaining power, but Soareboard sought to innovate. Solar power could be a more efficient and renewable resource, making the endeavor to create an electric skateboard using solar power a worthwhile pursuit.

The solar cells generated power that helped the rest of the subsystems operate through the step-up converter. This inclusion of solar cells was a departure from the traditional power source of electric skateboards, which were powered directly with electricity through a charger that could be plugged into an outlet. While that was a simpler method for obtaining power, the use of solar power could be a more efficient and renewable resource, making the endeavor to create an electric skateboard using solar power a worthwhile pursuit.

The use of solar power as a source of energy for the Soareboard had several advantages. Firstly, it was an environmentally friendly option as it reduced the carbon footprint associated with traditional power sources. Secondly, the use of solar power eliminated the need for charging, which could be a hassle, particularly for users who were always on the go.

Thirdly, solar power could provide an almost infinite source of energy, especially in areas with abundant sunshine.

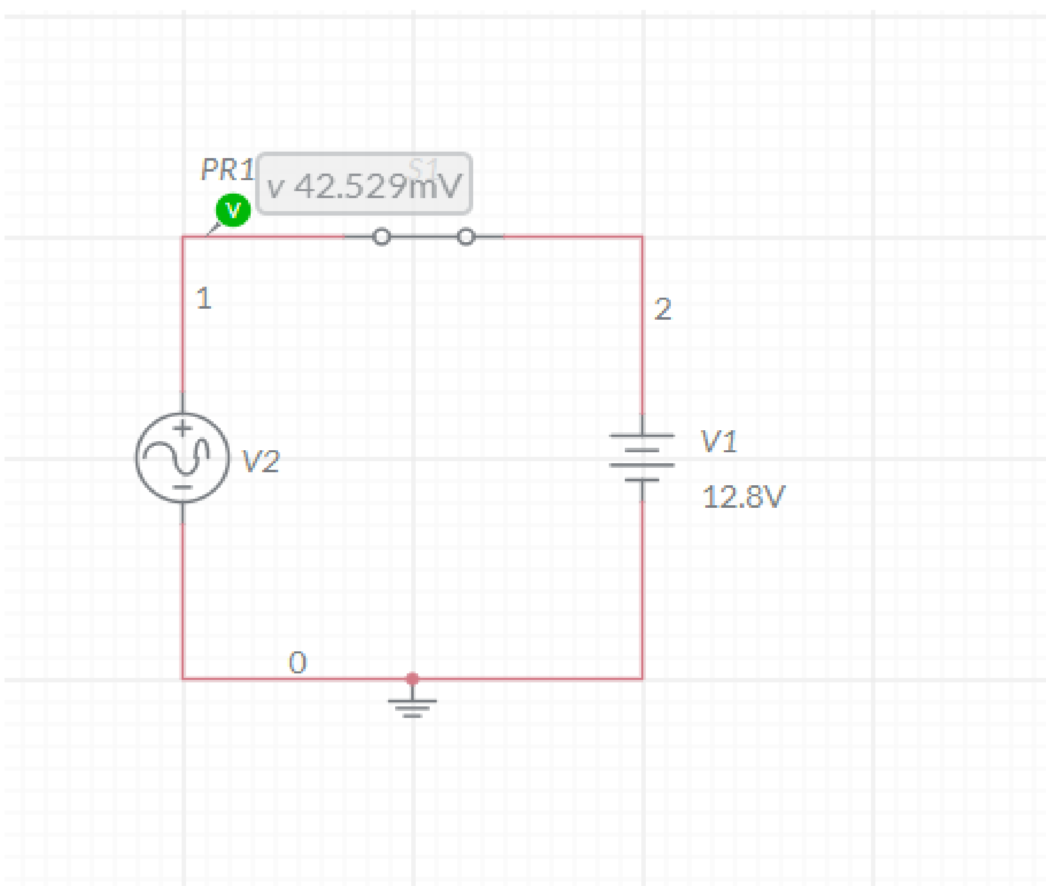


*Figure 36: First Subsystem Simulation*

To illustrate the practical application of the proposed subsystem, a circuit was developed and simulated in Multisim. The circuit consisted of a voltage source representing the solar cells, a DC to DC step-up converter, and a voltage source representing the battery. The voltage level of the battery was set to 12.8 volts to simulate the output of the selected battery, which was the "2000 Cycles 12V 6Ah Miady Lithium Iron Phosphate Battery" chosen for the project.

It is worth noting that grounding was a crucial aspect of any circuit, and the proposed subsystem was no exception. Therefore, a ground connection was added to ensure the proper functioning of the circuit.

To provide greater reliability and control, a switch was also added to the circuit. This switch served to indicate when the transfer of power from the solar cells to the battery should begin and when it should stop. This feature was crucial for ensuring that the system operated smoothly and efficiently. Without it, the system would have lacked the necessary level of control to function optimally.

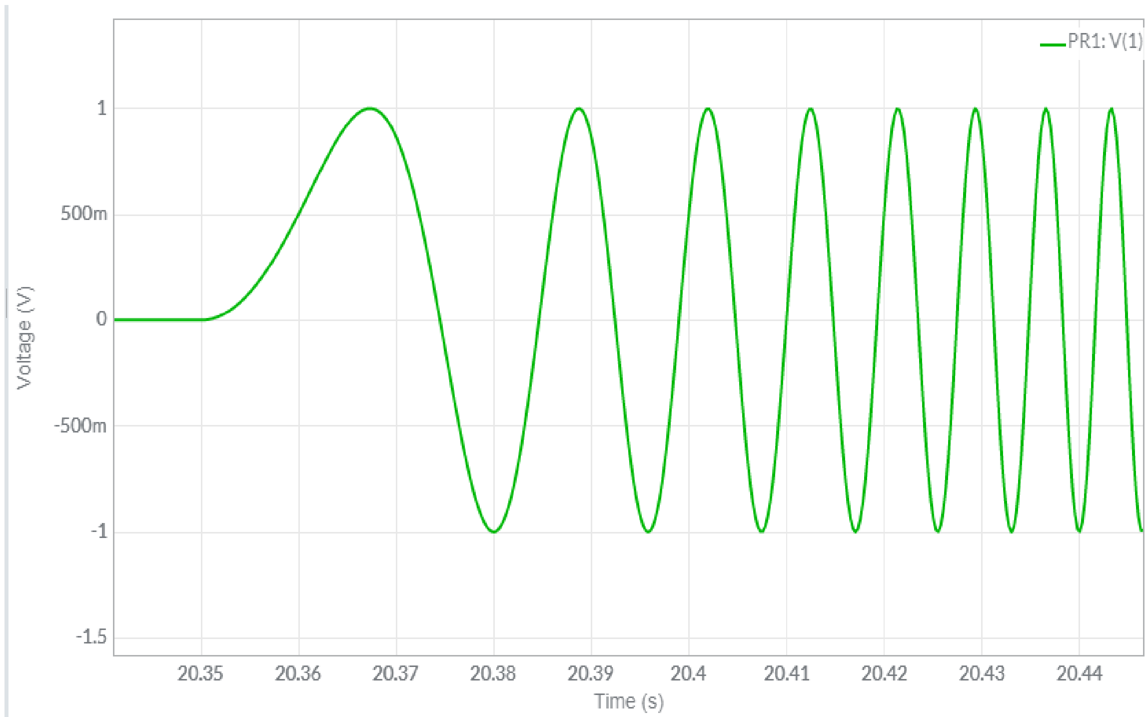


*Figure 37: Subsystem 1 voltage output*

This image represented a graph of the overall voltage distribution in the above circuit. The start of the graph indicated that the switch had been turned from off to on. It slowly gained in power until it reached its peak. Once it reached its peak, it went through a cycle of gaining and losing power. It represented the fact that the power generation from the solar cells would be inconsistent and correspondingly run on something of a cycle. This was accurately represented in our multisim simulation of the Soareboard to provide an accurate representation of how the actual power generation subsystem would function. The power generated from the solar cells, as indicated in the graph, would be stored in the other battery that would be used in this product.

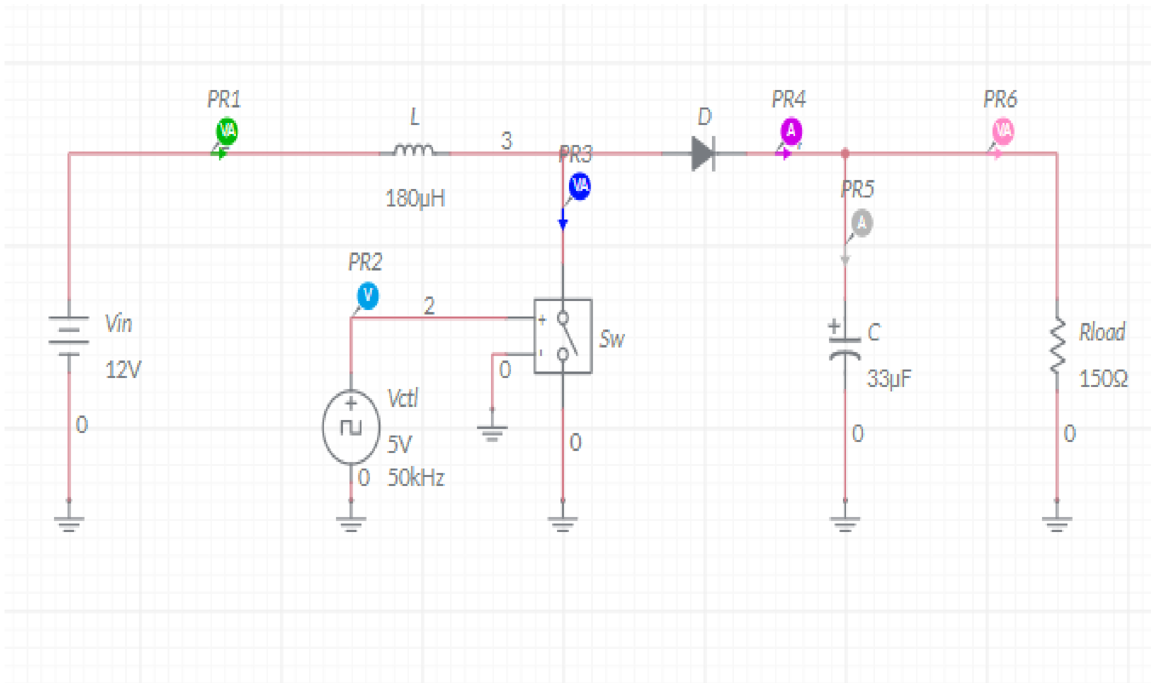


*Figure 38: DC to DC converter*

The DC to DC converter was a crucial element in the Soareboard project, as it allowed the solar cells to transfer their energy to the battery. The converter's primary function was to store electrical energy and convert it from one voltage level to another, which was precisely what we needed to charge our battery. Since the solar cells produced only 5 volts of electricity, we needed to step up this voltage to 12.8 volts, which was the voltage level required by our battery. This conversion process was made possible by the DC to DC converter, which temporarily stored the electrical energy and increased its voltage level.

To better understand how this process worked, we created a circuit in Multisim, which illustrated the conversion process. The circuit showed how the DC voltage generated by the solar cells was converted to a voltage level that could be used by our battery. Our research led us to select the AOSHIKE 10Pcs 5V 30mA Mini Solar Panels, which produced 5 volts of electricity, and the 2000 Cycles 12V 6Ah Miady Lithium Iron Phosphate Battery, which held 12.8 volts of electricity. With the DC to DC converter, we could take the 5 volts of electricity generated by the solar cells and step up the voltage to 12.8 volts, allowing us to charge the battery and keep our Soareboard running.

It was essential to choose the right schematic for the DC to DC converter to ensure that it fit best with our project's requirements. By selecting the appropriate schematic, we could ensure that the converter functioned correctly and provided the necessary voltage level for our battery. In conclusion, the DC to DC converter was a crucial component for the Soareboard project, and its implementation was necessary to make the project possible.

## 5.3 Second Subsystem

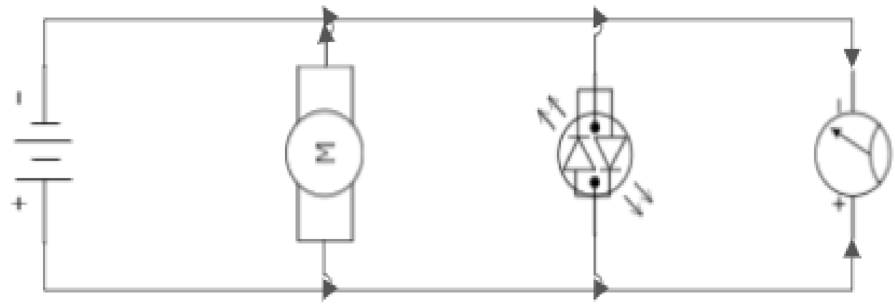

*Figure 39: Second Subsystem*

The second overall subsystem detailed how power was distributed from the battery to utilize the various features the Soareboard had to offer. The features of the Soareboard that drew power were the motor, a series of LEDs, and a speedometer. The motor functioned as indicated by the user through the third subsystem of a controller. When indicated, power was drawn from the battery to the motor for its operation. The second feature in this subsystem was the series of LEDs, indicated on the figure by opposing diodes. The LEDs drew a constant low stream of power whenever they were on, as indicated by the controller. The final component of this subsystem was the speedometer. This feature also drew a consistent low stream of power, similar to the series of LEDs. In contrast, the speedometer was constantly on as long as the board was turned on, regardless of the controller's indication.

The motor was a crucial component of the Soareboard, responsible for propelling the skateboard forward. The motor drew power from the battery, which was supplied through the controller. The user could control the speed and direction of the motor through the controller, which sent signals to the motor to adjust its output accordingly.

The second feature in this subsystem was the series of LEDs. The LEDs were indicated on the figure by opposing diodes and drew a constant low stream of power whenever they were turned on, as indicated by the controller. The LEDs served both as functional and aesthetic features, providing illumination and visibility to the rider, as well as enhancing the overall look of the skateboard.

The final component of this subsystem was the speedometer. This feature measured the speed of the skateboard and displayed it to the rider. The speedometer drew a consistent low stream of power, similar to the series of LEDs. Unlike the LEDs, however, the speedometer was constantly on as long as the board was turned on and could not be turned on or off through the controller.

The distribution of power from the battery to these various features was crucial to the overall operation of the Soareboard. The use of parallel connections ensured that each feature drew power independently of the others, allowing them to function simultaneously without any loss of power or efficiency. The controller served as the intermediary between the user and the various features of the skateboard, allowing for precise and intuitive control over the operation of the board.

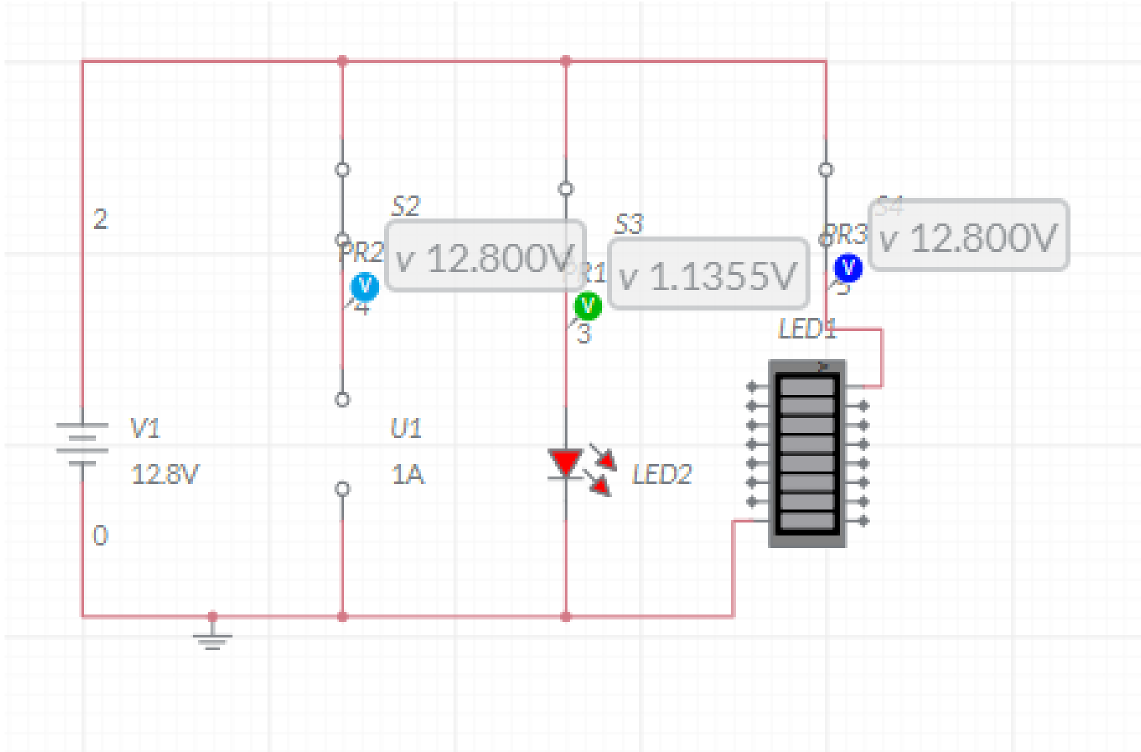


*Figure 40: Second Subsystem Simulation*

To demonstrate its potential use, the second subsystem was created and simulated in Multisim. It was designed to show the power distribution among the second main subsystem of the Soareboard. Power would be stored within the battery to be distributed among the major components of the Soareboard as indicated. The power distribution was indicated through switches. When a switch was activated, power flowed from the battery to the given component. Once the power was shared, the component had a voltage output of 12.8, matching the battery source. Each component was capable of running at the given voltage. Notably, each of the components had a passive voltage that occurred when not charged by the battery. The difference was a significant amount of voltage, with the passive voltage not being enough to power each component, while the active voltage was as shown with the LED.

### 5.4 Third Subsystem

*Figure 41: Third Subsystem*

The third and final major subsystem represented the controller and how it interacted with the battery through the MCU. The controller was created with analog controls that directed the board. There were a few major components that were controlled as directed by the controller, including the motor and the LEDs. The controller was connected to the battery and the other subsystems through a wireless connection, with options available such as Bluetooth. This connection was established by an MCU, where the logic was implemented through coding or an embedded system design. The device could be programmed with specific logic, allowing it to act as a small computer and perform the necessary functions.

The controller subsystem of Soareboard played a crucial role in directing the board's movement and controlling its various features. It was designed with analog controls that allowed the user to direct the board's movements, adjust the speed, and turn the board on and off. The controller was connected to the other subsystems of the board through a wireless connection, typically established using Bluetooth technology.

The wireless connection between the controller and the board was enabled through an MCU, which acted as a small computer to interpret the user's commands and control the flow of power to the various components. The MCU was programmed with specific logic, allowing it to interpret the user's commands and send signals to the relevant subsystems of the board.

The programming of the MCU for the Soareboard could vary depending on the specific design. One common approach was an embedded system design, which involved creating a specialized computer system specifically designed to perform certain functions. This method involved programming the system at a low level, using machine code or assembly language, to optimize performance and reduce the hardware required.

Another approach to programming the MCU was through coding. This method involved writing software code in a high-level language such as C++ or Python, which was then compiled into machine code that could be executed by the MCU. This approach offered more flexibility and ease of modification compared to an embedded system design but might require additional hardware to execute the necessary functions.

Regardless of the chosen method, the programming of the MCU was a critical component of the Soareboard's operation. The logic had to be designed to control the flow of power to the various components, interpret the user's commands accurately, and ensure the board operated safely and efficiently. Regular updates and optimization of the MCU's programming were important to maintain the board's peak performance.

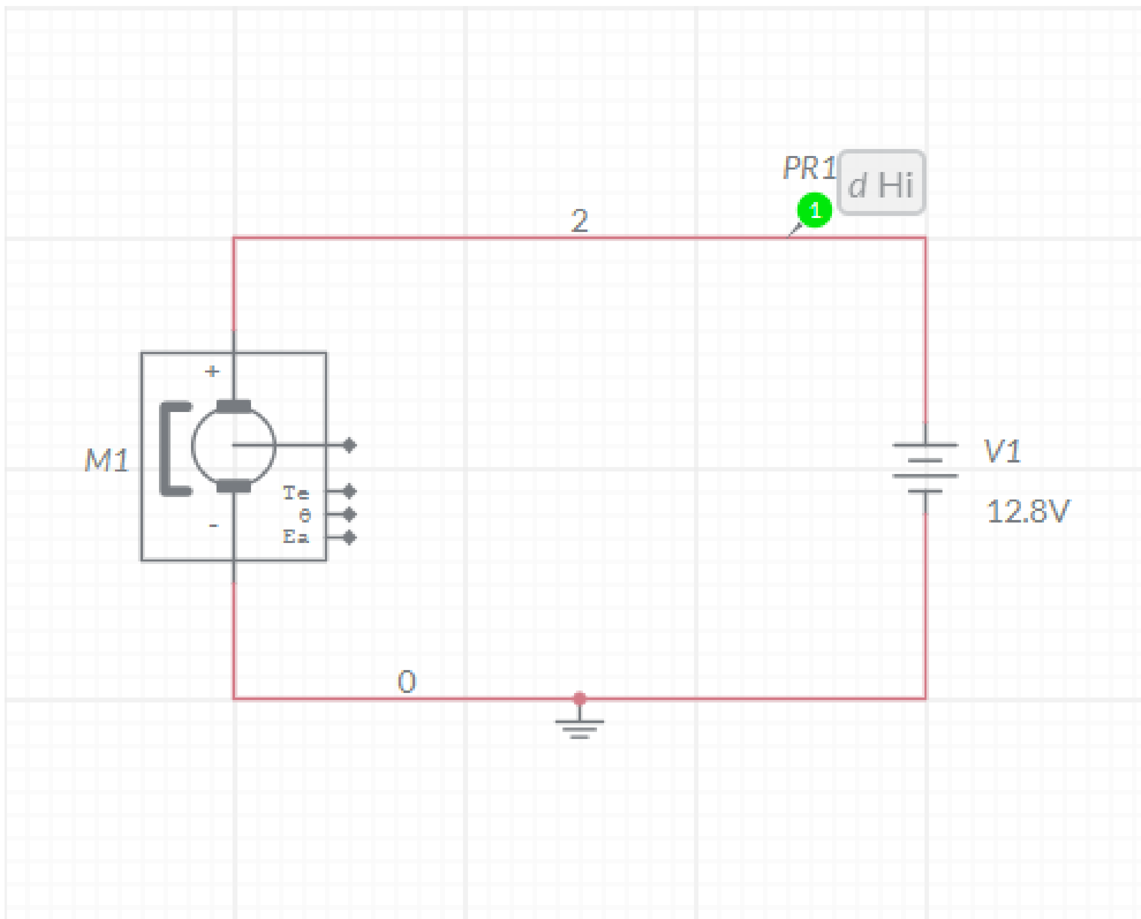


*Figure 42: Third Subsystem Simulation*

In the image displayed above, we can observe the third subsystem, which has been recreated in multisim. A notable difference between the circuit created for the third subsystem and the circuits created for the first and second subsystems is that the first two were physical circuits whose functionality could be demonstrated through voltage or current transfer. However, the third subsystem is a non-physical connection that is typically made through Bluetooth or other wireless communication methods. In this instance, the Arduino Uno is the controller that can be programmed through a computer to ensure that it carries out its intended function. The overall wireless connection is depicted in the multisim simulation, where the high digital signal indicator denotes that the controller has successfully connected to the battery. The third subsystem is crucial in determining the logic of the previous two subsystems, thereby ensuring that the entire system functions seamlessly.

### 5.5 Hardware Construction Plan

The construction of the Soareboard involved a comprehensive plan that included all of its components and features. Some of these features could be added as detachable accessories, while others could be integrated directly into the board to enhance its aesthetics and functionality. One such feature that could be built into the board was the solar cells, which were positioned on the top of the board where the rider stood. To provide a seamless and integrated experience, it was preferred that the solar cells be built into the board itself. This not only gave the board a more streamlined look but also ensured that the solar cells were protected from damage during use.

Similarly, the speedometer could also be integrated into the board, as it was positioned on the top of the board where the rider could easily view it. Building the speedometer into the board gave it a more cohesive look and made it more appealing to users. However, as the speedometer was not located in a critical position like the solar cells, it could be built into the board or attached to it using an adhesive.

The battery was a crucial component of the Soareboard as it powered the motor and other electrical components. Therefore, it was essential to ensure that it was securely fastened and positioned in a way that provided optimal connectivity with all the other components. The placement of the battery at the center of the board ensured that the weight was distributed evenly, which was crucial for stability and maneuverability.

To attach the battery to the board, there were a few options available. One option was to build the battery directly into the board by cutting a hole in the center and placing the battery inside. This method ensured that the battery was tightly secured and did not move around during use. Additionally, building the battery into the board provided a sleek and streamlined appearance, making the board more visually appealing.

Another option was to attach the battery to the board using an adhesive. This method was less invasive than building the battery into the board, and it allowed for easy removal and replacement if necessary. The adhesive used had to be strong enough to hold the weight of the battery and withstand the vibrations and movements that occurred during use.

Regardless of the method chosen, it was important to ensure that the battery was securely fastened to the board and that all electrical connections were properly made. A loose battery or poor connections could lead to malfunctioning or even dangerous situations, which was why it was crucial to take care when installing the battery on the Soareboard.

The battery, and most other components, were put onto the board with industrial strength velcro strips.

The motor, another essential component, was placed on the back axle of the board and directly connected to the battery. The LEDs, which added to the aesthetic appeal of the board and for safety, were connected to the battery and placed around the outside parameter of the board. They could also be attached to the board using an adhesive to ensure they were securely fastened. By incorporating all of these components into the design of the board, the Soareboard was not only aesthetically pleasing but also highly functional and efficient.

**5.6 Software Design**

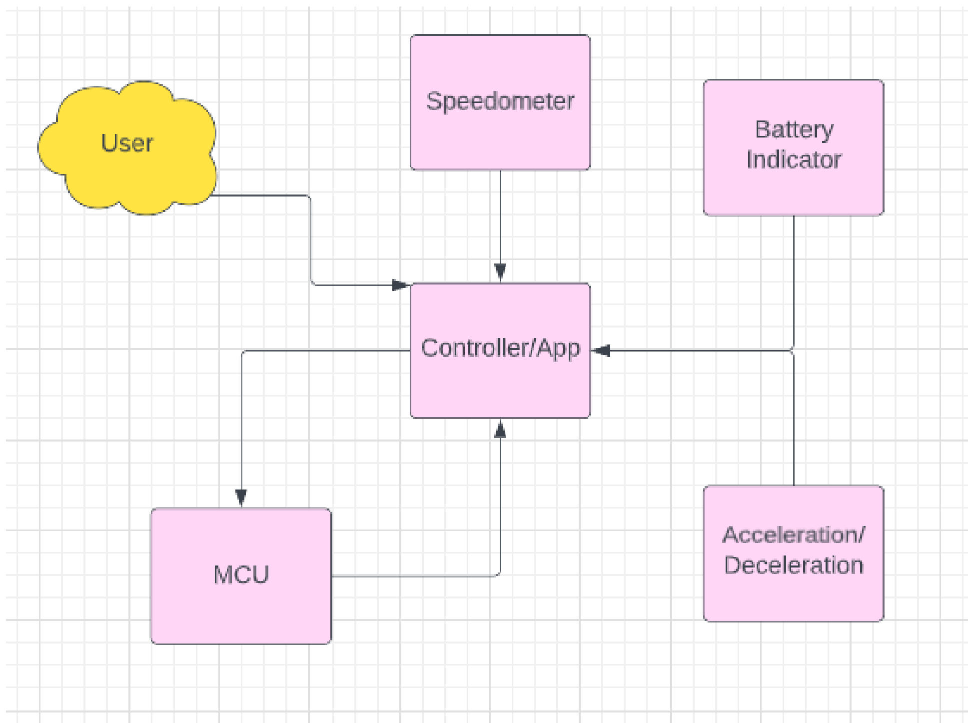


*Figure 43: Software Block Diagram*

The software block diagram was an important step for our team in planning the development of the app that will be used to control the electric skateboard. It helped us identify the key features that we needed to incorporate in the app to make it effective and user-friendly. As shown in Figure 12, we have identified three main features that will be available to the user.

The first feature is the speed control, which will allow the rider to increase or decrease the speed of the board as needed. This is an essential feature for maintaining control and staying safe while riding.

The second feature is the battery indicator, which is crucial for ensuring that the user is aware of how much battery life is remaining and when it is time to recharge the board. This will help the user avoid running out of battery while riding, which can be dangerous and inconvenient.

The third and final feature is the speedometer, which will display the current speed of the board. This will allow the user to monitor their speed and ensure that they are riding at a safe and appropriate speed.

One of the primary objectives of the app is to make it accessible and convenient for all users. Since most people carry their phones with them at all times, the app will be easily accessible and there will be no need to worry about carrying an additional controller or worrying about its battery life.

Overall, the software block diagram has been instrumental in helping us plan the development of the app for the electric skateboard, and we are excited to continue building out the features to make it an effective and user-friendly tool for riders.

For the second term of this project, the team ended up delivering reduced functionality due to two main reasons: one being a time constraint and the other being functionality. The battery will always be connected to the MPPT and the MPPT to the solar cells, which means that the battery will always be charged by the solar cells that are connected in parallel, so there is really no need to display the battery percentage of the app since there will not be a time when the battery will be running low. Another button that was taken away was the cruise speed one. There is really no need for this button since the speed stays constant as long as the user does not click the increase or decrease button. Finally, the last button that was not included at all was the speedometer; this was due to a time constraint.

### 5.6.1 App Design

When thinking about how to give the user the ability to control the Soareboard, we came up with two different approaches, the first being a controller and the other being an app. Controllers are really the way to go now, but since we are working on a renewable energy prototype, we thought it was better to just use the battery of one of the devices that humans use the most, phones.

While designing the layout of the app, a few concerns were brought to our attention. Since it will be controlling the speed, we decided that the increase and decrease should not be together or close to each other and should be labeled with different colors. We want to avoid confusion for the user as much as possible. Instead of putting them together, we have created a "Set Speed" button in the middle of them, so in case the traveler gets confused or clicks on the wrong spot, it will just set the specific speed that the board is traveling at that specific time. This velocity can always be modified. No stop button has been implemented since it can be really harmful to the user to suddenly stop.

Moreover, to give the board a styling factor, we will be setting up LED lights that will be attached to the border of the board, facing down, so they will basically illuminate the street or surface where the board is traveling. The user will also be able to control the color of the LED lights with the app; that way, a specific color will be chosen and later displayed while traveling. Besides the styling factor, it will also be a safety plus since it will help the user navigate through the dark and also let other people in the same environment know that they are coming through. Accordingly, the LED lights will only be modified at the time of pairing the board; no configuration will be later accessed since we wanted to keep all the speed factors together to avoid confusion and interruptions in emergencies.

On Figure 4, the layout of the app version is as follows: The user will start by opening the application, which will display the homepage where the user will be able to turn on the board, establish a connection to the board via Bluetooth, and set up the LED light's color. At first, the user will need to turn on the board to set up the connection with the board so later on the LED lights can be set up. If the user wishes not to connect the board or something happens while pairing up the device, then the process should be restarted by closing the app and trying it all over again. If the connection is successful, it will prompt the user with the landing page screen, where the velocity can be set, modified, and displayed, as well as keep track of what percentage of the battery is available. If the user has reached a certain destination and is done using the board, then the turn-off button is also available and ready to be clicked to turn the whole system down to save energy for later.

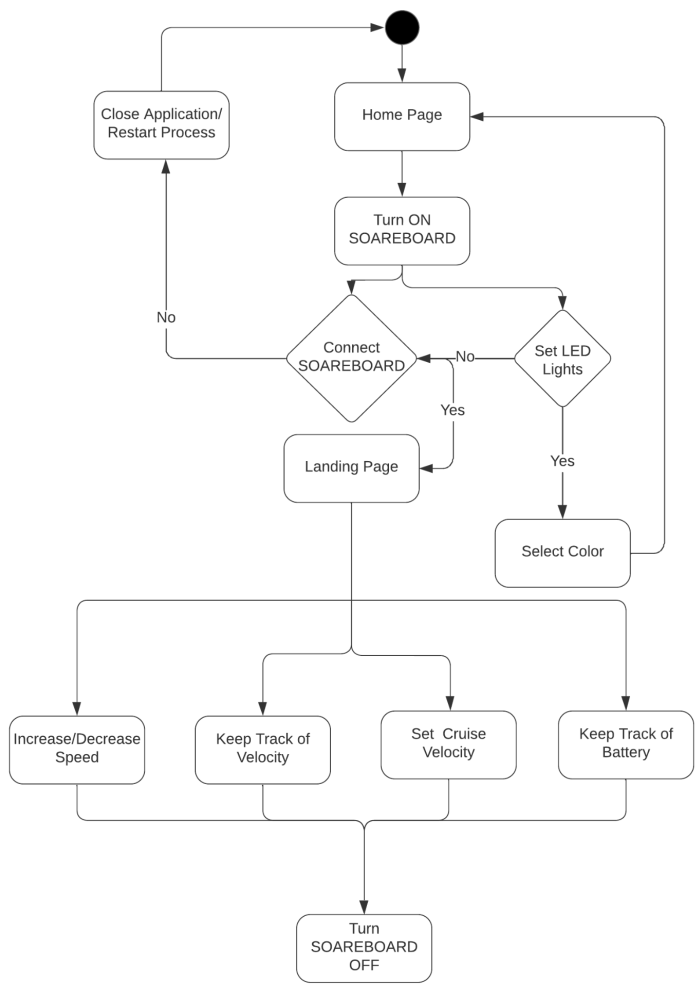


*Figure 44: Activity Diagram*

Once the user downloads the app, it will prompt the first window on the left, where it introduces the user to the name of the board, Soareboard, and later on there are three buttons, one to turn the board ON, one to connect the board and the last one to set up the LED lights. Is it necessary to turn on the board before trying to connect the board? Yes, this connection between the phone and the board is made possible by the microcontroller that enables a Bluetooth signal only when the board is on. This pairing will be made with the same steps as pairing up a normal Bluetooth device, through settings and Bluetooth configuration. Once the device pops up, select it, and everything is ready to go. It is really important to keep the board connected with the microcontroller in case of any emergency.

For this whole design, we utilized Figma. Figma is a very helpful tool for the development of apps and websites. It is an interface design tool that enables developers to design how the interface will look, giving them a rough idea before coding anything. Clearly, this is an application that saves a lot of development time since developers start coding once they are done or about to be done with the design of the interface, so the process is really straight-forward.

Figure 40 shows, where a lot of colors are available. Once the color has been selected, the user can proceed and click the "Ready" button to watch it be displayed on the board.

After the board is connected, it will display the window on the right (Figure 40). It will prompt the user at first with the current velocity that the board is traveling at to make consciousness and make sure that the user travels at its own risk. After that, the control of the velocity comes into play to give the ability to control the speed by increasing, decreasing, and setting a cruise velocity. What is cruise velocity? It is a determined speed that will remain constant unless the user presses the up or down arrow, which will result in changing the speed accordingly. It will increase the speed by 1mph and decrease the speed by the same 1mph factor.

The app will also display the battery percentage in real-time for the board, so the user can keep track of how much power is left after each interaction with the board. As a team, we considered that this was one of the most important features that the app should have in order to give the user an idea of how much more power is available for their planned travels and distances. Finally, it will display the OFF button next to it in order to give the user the ability to turn off the board whenever needed and save energy for the next day. If possible, the battery will also display a symbol inside the battery image to show when the battery is charging from the solar light.

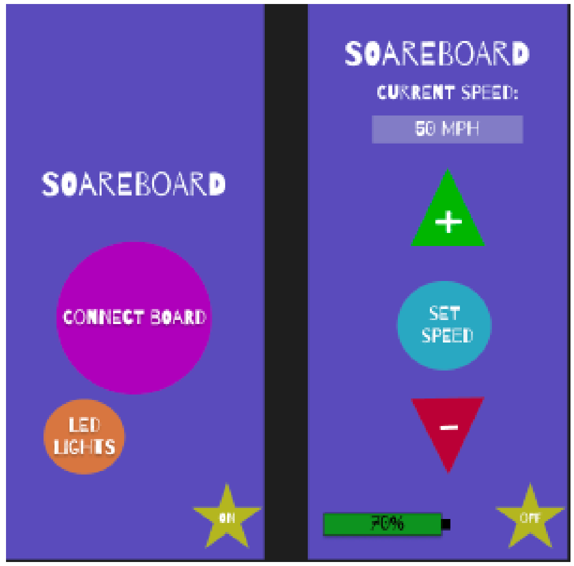


*Figure 45: App Design*

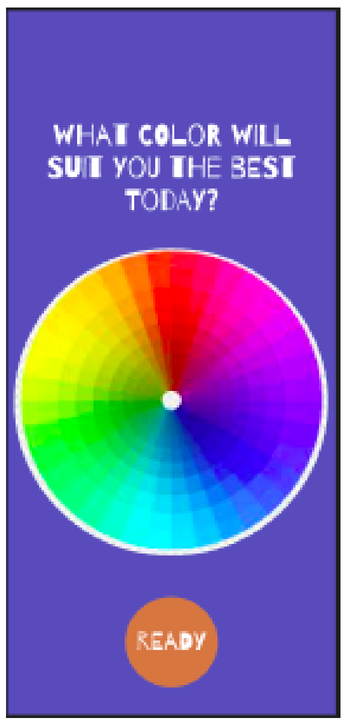


*Figure 46: LED App Design*

The app was developed on Android, which caused the team some problems with Bluetooth permission. Due to facing these specific problems with Android permissions, the team decided to stay with MIT App Inventor to showcase that the specifications were met within the project. Moreover, the team decided to add some other sensors, such as the ultrasonic sensor (SR04) and the Rain Sensor. Having these new sensors on the board enables the team to pair the LED lights with the ultrasonic sensor to track and keep the user away from obstacles that can possibly harm them, as well as make the user aware if there is enough space to go through. Besides, the team also decided to add the LED lights at the bottom of the board, so if the user is in the middle of the night and needs to get somewhere, there is enough light. This is the final design for the app. As shown below, there is a button to connect to the Bluetooth module, which is the board, and after it is connected, it will enable the user to increase and decrease speed in intervals of tens.

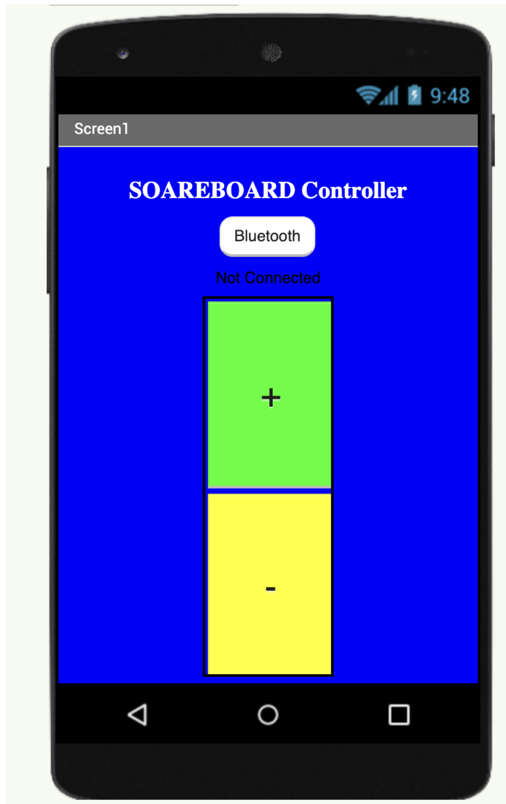


*Figure 47: Updated App Design*

After giving a broad idea of how the app will look and our mental process during its implementation, We have also created a sequence diagram (Figure 15) in order to give a better understanding of the sequence of events that will happen. How the user, the app, and the microcontroller work together, and how the interactions that the user has with the app will affect the microcontroller, as well as what information we will get from it.

As displayed on the diagram, the user will interact with the microcontroller in three instances. The first one is by turning on or off the board. Secondly, when it is pairing up the board through a Bluetooth connection. Finally, when the user has any type of interaction with the velocity, that being incrementing, decreasing, or setting a constant speed.

The Soareboard is designed to provide a safe and user-friendly experience for the rider. One of the ways we achieve this is by implementing real-time monitoring of two important factors: speed and battery percentage. The microcontroller will collect and process data from various sensors, including the motor and the solar battery, to calculate the speed of the board. This information will then be transmitted wirelessly to the application, which will display the speed in real-time.

In addition to the speed, the application will also show the percentage of battery remaining in real time. This feature is critical as it allows the rider to know when the battery is running low, indicating that it is time to charge the board. This way, the rider can avoid getting stranded with a dead battery.

The ability to control the speed of the board is also an essential feature that ensures the safety of the rider. With this feature, the rider can adjust the velocity to their comfort level, thus minimizing the risk of accidents. However, we must note that the rider controls the velocity at their own risk, and they must take responsibility for any consequences that may arise.

Finally, to ensure the longevity of the battery and the board's overall safety, we have implemented an automatic shut-off feature. This feature will turn off the board if it has been idle for a certain amount of time, preventing any damage or risk of overheating. The rider can also choose to turn off the board manually through the application once they are done using it for the day.

By providing real-time information and user-controlled features, the Soareboard offers a safe and customizable experience for riders. The implementation of automatic shut-off and other safety features ensures the longevity of the board, allowing the rider to enjoy it for years to come.

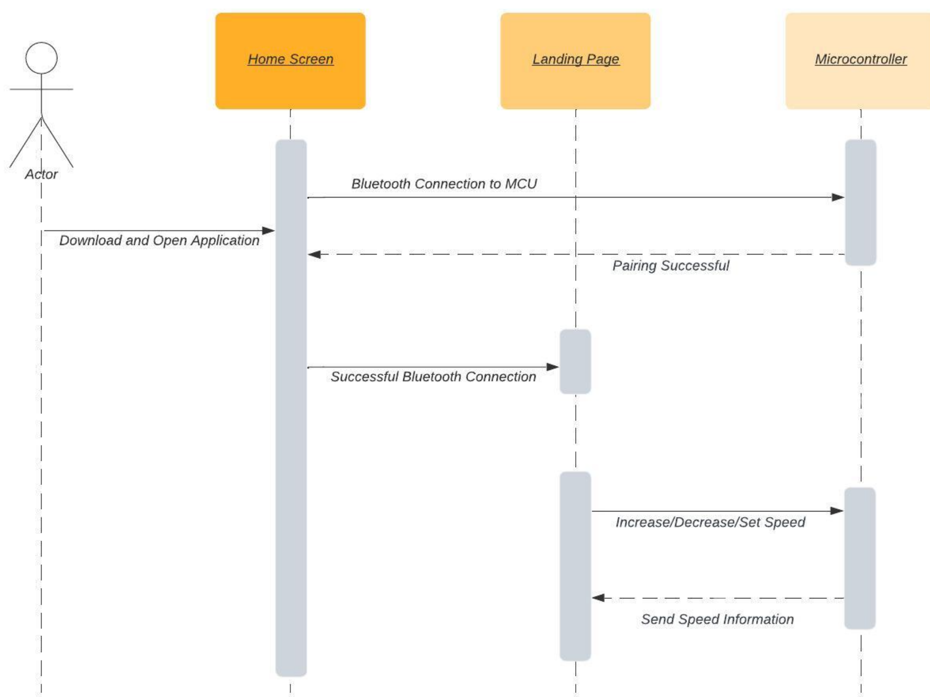


*Figure 48: Sequence Diagram*

After knowing how the app will work with the representation of each of the graphs, another important factor, and is what IDEs will be used and the difference between iOS and Android.

On one hand, iOS is suggested to work with mainly four IDEs, starting with XCode . In this IDE, only two languages are existent, Swift and Objective-C. Although there is no knowledge of either of these two languages among the teammates, the suggested language to be learned is Swift. The second app is called Appcode. This IDE works with C++, C and Objective C. The third one is Sublime Text 3, this one also supports Swift language. Finally, the last one is called CodeRunner 2. This IDE is very versatile and can support up to 23 languages. Having all of these options, we thought that the best one to go with is XCode since it is the best IDE for iOS app development, and has automatic features for Swift. In addition, no payment is required for Apple users to download this IDE or even use language selected, but since it is only for apple users, a Mac will be needed in order to start with the development. Two of the members in the team have Mac computers, so there is no issue with that. Besides, there is a fee that has to be paid in order to upload the app to the App Store, it is a $99 one-time payment.

On the other hand, Android relies on many IDEs. Among them, Android Studio works with Java, PhoneGap uses mainly HTML, CSS and JavaScript, Eclipse uses Java and Visual Studio that uses C#.  Since one of the team members is related and has experience with Java for the creation of websites, we have chosen to go with this one. Android Studio has a lot of advantages, between them teamwork, perfectly fitting to android devices, pre-built templates and Robust analytics. These advantages caught our attention since we will be working all together in the development of the app, and everyone should be aware of what changes have been made, and at the same push the changes they worked on. Besides, having some Pre-built templates also helps us since time is always a constraint and we can take an existing template and just modify it. Moreover, robust analytics are always good to have as it gives us the advantage to analyze the data from the user or users that have downloaded our app and improve the service, or also be able to give security to our app. In contrast with the App Store, Google Play Store has a one-time fee of $25 which is a more accessible price for us as students, since we are the ones supporting this project economically, and no there is no a sponsor.

After having the advantages and disadvantages in mind, and knowing what can possibly be done with each different IDE, we find out that Expo, a framework that extends React Native, can develop iOS and Android apps using a codebase written in JavaScript. Besides, it has a library that functionally works as bootstrap, making predetermined codes that will be useful to implement the different features to the app, as the battery,

This app will not just make the development easier, but it will also reduce the amount of time that it will take to develop the app. Since all of the members of the team do not have a clear understanding of how to use React, Besides, it has a built-in simulator where it will be easy to preview the changes made to the app in seconds. After creating the project in Expo, we can easily eject the project into either Xcode for iOS development or Android Studio for Android development.

For the app development part, it was developed on Expo at first, and then the project was ejected into React-native. So the basics were done with Expo, but for the bluetooth feature React-native framework in order to enable the wireless connection between the board and the phone. Due to some issues that were faced, the development of the app after the ejection part was not completed.

### 5.6.2 Microcontroller Programming

The key part of this project is the microcontroller, in this case, the Arduino. The Arduino will be in charge of enabling a connection between the board and the user. In order to make this connection possible, this code will be written in the Arduino programming language, which is mainly a set of C and C++ functions. Moreover, after watching the many options that there are for Arduino boards, in this case Arduino UNO Wifi Rev5 board. As a result, the board can now be controlled using the user's phone, just as a controller will work.

In short, there will be about five functions that will be created for the MCU to either send information back to the app or control the skateboard's velocity, state, and LED lights. To start with the functions, the first two are for increasing and decreasing the speed. Next, there will be one for a cruise velocity that will remain constant as long as the user wants. Moreover, the fourth and fifth ones will be about retrieving the speed and battery information from the MCU in order to display it on the landing page. Besides, we will have one more for the LED light configuration. This function will take the color as a hex value, so it can later be translated to the MCU and displayed. Additionally, there will be a function to connect the board through Bluetooth, and the last function will control the state of the board, whether it is on or off.

The process of developing an app for the Soareboard involves understanding the different functions that the app and the MCU will perform. Figure 43 provides a brainstorming session that helps to identify the various functions that the app needs to perform and the corresponding functions that the MCU needs to carry out. This brainstorming session is crucial in understanding the relationships between the app and the MCU, which is then used to develop the sequence diagram shown in Figure 43.

The sequence diagram shown in Figure 43 is an essential tool for understanding how the MCU and the app communicate with each other and perform their respective functions. To ensure a clear understanding of the different functions, the diagram uses color coding to represent the functions of the MCU and the app. The baby blue boxes represent the functions of the MCU, which include the initialization of the board and the motor, the control of the motor speed, and the monitoring of the battery level. On the other hand, the baby yellow boxes represent the functions of the app, which include the connection to the MCU, the display of the battery level, and the control of the motor speed.

By clearly identifying the functions of the app and the MCU, the development of the app can be optimized, and the MCU can be set up to perform the necessary functions. The sequence diagram helps the development team to understand the flow of information between the MCU and the app and to identify any potential problems that may arise during the communication process. This can help to ensure that the app is developed in a way that is compatible with the MCU and that it can effectively control the motor speed and monitor the battery level.

By using the brainstorming session in Figure 43 and the sequence diagram in Figure 18, developers can better understand the relationship between the app and the MCU. This understanding can be used to create an app that functions seamlessly with the Soareboard and ensures that the MCU is configured to perform the necessary functions. In summary, a clear understanding of the functions of the app and the MCU is crucial for the successful development of the Scoreboard app.

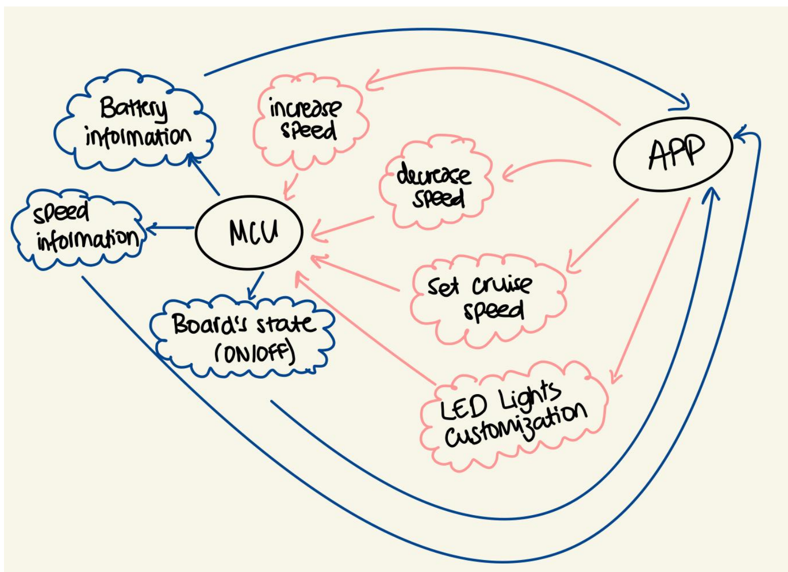

*Figure 49: Brainstorm App and MCU Interaction*

Having this brainstorm in mind, the team utilized the ATmega328p that is assembled in the Arduino UNO Board. That way, the set-up was a lot easier, and the pins that were used for the motor driver and the ultrasonic sensor can still work with the MCU since it has the same digital and analog pins. To make this part possible, the team burned the bootloader on the MCU with the help of a crystal and two capacitors. The crystal and the two capacitors are helpful to make the download of the code into the MCU smooth and make sure that everything works accordingly. If we don't have these components along with the MCU, some issues will be encountered, making it impossible to download the code.

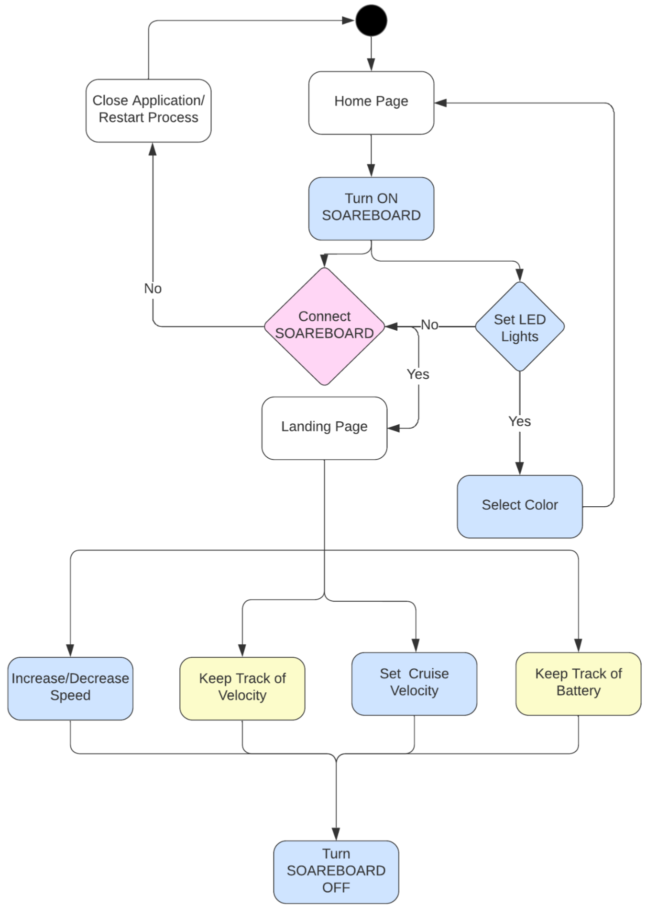


*Figure 50: App and MCU Interaction Activity Diagram*

Due to time constraints, this is the last version of the software flowchart. The team includes the rain sensor as well as the ultrasonic sensor which controls the LEDs, just to make sure that the user is aware if something is close to the board, and at the same time to avoid it.

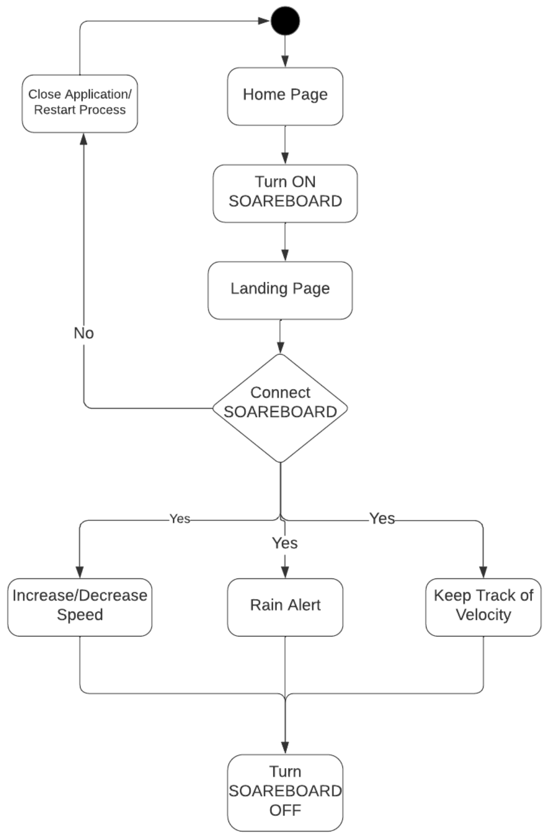


*Figure 51: Updated App and MCU Interaction Activity Diagram*

## 6.0 Project Prototype Construction

Designing a printed circuit board (PCB) is a crucial aspect of the project as it enables us to create a functional prototype that we can test and improve upon. In this section, we will provide an overview of the process involved in designing the PCB, highlighting the key steps and considerations. The ability to conduct tests on the prototype is essential in helping us to improve the functionality of the electric skateboard, ensuring that we deliver a top-quality product that meets and exceeds our expectations.

There are a large amount of facilities and equipment that can be used to create the PCB that has been designed, through the use of software such as EAGLE. One significant manufacturer that could be used to create the PCB is WELL PCB. The overall design can be outsourced to this company, and they will manufacture it for us, delivering us in return a finished and fully operational Circuit Board.

Once the Printed Circuit Board has been designed, then it will be outsourced to an outside company that specializes in PCB construction. A prototype of our PCB design will be constructed. Once this prototype is received, then it will be tested. The design team will have to determine whether this design will be significant, or it will have to be redone. If it is determined that the PCB design, then an overview will have to be conducted to improve the overall quality of this design.

### 6.1 Printed Circuit Board

This section pertains to the process of creating the first prototype of the Soareboard, which is essential for testing its functionality in real-life scenarios rather than just simulations. To design the printed circuit board (PCB) for the Soareboard, our group has decided to use AutoCad Eagle. This software is ideal for our project since all four members of our group have prior experience using it, and it is available on both our personal computers and the engineering facility's computers.

AutoCad Eagle is an electronic design automation tool that allows its users to create PCBs with different schematics and board layouts. Our group plans to design the motor controller for the Soareboard using Eagle's extensive library of parts. We will conduct research to ensure that the software has the necessary components required to design our motor controller. If required, we will add more components to the library to meet our needs.

We appreciate that our university provides us with AutoCad Eagle, making it accessible for students to create schematics for various projects. It offers several benefits, including an electric rule check feature that helps to identify any potential errors in the project. Although Eagle has a vast selection of parts, we acknowledge that we need to do more research to ensure that we are creating a PCB that meets the requirements of a motor controller.

To design the Soareboard's motor controller PCB using AutoCad Eagle, our group will utilize tutorials and other resources available on Google to help us create a functional prototype. We plan to keep the design simple, considering that motor controller PCBs can be complex. By following best practices and utilizing available resources, we are confident in our ability to design a functional motor controller PCB that will help bring the Soareboard to life.

The process of designing the printed circuit board (PCB) for the Soareboard is crucial, and understanding this process is essential. We will begin by creating a new file in AutoCad Eagle and adding in any necessary components that are not already included in the software's library by importing them from other sources available online.

One of the crucial decisions we need to make during the design process is choosing whether to use through-hole or surface mount components. For the prototype design, we plan to use through-hole components since they are easier to work with and facilitate easier testing of the board's functionality. However, for the final design, we believe that surface mount components will be more appropriate since they occupy less space and are more cost-effective. This decision will ensure that the final design is efficient and optimized for mass production.

After importing all the necessary components into Eagle, we will wire the board, ensuring that all components are properly connected. If we have separate segments, we will also connect them appropriately. The auto-wire function on Eagle will be beneficial in ensuring that the wiring is organized and aesthetically pleasing. We will also ensure that each segment is appropriately labeled, and each component is assigned its appropriate value.

Once we complete the design process, we will use Eagle's component links to find the components required to assemble the board in person. However, if the required components are not available through the Eagle links, we will source them from other reliable sources. We will compile a list of components needed to purchase and assemble the board, ensuring that all components are available and of high quality.

Once we have completed the schematic design for the PCB, the next crucial step is to create a physical layout of the board. We will use the available tools in Eagle to achieve this. Eagle provides a space for the board where we can arrange the components in the desired configuration. This space is typically proportional to the size of the board and offers an accurate representation of the final product.

By using Eagle's tools, we can determine the optimal positioning of the components to achieve the best possible results from our original schematic design. The tool allows us to position and connect the components precisely, while ensuring that there are no overlaps or collisions between the components. Once we have all the parts placed in their correct positions, we will finalize the wiring of the board using the software's automated routing capabilities.

After completing the physical layout of the board, the next step is to manufacture the PCB. When we have a final design for the PCB and all the necessary components have been acquired, we will begin the assembly process by soldering all of our components onto the board. This process requires attention to detail and precision to ensure that all components are correctly placed and connected.

Once all the components have been assembled and soldered onto the PCB, we will perform testing to ensure that the board is functioning correctly. We will use multimeters and other appropriate testing tools to ensure that the board is working correctly and that there are no issues with the design.

In conclusion, the process of creating a functional PCB involves many steps, including designing a schematic, creating a physical layout, and assembling the components. By using tools like Eagle, we can simplify the process and ensure that we achieve the best possible results. Once we have completed the assembly, testing, and validation of the board, we can be confident in the functionality and reliability of our design.

### 6.1.1 PCB Final Design

The journey towards the final PCB design was marked by perseverance and dedication as the group navigated through a series of trial and error processes. Over the course of development, they explored three distinct designs, investing considerable time and effort in honing their skills and expertise. The path to the ultimate design was both challenging and rewarding, ultimately leading to an optimized solution.

The final PCB design was crafted with meticulous consideration, taking into account specific constraints and requirements. A crucial factor in the design was the realization that the Bluetooth module was not viable for direct integration into the PCB. As a result, the team ingeniously devised an alternative approach, opting to utilize a breadboard to enable Bluetooth functionality. This decision showcased their adaptability and problem-solving acumen, ensuring that the board's communication capabilities remained intact despite the module's limitations.

Emphasizing efficiency and practicality, the final PCB design expertly incorporated all the necessary components, optimizing their placement to ensure a compact yet functional layout. This meticulous arrangement allowed for seamless interaction among the various components, enhancing the board's overall performance and functionality.

Furthermore, the PCB design featured strategically placed holes, facilitating the soldering process for external components. This foresight demonstrated the team's meticulous attention to detail, ensuring that the board could easily accommodate additional elements and enhancements in the future, if necessary.

During the final presentation and demonstration, the team proudly showcased their well-crafted design. The audience witnessed not only the PCB's ingenuity but also the seamless integration of the Bluetooth functionality using the breadboard. This successful amalgamation of components and technologies exemplified the team's innovative spirit and their ability to adapt and overcome challenges.

In conclusion, the group's journey to the final PCB design exemplified their commitment and resilience in the face of obstacles. The iterative process of trial and error culminated in an efficient and functional design, strategically incorporating all necessary components and providing room for further expansion. Through their resourcefulness and creative problem-solving, the team delivered a remarkable solution, leaving a lasting impression during their final presentation and demo.

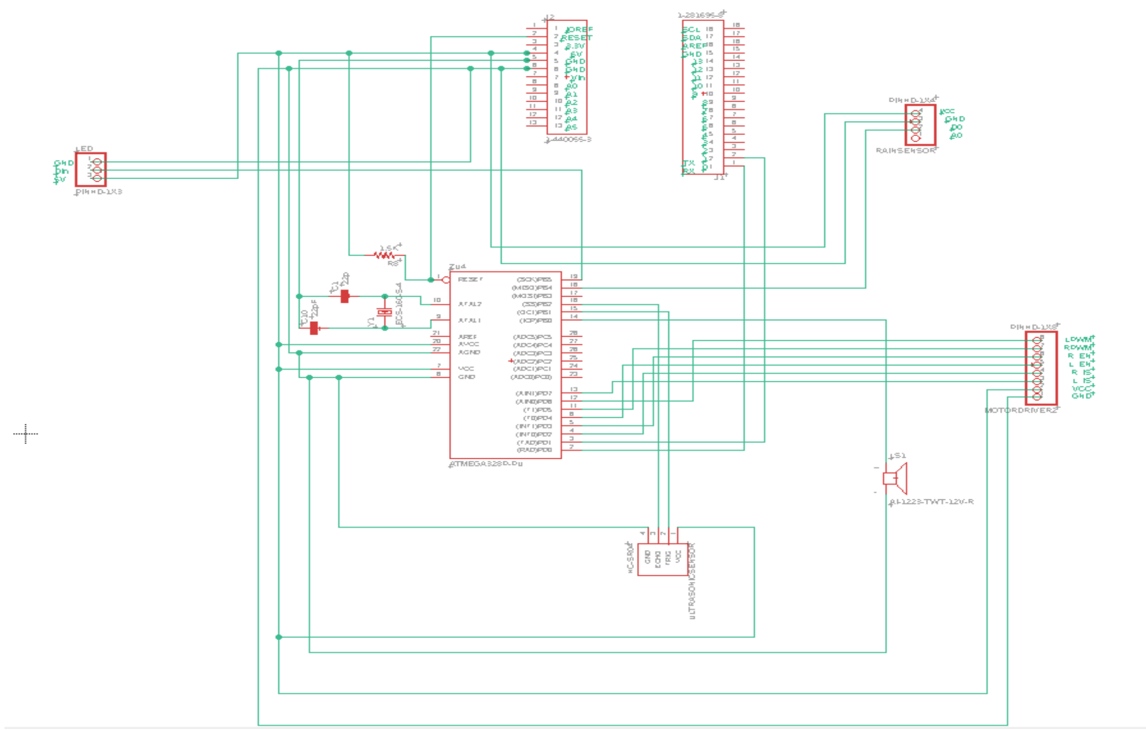

*Figure 52: Final PCB Schematic*

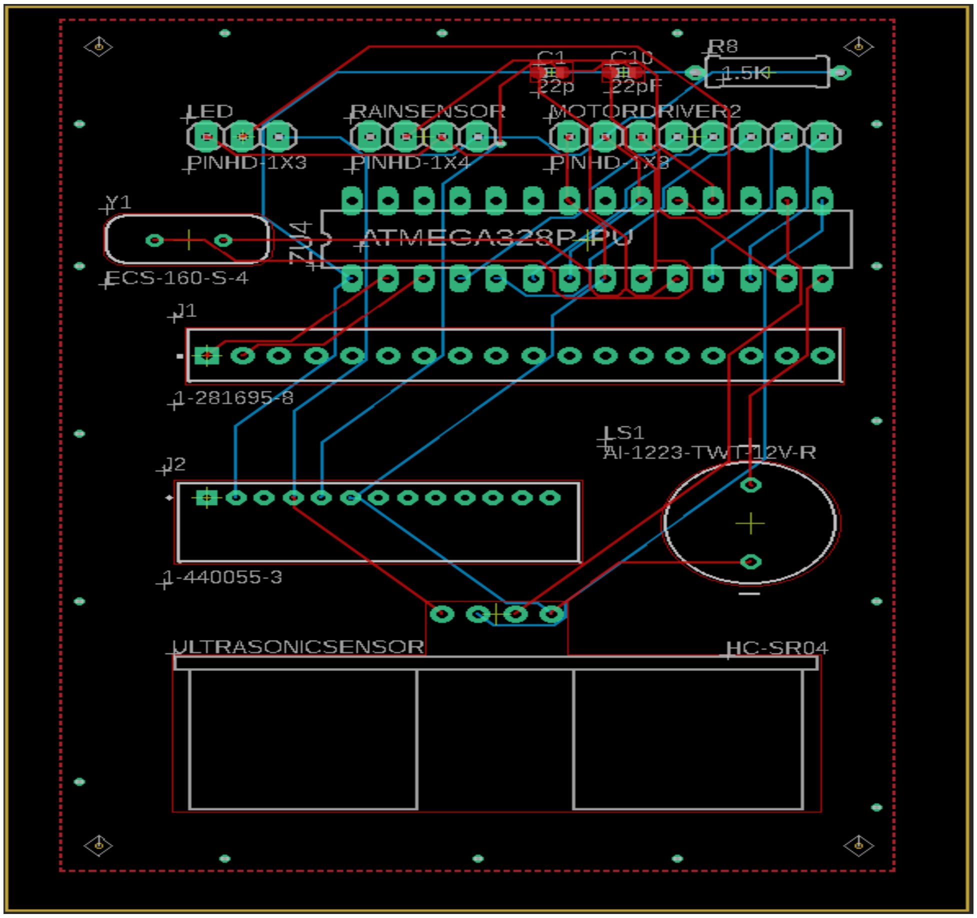


*Figure 53: Final PCB*

## 6.2 Facilities and Equipment

Our school, the University of Central Florida, has a great college of engineering and computer science (CECS). The CECS provides engineering students with a lot of different facilities and equipment that we are able to use at our disposal, and it is a great resource for building our project and conducting testing on it as well. There are two open areas for students to use to do different projects at: the senior design lab and the TI lab. Both of these places are located in the engineering buildings on UCF's campus.

Senior Design Lab:

This lab is only open to students that are in the electrical and computer engineering (ECE) senior design class. This room will only open with your student ID, and you have to be granted access to enter. The fact that this lab is by key card access only makes it a quiet and relatively empty place to work on our project, which is ideal. We will be doing most of our in person work in this lab. It comes with oscilloscopes, multimeters, power generators, computers, breadboards, and a lot of components that are necessary to do our project. Most of the project was created inside of the senior design lab.

TI Lab:

This lab is open to many students, and therefore is usually quite busy. This lab has soldering irons, which is something the senior design lab does not always have the ability to supply. Since there are soldering irons in this lab, our group will be using it for the soldering parts of our project, but otherwise we will spend more time in the senior design lab. If we are already in this lab though, we will inevitably end up doing some hardware testing in this lab.

In order to complete our electric skateboard project, there are several necessary supplies that we need to have on hand. These include a multimeter, a power supply, and a soldering iron. The multimeter is a crucial piece of equipment that can be found in both the senior design lab and the TI lab. With the multimeter, we will be able to properly test our prototype, ensuring that all of our supplies are working as they should and that the prototype is functioning correctly. It will help us identify any issues that need to be addressed and ensure that the final product is of high quality.

Fortunately, every person in our group already knows how to use a multimeter, which saves us a significant amount of time when it comes to testing. Because no one needs to spend time learning how to use this equipment, anyone in the group can easily step in and perform necessary testing at any time. This helps us to make the most efficient use of our time and ensures that we are able to complete the project as quickly and accurately as possible.

In addition to the multimeter, we also need a DC power supply. This equipment is especially important since we are not sure when our battery will arrive. The power supply will enable us to supply the necessary voltages that we would eventually get from our battery. Everyone in our group is familiar with how to use a DC power supply from our various classes with labs that use it. Having a good understanding of how this equipment works will enable us to efficiently use it in the project and avoid wasting any time.

Lastly, the soldering iron is another essential piece of equipment. It will allow us to make the boards necessary to be able to test our prototype. Soldering is a key part of creating a circuit board and requires a steady hand and careful attention to detail. Luckily, at least one person in our group has prior experience with soldering, which means we can save time by not having to spend extra time teaching everyone how to solder. This leaves us with more time to focus on the design of the project and ensures that we can complete the project as efficiently as possible.

**6.3 Vendors and Pricing**

Our team plans to start testing our prototype PCB using breadboards, but we aim to eventually have our final PCB manufactured by a professional company. After researching and exploring various PCB manufacturers, one company stood out to us as the best fit for our project: JLCPCB. Their website offers user-friendly navigation and a diverse range of manufacturing options to cater to our specific needs. One of the key benefits of JLCPCB is its affordability. Their pricing is relatively low compared to other

PCB manufacturers, and they provide a range of options for design features, colors, dimensions, and more.

JLCPCB also allows us to select the lowest number of panels for our PCBs, which is five. This means that each member of our group can have their own panel to work with. Additionally, JLCPCB is currently offering a sale for standard PCBs, making the prices even more affordable than we initially anticipated. We have also noticed that JLCPCB offers several different pricing options for PCB manufacturing, so we will be able to select the option that is most cost-effective for us.

Two Layer:

For a standard 2 layer, 1x1 inch PCB it is $2.00. This comes with 5 panels and will be built in 2-3 days. There is an additional shipping fee of $6.17, and it would arrive in 8-14 business days of ordering. This only has 1 design of the PCB. The total will come out to be $8.17. For a standard 2 layer 2x2 inch PCB it is also $2.00, plus the additional shipping fee.

For a standard 2 layer 1x1 inch PCB with two different designs is $8.40. This also comes with 5 panels and has the same shipping fee of $6.17. This has the same build time and shipping time as well. The total of this will come out to be $14.57. For a standard 2 layer 2x2 inch PCB with 2 designs it is $9.20, plus the additional shipping fee.

For a standard 2 layer 1x1 inch PCB with 4 different designs it is $16.40. This also comes with 5 panels and has the same shipping fee of $6.17. It has the same build time and shipping time as the other two. The total comes out to be $22.57. For a standard 2 layer 2x2 inch PCB with 4 designs it is $17.20, plus the additional shipping fee.

Four Layer:

For a standard 4 layer, 1x1 inch PCB it is $2.00. This only comes with 1 design, but also comes with 5 panels. There is an additional shipping fee, which is the same fee above, at $6.17. It will take the same amount of time to be made and shipped, and the total will come out to $8.17. For a standard 4 layer 2x2 inch PCB with 1 design it is $2.00, plus the additional shipping fee.

For a standard 4 layer 1x1 inch PCB with 2 designs it is $48.40, which is substantially more than the 1 design, but we believe the PCB with 1 design is that cheap because of the special offer the website is giving out now. This comes with the same times and the same shipping fee, to a total of $54.57. For a standard 4 layer 2x2 inch with 2 designs it is $49.40, with the same additional shipping fee.

For a standard 4 layer 1x1 inch PCB with 4 designs it is $78.50, plus the additional shipping fee, bringing it to $84.67. With 2x2 inch it will cost $79.20, plus the additional shipping fee.

There are some specifications for these manufactured PCB boards. All of these are also shown on the website when ordering. These include:

- Base material - FR4 because of the low cost, moisture resistant, and temperature resistant
- Product type - consumer electronics
- Delivery format - panel by customer
- PCB thickness - 1.6mm
- Material type - FR4-Standard TG 135-140
- Surface finish - HALS(with lead)
- Outer copper weight - 1 oz
- Inner copper weight - 0.5 oz
- Via covering - tented
- Min via hole size/diameter - 0.3/0.4 mm
- Flying probe test - fully test

Ultimately, the team went with JLCPCB with a two layer board that is 88.9 mm* 67.3 mm, and the price was really low compared to some other parts of the project.

**6.4 Safety Precautions**

The design and implementation of a project involving electrical components require careful consideration of safety precautions. As our group embarks on this project, we must prioritize the safety of all individuals involved, including ourselves and others who may come into contact with the project.

Working with circuits, voltage, and PCBs involves inherent risks that can lead to potentially harmful outcomes if not handled with care. Therefore, it is crucial to have the necessary equipment and training to ensure that all safety precautions are taken.

To mitigate the risks associated with electrical components, it is recommended to wear appropriate safety gear, such as insulated gloves, safety goggles, and non-conductive footwear. Additionally, we must be cautious when handling electrical components, such as capacitors, resistors, and transistors, to prevent electrical shock or burns.

Furthermore, we must ensure that we follow proper protocols and procedures when working with electrical components, such as disconnecting power sources before working on the circuit, testing circuits with a multimeter, and avoiding contact with live wires.

Our group must prioritize safety by following proper protocols, wearing appropriate safety gear, and ensuring that we have the necessary equipment and training to handle electrical components safely. By doing so, we can prevent potential accidents or injuries and ensure a safe and successful project implementation.

Developing components involving electrical circuits can be hazardous if not handled properly, and it is crucial to prioritize safety precautions. The first step in ensuring safety is to wear appropriate protective gear such as anti-conducting clothing materials, shock-resistant gloves, rubber gloves, rubber soled shoes, and cotton clothes. Additionally, goggles are essential to protect the eyes from possible electrical sparks or debris.

Before working on electrical components, it is necessary to ensure that the power supply is off, and all necessary safety procedures are followed. Using insulated tools, and maintaining a clean and dry work environment are important steps to prevent electrical accidents. It is also important to follow IEEE standards for electrical safety guidelines to ensure that our project meets industry standards.

Maintaining a clean and organized workspace is also essential when working with electrical components. Proper wire placement is necessary to prevent tripping hazards or accidental exposure to live electricity. Similarly, the use of a soldering iron requires an organized workspace to prevent fires and other hazards.

Working with electrical components requires taking all necessary precautions to prevent accidents or injuries. Therefore, our group will prioritize safety by following established safety protocols and wearing appropriate protective gear. By prioritizing safety, we can minimize the risk of harm to ourselves and others around us.

Soldering is an essential skill when it comes to building electronic components, and although it may seem daunting, it is not difficult to learn with proper instruction and the right equipment. However, it is important to be aware of the potential risks involved in soldering. There is a chance of burning oneself or teammates who are in close proximity to the soldering area. Thus, it is essential to wear appropriate protective gear such as heat-resistant gloves, goggles, and a face shield. In addition, it is advisable to wear long sleeve clothing and closed-toe shoes to ensure that no sparks or hot debris come into contact with bare skin.

To prevent inhalation of harmful fumes, we will always make sure to solder in a well-ventilated area. The use of a fire-resistant surface is also a crucial safety measure. Fortunately, the two labs have fire-resistant surfaces that will minimize the risk of fires. We will also make sure to keep any flammable materials away from the soldering iron to further minimize the risk of accidents.

It is essential to handle soldering irons with extreme caution as they can be hazardous if not handled properly. To prevent accidents and ensure safety, our group will always follow established safety protocols and use appropriate protective gear. In the end, prioritizing safety will allow us to successfully solder our electronic components and minimize the risk of harm to ourselves and others around us.

Our group will be using a variety of electrical components and testing equipment for our Soareboard project, so it is crucial that we prioritize safety precautions. Working with electrical current can be hazardous, but using a multimeter will help us ensure that the current is flowing correctly within the circuits. This is particularly important because overheating of the components can cause damage and even lead to a fire hazard. Thus, we will take all necessary precautions to prevent overheating and smoking of the components by monitoring them closely with the multimeter.

In case a component does overheat and starts smoking, our team will immediately stop working with it and handle it with caution. We will make sure to turn off the power supply and provide ample ventilation with cool air around the affected component. It is essential to not touch the component with bare hands, as it may still be hot and cause burns. Instead, we will use proper tools such as heat-resistant gloves to handle the overheated part.

Furthermore, we will ensure that all the testing equipment and tools we use are properly maintained and calibrated. Faulty or damaged equipment can lead to unpredictable outcomes, posing a significant risk to our team's safety. Therefore, we will regularly check and maintain our equipment to ensure that it is working correctly and safely.

As our Soareboard design includes moving parts, we must also consider exterior safety precautions to ensure the safety of the user. The board will have a battery and motor attached to the underside, along with wires that connect various components together. It is important to ensure that these components are placed on the board in an organized manner to minimize the risk of any entanglement or interference with the moving parts.

To avoid the wires from becoming a safety hazard, we will make sure that they are properly secured and tied down, away from the moving parts. We will use cable ties and cable wraps to secure the wires and prevent them from getting tangled or caught in any moving parts. Additionally, we will ensure that the battery and motor are securely fastened to the board using appropriate hardware such as screws and bolts, to prevent them from becoming dislodged during use.

Moreover, we will also consider the user's safety by ensuring that the board is not too heavy and the weight is distributed evenly to avoid causing any physical strain on the user. We will also consider the board's center of gravity to ensure that it is stable and easy to maneuver, especially when turning or changing directions.

In addition to the safety precautions we've mentioned before, there are some additional safety considerations that we must take into account when testing the Soareboard. Since the board is designed to be ridden like a skateboard, there is a risk of falling or losing control while riding. To minimize the risk of injury, the rider must be experienced and have the necessary skills to control the board. We will also make sure that the rider wears additional safety equipment, such as knee and elbow pads, wrist guards, and a full-face helmet to protect against head injuries. The helmet is especially important since head injuries can be life-threatening, and we want to make sure that the rider is as safe as possible while testing the board.

It is also important to note that the rider should only test the board in a controlled environment, away from traffic and pedestrians. We will be selecting an appropriate testing location that is flat and free from obstacles, such as rocks or tree branches, that could cause the rider to lose balance or fall. In addition, we will ensure that the rider is always accompanied by at least one other person who can provide assistance or call for emergency services if necessary.

Finally, we will limit the speed and duration of the test rides to ensure the safety of the rider. The rider will be instructed to ride at a safe speed and to avoid any risky maneuvers that could result in injury. We will also monitor the battery level to ensure that the board does not suddenly stop while the rider is in motion, which could cause them to fall. By taking these safety precautions, we can minimize the risk of injury and ensure a successful and safe testing process for the Soareboard.

## 7.0 Project Prototype Testing Plan

Testing the hardware and software of the Soareboard is crucial to ensure that the electric skateboard is functional, reliable, and safe to use. In this section, we will outline the different testing protocols that our group will employ to test each part of the Soareboard.

While we do not yet have a physical prototype of the Soareboard, we can still develop a comprehensive testing plan based on our design and specifications. Our testing plan will include testing protocols for the hardware components such as the motor, battery, solar cells, and the PCB, as well as the software components such as firmware and control systems. Our group currently has the motor, the battery, the solar cells, and the Arduino Uno microcontroller.

The testing protocol for the hardware components will involve a series of tests to ensure that they meet the required specifications and standards. The testing protocol for the PCB will involve verifying the connectivity and functionality of the circuit board using specialized equipment. The testing protocol for the software components will involve verifying the functionality and performance of the firmware and control systems, and we will simulate real life scenarios and use cases to evaluate the responsiveness, stability, and accuracy of the software components.

Our testing plan will also include safety tests to ensure that the electric skateboard meets the required safety standards. Testing is an essential aspect of the development process for the Soareboard. By conducting rigorous testing, we can identify and address any design flaws and ensure that the Soareboard is functional, reliable, and safe to use.

### 7.1 Hardware Testing

Building an electric skateboard involves choosing various components and integrating them seamlessly to create a functional product. To achieve this, extensive testing of the chosen hardware components is essential. This testing involves subjecting the components to various operating conditions and scenarios to ensure they work as intended. Engineers and technicians carefully test each component to identify potential issues or areas that require improvement, allowing them to address these issues before the final product is released. Testing also ensures that the components can work together seamlessly, enabling smooth operation of the skateboard. It is important to note that testing is not a one-time process but a continuous effort that helps refine the design and improve its overall functionality. By investing in testing, we can ensure that the electric skateboard is not only safe to use but also performs optimally in different situations, meeting the expectations of the user.

In order to begin the development process of our electric skateboard, we decided to focus on acquiring four critical components that will define the main features of our design. These components include a motor, an Arduino board, a battery, a DC to DC converter, and solar cells. Once we had all of the components, our team immediately began testing each one to ensure proper functionality and identify any potential issues.

The initial testing stage was essential in determining the behavior of each component, which helped us to gain a better understanding of how they would perform in our design. We also conducted a thorough evaluation to ensure that each component was working correctly and in case we needed to return any of them for replacement or repair.

By conducting testing on each component individually, we were able to identify any issues that arose and address them accordingly. For example, if a component was found to be faulty, we could return it and receive a replacement quickly, minimizing any potential delays in the development process. Additionally, by ensuring that each component was working correctly, we could be confident that our final product would function seamlessly and provide the best possible experience for the rider.

### 7.1.1 Hardware Testing Environment

To start our testing process, we will first conduct hardware testing on simulation software to evaluate the performance of our system. This is a crucial step in our testing process because it allows us to identify and correct any potential errors or issues in our circuit design before we move on to physical testing. Additionally, using simulation software minimizes the risk of damage to any hardware components that could occur during early physical testing.

Using simulation software provides us with a visual representation of how our system will operate and helps us understand its behavior under different conditions. We will be using Multisim, a free tool that we are all familiar with using. It offers various simulation features that allow us to test different aspects of our design, such as testing the response of our circuits to different inputs and verifying the behavior of different components in our design.

Multisim will also help us to simulate the different parameters of our circuits and predict their expected behavior. This will enable us to optimize our design before we start building it physically, saving us time and resources. Overall, the use of simulation software is a valuable step in our testing process and will ensure that we have a more efficient and successful final product.

To perform accurate physical tests on our components, it is crucial that we have access to the proper equipment that can provide us with precise measurements and readings. This equipment may include various tools such as oscilloscopes, multimeters, function generators, and more. Fortunately, our school has provided us with access to all of these necessary tools and equipment for our project.

As discussed earlier in section 6.2, we are fortunate enough to have a designated private lab space for our senior design project. This lab is fully stocked with all of the necessary equipment and resources we need to conduct our tests with accuracy and efficiency. We plan to make use of this lab and its resources to conduct a majority of our physical tests and to record our results.

Having access to this equipment will also help us to detect any possible issues or errors in our circuit design during physical testing. By using these tools, we can monitor the behavior of our circuit and detect any discrepancies that may not have been apparent during the simulation testing phase. Additionally, using the equipment will allow us to ensure that our circuit design is working within safe limits and that there are no potential hazards during operation.

Overall, having access to the proper equipment is essential for the success of our project, and we are grateful for the resources that our school has provided us with. We plan to utilize this equipment to its fullest potential to ensure that our project meets all requirements and is safe and efficient in its operation.

The board was able to endure testing outside and in a parking garage for final testing.

### 7.1.2 Solar Cell Testing

To ensure the accuracy of our data, we recognized that hardware testing for solar cells could not solely rely on simulation software. We needed to conduct physical tests in outdoor areas to collect precise information. As solar cell testing is heavily influenced by weather conditions, we needed to run multiple tests under varying conditions to obtain a diverse range of data that we could analyze and utilize to enhance our electric skateboard.

Our tests had to be conducted on days with different weather conditions, such as cloudy, partly cloudy, and sunny days. Temperature was also a crucial factor that needed to be monitored closely during testing. By measuring the voltage and current from the solar cells in each test, we could determine how much energy was being produced. We also ensured that we conducted our tests with no load attached to the cells to ensure that the measurements we obtained were not affected by external factors.

We understood the importance of collecting accurate data during our solar cell testing. By continuously testing under different weather conditions, we could collect a comprehensive dataset that would allow us to identify any flaws in our solar cell system and make necessary improvements. As a result, we could ensure that our electric skateboard would function optimally under a variety of weather conditions and provide an efficient and eco-friendly mode of transportation for our users.

Upon the arrival of the Solar Cells, our team had to perform a series of tests to ensure that the cells were functional and could meet our project's needs. The testing process was quite different from the testing we had performed on other components like the motor, battery, and controller. Due to the nature of solar cells, we could not test them in the safety and comfort of the senior design lab, as they needed direct sunlight to function.

To test the Solar Cells, we had to take them outside and place them on the ground, exposing them to direct sunlight. We had to wait for some time to allow the cells to charge up sufficiently before we could perform any tests. Once we had verified that the cells had been charged, we used a portable multimeter to measure the voltage output of the cells. The cells were deemed to be sufficient if the multimeter detected a voltage reading.

Fortunately, our tests were successful, and we determined that the solar cells we had obtained were suitable for our purposes in the Soareboard project. We did not find any major deficiencies in the cells that would necessitate returning the product and selecting a different type of solar cell. Thus, we were confident that the solar cells would be a good fit for our project, and we could proceed with using them in our design.

However, we knew that we had to continue testing the solar cells under various weather conditions to gather more data that we could use to improve our design. We needed to determine how the cells would perform on cloudy and partly cloudy days as well as sunny days, taking into account the temperature of each day. By doing so, we could gain a wider range of data that would be useful in refining the Soareboard's overall performance.

It is important to note that we will have to test the Solar Cells numerous times throughout the process of construction to ensure it functions properly.

The solar cells were tested outside and were able to endure the sunlight and we were able to connect them to the battery to charge it. The solar cells were also connected to the MPPT and it can be seen that they are connected when the LED on the MPPT is on.

### 7.1.3 Motor Testing

In order to ensure that the board is operating at the correct speed safely, the motor must be tested. This will be done by measuring the power that the motor receives from the ESC. By using equipment, such as a multimeter, we will be measuring the voltage received by the motor when the system is running. These tests will be conducted after we do our simulation tests. Measuring the voltage when the motor is set to different speeds allows us to ensure the integrity of the motor and its wiring. In addition to using a multimeter, we will also be using an oscilloscope to measure the incoming PWM signal from the ESC and measure the duty cycle. This will tell us whether the motor is operating at the correct speed that the ESC requests it to.

Upon receiving the motor component, we immediately took it to the senior design lab for testing. Our team was eager to understand how this specific motor would function and whether it would meet our project's needs. To start our testing, we connected the motor to a power source and sent a pulse to it. Then, we connected the motor to an oscilloscope to measure resistance. We rotated the motor and observed the effects of resistance and torque, which varied depending on the position of the gears in the motor. This allowed us to gain a better understanding of how the motor would function in our project and whether it would be suitable for our needs.

After careful consideration and analysis of our testing results, we came to the decision that we should consider replacing this motor with another one that would be more compatible with the other components in our project. The Boosted Board motor we tested showed incompatibility with other components, such as the battery and the controller, which were already selected for our project. Furthermore, the motor did not align with the overall vision of our project. While the motor did function as intended, incorporating it into our project would require significant design alterations, which would hinder the development process.

We decided to return the motor and select a new one that would be a better fit for our project as a whole. The new motor would have to be compatible with the other components and align with our project's vision. By selecting a more suitable motor, we could ensure that our project would function seamlessly, and we could avoid any complications that may arise from using an incompatible component. Overall, our team remained committed to achieving the best possible outcome for our project, and we were willing to make the necessary changes to ensure its success.

It is important to note that we tested the motor numerous times throughout the process of construction to ensure it functions properly.

#### 7.1.4 DC to DC step up Converter Testing

It is true that most of the responsibility is held by the solar cells to make this project work, but since they do not hold the input voltage needed to charge the battery on their own, a DC to DC step up converter is needed.

To test this part of the project, we will start by charging the solar cells and making sure that they are holding the maximum amount of voltage that they can, which is around 5 volts or a little more. On average, a solar cell can take up to nine hours to charge.

Once the charging phase is complete, it's essential to ensure that each solar cell is generating at least three volts of power. This is necessary to avoid any damage to other electronic components when using the DC to DC step-up converter. To check the voltage output, we will use a multimeter. If the voltage output is adequate, we can move on to the next step of connecting the converter to the battery. However, since the battery will be located on the other side of the board, we will need to solder wires to the step-up converter to connect it to the battery.

Once the wires are soldered to the converter, we can clip the two poles on the solar cells to the two poles on one side of the converter. Then, we need to solder two other wires to the output poles on the other side of the converter. It's crucial to check if there is the required step-up voltage from five volts to at least twelve volts to ensure that the voltage required by the battery is supplied by the solar cells. We will use the two clips of the multimeter to track the voltage output and ensure that it's sufficient.

We have provided an image to illustrate the process of testing the solar cells and connecting the converter to the battery. This way, we can ensure that the solar energy part of the board is completed successfully, and we can deliver 100 percent renewable energy to power the skateboard.

Soldering the output wires from the converter to the battery is a crucial step in completing the solar energy part of the project. This step requires precision and attention to detail to ensure that the connection is stable and secure, and that there are no loose connections or exposed wires that could potentially cause damage or injury.

Once the connection is established, the solar energy system will be fully functional, and we will be able to harness 100 percent renewable energy to power the Soareboard. This is a significant achievement, as it not only reduces our reliance on non-renewable energy sources but also makes the project more environmentally friendly and sustainable.

Using renewable energy sources like solar power is crucial in mitigating the effects of climate change, reducing greenhouse gas emissions, and preserving the environment for future generations. By incorporating renewable energy technology into our project, we are doing our part to promote sustainability and raise awareness about the importance of using clean energy sources.

In addition to the environmental benefits, incorporating renewable energy sources also has economic advantages, such as reducing the cost of energy bills over time, and increasing the efficiency of the project. This can translate to significant savings and a more cost-effective approach to powering the Soareboard.

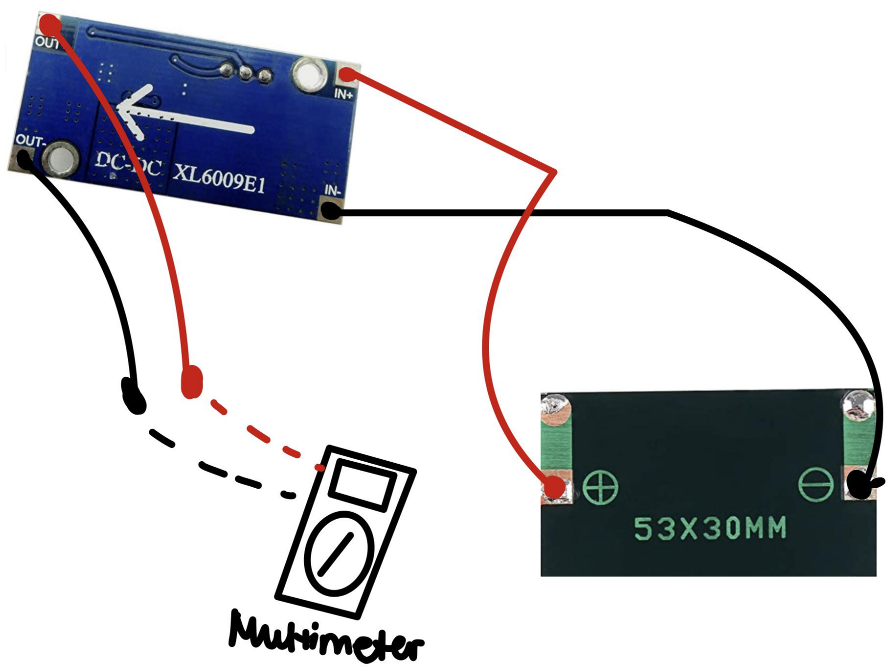


*Figure 54: DC to DC Testing*

After going through the actual design process, we decided we did not need the DC to DC converter for the final design, so testing it was not necessary.

### 7.1.5 Battery Testing

Our project revolves around the use of storing solar energy. Due to this, we must effectively test a battery to ensure that it is getting a significant amount of energy from the solar panels and the DC to DC step up converter, while also being able to effectively hold and distribute this energy to the other components.

To test this, we will be measuring the voltage and current being supplied by the solar cells to the battery itself when they are connected. Making sure that the circuit works as intended allows us to know that the battery is indeed receiving a sufficient amount of energy to operate. Once that section is tested, we will move on to test the power storing of the battery itself. This will be done by testing to make sure that no energy is dissipated by the battery when the board is not in use. The next step relates to the power output of the battery to the rest of the components. Without a constant flow of energy to the rest of the components, the board cannot operate properly and safely. By measuring the output of the battery, we can analyze the current and voltage levels exiting the battery and ensure these are the ones we desire.

In addition to all of these tests, another important test is that of temperature management. A dangerous issue that arises from storing large amounts of energy in a battery is overheating. This may result in damage to the battery and, in extreme cases, the combustion of the battery itself. By overseeing the temperature of the battery throughout each test, we can strive to prevent this issue from occurring.

After connecting the battery directly to the Multimeter, it was determined that the voltage readout was higher than expected. This can be common with products that have a range of acceptable values, rather than a single exact value. However, it was important to confirm that the battery was still functional and would work well with our project.

The next step in testing was to connect the battery to a breadboard and measure the voltage through the board to ensure that it could be used as a power source for our components. This was an important step because we needed to ensure that the voltage from the battery was being transferred through the board and could be used to power our circuit. Once this was confirmed, we were able to move forward with testing the battery in a practical setting.

Initially, we attempted to construct a simple LED circuit to demonstrate the power of the battery. Unfortunately, due to a mistake in construction, the LED was blown, serving as a reminder of the importance of lab safety precautions. Despite this setback, we were still able to move forward with testing and opted to build a basic circuit that took in a signal from a function generator and modulated it, using our battery as the main power source. The output of this circuit proved that the battery could be used in a practical setting and served as confirmation that we had selected a good battery for our project.

Through thorough and intense testing, we determined that the battery was fully operational and would serve as a key component in our electric skateboard. However, one potential issue we identified was the dimensions of the battery. Its placement on the bottom of the board could affect the overall motion of the board, but we are confident that we can design around this issue during the construction of the Soareboard.

Overall, testing the battery was an important step in ensuring the success of our project. By conducting various tests and applications, we were able to confirm that the battery we selected was a good choice and would work well with our components. Through these tests, we also identified potential issues that could arise and are now better prepared to address them during the construction phase.

It is important to note that we should and will test the battery at numerous stages along the process of construction to ensure that it functions properly.

### 7.2 Software Testing

Software testing is a critical component of any project, including the development of an electric skateboard. In this section, we will outline our testing environments and the different types of testing that we plan to undertake.

Testing environments are used to simulate the different operating conditions and scenarios that the software will encounter in the real world. Our testing environments will include both physical and virtual environments. In addition to that, we will also conduct performance testing, security testing, and regression testing to ensure that the software meets the required performance standards, is secure from potential threats, and does not have any unintended side effects on previously tested functionality.

There are four different types of testing that we plan to undertake:

- Unit Testing: this involves testing individual software components to ensure they work as expected.

- Integration Testing: this involves testing how the different software components work together to ensure that they function seamlessly.

- System Testing: this involves testing the entire system to ensure that it meets the specified requirements and standards.

- User Acceptance Testing: this involves testing the software from the user's perspective to ensure that it is user-friendly, intuitive, and meets the user's requirements.

In addition to being critical to the development of the electric skateboard, software testing is also important for ensuring the safety of the rider. The app serves as the main control interface for the board, and any malfunctions or errors in the software could potentially lead to dangerous situations. Therefore, it was crucial that we were diligent in our testing process to make sure that all aspects of the app were functioning properly and that it could effectively communicate with the board. Additionally, the app provides an important user experience for the rider, as it allows them to control the speed of the board and monitor important information such as battery life and speed. By taking the time to carefully develop and test the app, we can ensure that riders have a smooth and enjoyable experience while using the Soareboard.

### 7.2.1 Software Testing Environment

All of our software will be compatible with iOS and android applications. Since it is software testing, there are a lot of places that the applications will be available, but we are only picking three testing environments to not only make it easier for us, but because these are the most common environments that the software will be used in. Though it is only three, there are many further applications that can be used from just testing. These are the environments that we will be testing in:

- Developmental - MIT App Inventor, and Expo; with the iOS and android IDEs
- Cell Phones - where the app will be
- Outside - where the skateboard will be conducting tests, since we need the app in order to control the board

Our project involves a series of steps that we see as a staircase, with each step building on the previous one. The first step is the developmental environment, this part divides on two main parts, the first one being the MIT App inventor. This invention was developed by the Massachusetts Institute of Technology (MIT) to make the development of apps accessible to anyone, but mainly kids, since sometimes they do not have the coding skills needed to create an app, but with this invention, people use blocks of code with actions. So no coding experience is needed to use this, and it is completely free. After the project is done, the MIT app needs to be downloaded to the phone that is either iOS or Android operating system. Once the app is downloaded there is a camera icon that can be clicked to scan a QR code that our project will generate to “download” our project into the simulator. This will help us a lot to test that we are able to control the board through bluetooth and our app.

Hence, this MIT App Inventor will help us save some time with the setup between the Arduino and the app. We want to make sure that the wireless communication is working before we start working on the real app.

Now, the second part is where the app will be created using either iOS Studio or Android Studio. To facilitate this process, we have decided to use Expo, which is compatible with both iOS and Android platforms and allows us to test changes immediately after editing the code. Completing this stage will enable us to move on to the next step in the staircase, which is developing the app for cell phones.

Cell phones are the ultimate destination for our app, so after completing the development phase in Expo, we will eject the project and upload it to the App Store and Google Play Store. This step will allow us to test the app and gather feedback from judges and friends, which will help us improve the app for future versions. We see this step as crucial for our development because it enables us to have others try the app, ensuring that the connection between the skateboard and phone works smoothly and that the app provides a safe and reliable experience for our users.

By following this staircase approach, we are setting ourselves up for success. Each step builds on the previous one, ensuring that we are thoroughly testing and refining the app as we go. This approach will enable us to make any necessary modifications or improvements to the app, giving our users a high-quality experience. We are excited about the potential of this project, and we believe that this staircase approach will help us achieve our goals and create a successful and user-friendly app for our customers.

### 7.2.2 App Testing

We will start with the developmental testing for the app. The reason behind this is so we can make sure the code actually works and will have no bugs. As explained earlier, we will be using MIT App Inventor to mainly test that the communication is working, and that the phone is really keeping track of the different features that the app will have. In other words, this App inventor will work as a trial and error phase, which will set up a starting point to our app development.

Expo will help us develop the communication between the phone and the board, will help us to work on the app and later on be ejected into either XCode in order to do this for iOS, or for Android we will be using Java. This ensures that it is compatible with the applications. The developmental environment is enormously important to software testing because it will ensure that we will identify any defects in the code. It is also good for improving the quality of the app, and also enhances the experience of the user. This phase of testing is very important due to the ability of testing every possibility in a developmental environment, so mistakes can be made, found, and fixed.

Testing the app on cell phones is a critical step in the software testing process for our project. It is essential that the app is available on both iOS and Android devices, which requires us to develop and test the app on both platforms. During this phase of testing, we will ensure that all the buttons on the app work as intended, all necessary functions are present, and all displays are appropriately visible. We need to make sure that the app's functionality is consistent with our developmental phase of testing, as any deviations may suggest the presence of unidentified bugs. If such issues arise, we will need to return to the developmental phase to resolve them.

In addition to ensuring the app's functionality and consistency, we will also verify that the app remains stable throughout usage and does not crash. This is a crucial aspect to test as an unstable app can hinder the user experience and potentially damage the user's trust in the product. We will also examine the app's responsiveness to user actions and ensure that it works seamlessly with the board. This is important because the app and board must work in tandem to provide the desired user experience.

All in all, cell phone testing is a critical phase in software testing. It allows us to verify the app's functionality and stability while ensuring that it is compatible with both iOS and

Android devices. Through rigorous testing and analysis, we can guarantee that the app works as intended and meets the expectations of our users.

The third and final phase of testing is a crucial step in ensuring that the Soareboard app is functional and can communicate seamlessly with the board. This phase requires extensive testing to ensure that the Bluetooth connectivity is reliable and the app can control the board’s speed accurately.

The first step in this phase is to establish a connection between the app and the microcontroller. This connection is critical because it links the app to the motors and tells the board to move or not. It is imperative to test the connection speed and the distance from which the connection can be established. We need to ensure that the connection is robust and stable, even when there is interference from external sources.

After successfully establishing the connection, the testing phase moves to the motor’s response time when the buttons are pressed. We need to ensure that the motor’s speed changes accurately, and the app can increase or decrease the speed precisely as per the user's requirements. We will also test the motors' response time to make sure that it stays within the specifications mentioned earlier.

The next critical step in the testing phase is to check the app's display, which should show the current speed and battery life accurately. These parameters are crucial to the user as they need to know how fast they are going and when to recharge the battery. We will test the maximum and minimum speeds the board can achieve, and the app must display them correctly.

For the actual testing of the board, we will use four different cell phones, and all members of the group will test it. This testing approach ensures that the interface works on all phones and works in real-time in real-life scenarios. Additionally, testing with varying weights is crucial to ensure that the board can handle different user weights and still perform efficiently.

Finally, we will conduct extensive testing to ensure that the app can connect and disconnect quickly, and the speed changes are smooth and accurate. We will also test the board's maximum speed to ensure it aligns with the project's specifications.

Here is what we will test:

- Maximum speed per rider, using different people
- How long the battery lasts
- Time it takes to slow down when there are different people riding
- Time for the app to change the speeds on different interfaces

With the MIT App Inventor project in hand, our team can finally move on to the actual development of the app with more confidence. We can be sure that the communication between the board and the phone through Bluetooth is working properly, which is a critical aspect of the project. Knowing that the communication is reliable and stable will save us time and effort that would have been spent troubleshooting connection issues.

Once the project is finalized, we will start testing the app in various outdoor environments. This is important because skateboarders don't always ride on smooth roads, and we need to ensure that the app is functional in different scenarios. We will test the app on bumpy and uneven terrains, different weather conditions, and various inclines to simulate real-life situations. By testing in diverse environments, we can identify any potential bugs or issues that we may not have encountered during the developmental and cell phone testing phases.

In addition to ensuring that the app functions well, we will also check that the app is easy to use while riding a skateboard. We will gather feedback from skateboarders who have tested the app and use their suggestions to improve the app's user experience.

Overall, testing the app in different outdoor environments will be crucial in ensuring that the app is reliable, functional, and easy to use for skateboarders. By conducting thorough tests, we can identify and address any potential issues and deliver a high-quality app to our users.

### 7.2.3 Microcontroller Testing

The process of microcontroller testing is an integral part of ensuring the proper functioning of electronic devices. This process begins with the developmental stage where the software code is written, which will then be used to test the microcontroller. In order to ensure that the microcontroller operates effectively, it is necessary to test each individual component separately.

One of the most important components to test is the motor. This requires testing the ability of the motor to move individually and function properly. This testing process is critical to ensuring that the board is capable of movement.

Additionally, there are various tests that must be conducted to ensure that the motors are working properly in different scenarios. These tests include checking how the motor works when the board moves forward or slows down. This will ensure that the device operates correctly in all situations.

Moreover, it is essential to check the Bluetooth connectivity of the microcontroller. This requires testing the signal reception and connectivity of the microcontroller to the app. This is crucial to ensure that the device can be controlled by the user through the app.

When the microcontroller was shipped to one of our team members’ house, we performed a thorough testing process to ensure its proper functioning. We then came together as a team in the Senior Design lab, located in the engineering building. This lab provided us with access to computers, components, and necessary USB cords to connect the microcontroller to the Arduino IDE, making it easier to carry out the testing process.

During the testing process, we ensured that the microcontroller was programmable. This was a crucial step, as the microcontroller's programmability determines its ability to carry out specific tasks. Additionally, we tested the microcontroller's ability to connect to wifi. This test was necessary to ensure that the device could connect to wireless networks, making it easier for the user to control it remotely.

In addition to these tests, we also carried out various other tests to ensure that the microcontroller was working as expected. We checked the microcontroller's input and output functions, ensuring that the device was able to receive and send signals accurately. We also checked the device's power consumption, making sure that it was operating efficiently without consuming excessive power.

To ensure that the microcontroller was programmable, we used the Arduino IDE and connected our microcontroller via USB. We utilized example codes that were specifically designed for the Rev2 version of the IDE. Our team used multiple codes for testing, including but not limited to, turning on an LED for 1.5 seconds and then turning it off for 0.5 seconds automatically, using the buttons on the microcontroller to turn the LED on/OFF, detecting a sound nearby, and responding with a "knock!" message, analyzing characters by sending a byte and receiving feedback from the sketch, and an ASCII table code.

We conducted these tests to ensure that the microcontroller could perform basic operations accurately and without any issues. We also wanted to ensure that the microcontroller was capable of processing various types of input and output commands, making it versatile enough for different use cases.

Our team also performed Bluetooth testing to determine if the microcontroller could connect to Wifi. We connected the Arduino Uno Rev2 to a computer through USB type B and utilized example codes to test its connectivity. We were pleased to find that our microcontroller was able to connect to Wifi successfully.

Overall, microcontroller testing is a crucial step in the development process of electronic devices. Our testing process was thorough and comprehensive, covering various aspects of the microcontroller's functioning. By performing comprehensive tests on each individual component, including the motor and Bluetooth connectivity, it is possible to ensure that the device will operate correctly and meet the expectations of the end-users.

### 7.2.4 Conclusion of Software Testing

As of now, we do not have a finalized code for our microcontroller, and as a result, our testing procedures are still in their early stages. While we have established some basic testing procedures, these procedures may evolve and change depending on a variety of factors, including outside variables that we may have not even considered yet.

It is important to note that the testing procedures that we have established thus far are merely outlines, and they will likely change as we continue to develop and refine our software. As we gain a better understanding of the software's capabilities and limitations, we may need to modify our testing procedures to ensure that we are accurately evaluating the microcontroller's performance.

Furthermore, the interaction between the software and hardware can also impact the testing procedures. Different types of software and their corresponding code can have different effects on the hardware, and this can impact the testing procedures we use to evaluate the microcontroller.

In order to ensure that our testing procedures are effective and accurate, we need to remain flexible and open to modifications. By staying alert to changes in the software and hardware, we can modify our testing procedures accordingly to ensure that we are obtaining accurate and reliable results. This will enable us to develop a microcontroller that meets our design requirements and functions effectively for the end-users.

### 7.3 Troubleshooting

As projects are developed and tested, it is inevitable that unforeseen complications and issues will arise. These can range from minor setbacks to major roadblocks that significantly hinder the progress of the project. Therefore, it is essential to have a well-defined strategy in place to troubleshoot any problems that may occur. This not only helps to mitigate the impact of these issues but also ensures that the project stays on track and on schedule.

To troubleshoot common complications, there are several tips and tricks that our group has compiled. Firstly, it is important to thoroughly understand the problem and gather as much information as possible about the issue. This includes gathering data and examining the system to identify any potential faults. Once this information has been collected, the group can work together to develop a plan of action to address the problem.

Another key aspect of troubleshooting is communication. The team members should communicate with each other regularly to keep everyone informed about the progress of the project and any issues that have been encountered. This helps to ensure that everyone is aware of the current state of the project and can provide input and feedback as needed. Additionally, it is important to communicate with external resources such as instructors or experts in the field, who can provide valuable insights and advice.

First and foremost, it is important to thoroughly review the code and hardware setup to identify any errors or issues that may be present. This can involve checking for typos or syntax errors in the code, as well as ensuring that all components are correctly connected and functioning as intended.

In addition to reviewing the code and hardware setup, it can be also helpful to consult with team members and experts to seek input and suggestions for resolving the problem.

Collaboration and brainstorming can often lead to new insights and perspectives that can aid in identifying the root cause of the issue.

Another strategy for troubleshooting is to systematically test each component of the project to identify the source of the problem. This can involve testing individual sensors, actuators, or other components to determine if they are functioning properly. By narrowing down the issue to a specific component it becomes easier to identify and address the problem.

It is also important to keep detailed notes and documentation throughout the troubleshooting process. This can help to identify patterns or recurring issues that may require additional attention or modification in the design.

Overall, troubleshooting is an essential part of the development and testing process, and having a strategy in place can help to streamline the process and ensure that issues are resolved quickly and efficiently. By utilizing these tips and tricks, our group can effectively troubleshoot common complications and continue to make progress towards our goals.

### 7.3.1 Hardware Troubleshooting

When it comes to hardware testing, it’s important to be prepared for unforeseen issues that may arise during the process. Troubleshooting can be intense and time-consuming, but it is a crucial step in ensuring that the final product is safe and functional.

Our group has come up with several tips for hardware troubleshooting to help mitigate any potential problems that may arise during testing. Firstly, if the board does not connect to the app, we recommend checking the battery life. It is a common issue and can be easily resolved by charging the battery. If the battery is not the problem, checking the wiring on the underside of the board can help ensure that everything is in the right place.

Another issue that can arise during hardware testing is incorrect speed on the app compared to the board. In this case, it is important to ensure that the app is actually connected to the board. If the app is not connected, the rider should get off the board until it is safely connected. Before remounting the board, the rider should exit the app and reopen it, making sure that the app and board are connected before getting on and riding.

Debris from the ground can also affect the wheels, causing them to move in a weird way. If this happens, we recommend cleaning odd the wheels and bearings to ensure smooth operation. If the board is moving unusually, the rider should get off the board immediately and check to see if something hit the underside of the board immediately and check to see if something hit the underside of the board and knocked something off. If the wheels are dirty, they should be cleaned before continuing to ride.

It is important to keep the board and underside of the board clean to ensure proper operation. If the top of the board is dirty, the solar panels may not get the right amount of sunlight to charge the battery, which can affect the board's performance. If the bottom of the board is dirty it should be cleaned immediately. The rider should not ride the board if something is on the wheels or if something is interfering with the underside of the board.

Overall, hardware testing can be challenging, but with the right troubleshooting techniques and attention to detail, we can ensure that our board is safe and functional. These tips are just the beginning of what we will do to ensure the success of our project, and we will continue to adapt and evolve our strategies as we encounter new challenges.

In order to ensure the quality of our project, we must commit to consistently troubleshoot any potential issues. We must remain vigilant, keeping a watch on the above related issues. Any issues that could occur might negatively affect the project, and we must use our knowledge and skills to address those issues.

### 7.3.2 Software Troubleshooting

When testing the app and using it with the board, there are several issues that may arise, which is why it is essential to know how to troubleshoot them. Here are some tips and tricks that can be helpful:

- If the microcontroller does not connect to the phone, restarting the app might help. Also, check if any wires are disconnected on the board, as this could cause connectivity issues.

- If the app does not turn on, try exciting and reopening it. Additionally, make sure that the phone is compatible with the app and the app version matches the microcontroller's firmware.

- If the motors are not moving when the app is connected, first try to exit out of the app and reconnect it to the microcontroller. If that does not work, check the writing under the board to see if anything has disconnected. The battery life could also be a factor, so ensure that the battery is charged.

- If the board is not responding or not connecting, ensure that the board and phone are close enough to each other. It is also a good idea to check the Bluetooth settings on the phone and ensure that the board is visible to other devices.

- If the app freezes or crashes, try clearing the app's cache and data, or uninstalling and reinstalling the app altogether.

- It is important to keep the app and firmware up-to-date, as outdated software can cause compatibility issues.

The software indicates to the hardware how the system is to perform, making it absolutely crucial that there are no available errors. Any errors that are present will need to be taken account of and fixed as soon as possible. We will use our knowledge and skills to troubleshoot any potential problems present in Soareboard's software and coding. Through years of taking computer classes and programming classes we have learned to address such issues.

Overall, troubleshooting is an essential part of the process, and being aware of common issues and knowing how to address them can save a lot of time and effort.

## 8.0 Administrative Content

It was crucial to start this section off by discussing two key topics. The budget is the first one. We first discussed it collectively to determine if it was something that could be accomplished under everyone's expenses, as this project is self-funded, which means that each member will contribute the same amount of money for the project. As the second key aspect, the team needed to set some milestones in order to keep moving forward and keep track of any dead ends that needed to be followed up on with Webcourses or even testing to make sure we don't fall behind. We delivered this portion while keeping in mind all of these crucial due dates and typical costs, ensuring that each team member is at ease and prepared to cooperate with the defined procedures.

The budget is a key aspect that needed to be discussed as a feature of this project. The team needed to determine if the project was financially feasible and if each member could contribute the necessary amount of money. To balance the complicated and delicate nature of something such as finances, This required consideration of the costs involved, including materials, tools, and any other potential expenses.

After establishing a budget, it is important to set milestones to ensure that the team can stay on track and don't fall behind schedule. Establishing a plan for the gradual completion of this project over the course of both the Spring and Summer semesters. These milestones are designed to help the team keep track of any potential issues that may occur and to follow up on any issues with advisors and correct those mistakes well ahead of schedule. In creating these milestones, the goal was to allow us to stay organized and focused on the task at hand, ensuring that our final project is completed on time and within budget.

### 8.1 Milestone Discussion

Having a well-planned and detailed timeline is crucial for the success of any project, and our senior design project is no exception. We recognize the importance of having clearly defined milestones in order to keep us on track and ensure that we are making progress towards our ultimate goal.

Table 2, which outlines our timeline, is divided into two parts: Senior Design I and Senior Design II. We have identified specific milestones for Senior Design II, although we are still awaiting the official dates from our instructor.

One important aspect of our timeline is ensuring that all documentation is completed by the end of Senior Design I. This includes detailed reports, research findings, and any other relevant information that will be required for the successful completion of the project.

While research cannot be scheduled at specific times, we will be continuously learning and researching throughout the project. We will be conducting tests and analyzing the outcomes to refine our design and ensure that we are meeting the project requirements.

Another crucial milestone is having at least one PCB design completed by a certain date. This will enable us to test the various components we implement over time and make any necessary adjustments. It will also allow us to test all the major components together, which is essential for the development of a precise and robust product.

Overall, our timeline serves as a guide for us to stay on track and meet our project objectives. We understand the importance of being flexible and adaptable to unforeseen challenges, but having a clear plan in place will ensure that we are making progress towards our goal of creating a functional and effective electric skateboard.

Consequently, since the project has to keep moving forward with testing and assembling hardware and software, these milestones were determined.

| **Number** | **Milestone** | **Description of the Milestone** | **Start** | **End** | **Status** |
|---|---|---|---|---|---|
| | | **Senior Design I** | | | |
| 1 | Brainstorm | Each member comes up with five possible ideas. | January 13$^{th}$, 2023 | January 15$^{th}$, 2023 | Complete |
| 2 | Form Faculty Committee | Contact a total of three professors to be our Senior Design Committee. | January 16$^{th}$, 2023 | January 30$^{th}$, 2023 | Complete |
| 3 | Divide and Conquer Document | Write a ten-page document with the project's description, constraints, and hardware and software requirements. | January 30$^{th}$, 2023 | February 3$^{rd}$, 2023 | Complete |
| 4 | Research | Team members dive deeper into how to make the project possible and about the many technologies that will be used. | February 10$^{th}$, 2023 | March 10$^{th}$, 2023 | Complete |

| | | | | | |
|---|---|---|---|---|---|
| 5 | 60 Page Draft Senior Design Documentation | Team members need to write in depth about the project's development, constraints, software and hardware implementation, budget, and milestones. | March 13th, 2023 | March 24th, 2023 | Complete |
| 6 | Review of the document with Dr. Wei | Meeting with Dr. Wei to get feedback on the 60-page draft. | March 27th, 2023 | March 27th, 2023 | Complete |
| 7 | Update 60 Page Draft | Make changes to the draft based on the feedback given. | March 28th, 2023 | March 30th , 2023 | Complete |
| 8 | Add 60 Page Draft to website | Link the Google doc of the 60 page draft to SOAREBOARD's Website. | March 31st, 2023 | March 31st, 2023 | Complete |
| 9 | Research | Team members dive deeper into the implementation of the app and hardware. | April 1st , 2023 | April 7th, 2023 | Complete |
| 10 | Video Upload | Make a 3 min video of three of the major components being tested | April 1st , 2023 | April 18th, 2023 | Complete |
| 11 | PCB Design | Have a finalized PCB design to start testing. | April 10th, 2023 | April 17th, 2023 | Complete |

| | | | | | |
|---|---|---|---|---|---|
| 12 | Final Document | Team members write in depth about the project's development, constraints, software and hardware implementation, budget, and milestones. | April 18th, 2023 | April 25th, 2023 | Complete |
| 13 | Add Final Document | Link the Google doc of the 60 page draft to SOAREBOARD's Website. | April 25th, 2023 | April 25th, 2023 | Complete |
| **Senior Design II** | | | | | |
| 14 | Order Parts | Order Arduinos, skateboard parts, LED lights, solar cells, resin, motor, battery, and converter. | May 17th, 2023 | May 20th, 2023 | Complete |
| 15 | Print Finalized PCB Design | Print the finalized version of the PCB so testing can start. | May 22nd, 2023 | May 30th, 2023 | Complete |
| 16 | Hardware & Software Testing | Start testing solar cells and power storage, as well as the app connecting to the hardware. | June 1st, 2023 | June 20th, 2023 | Complete |
| 17 | Build Prototype | Build the prototype after all the testing is done, and make sure everything works. | June 24th, 2023 | June 30th, 2023 | Complete |
| 18 | Improve prototype | If anything goes wrong, now is the time to fix errors and improve the prototype. | July 1st, 2023 | July 14th, 2023 | Complete |

| | | | | | |
|---|---|---|---|---|---|
| 19 | Final Presentation and Demo | By the end of the semester, SD groups are expected to present their projects to faculty. | July 1, 2023 | July 19th, 3034 | Complete |

**Table 21: Milestones**

### 8.2 Budget and Finance Discussion

Equally important, a budget is always something that has to be developed first to see if everyone on the team or the sponsor is willing to support the project economically. In this case, we do not have a sponsor, and since the project will cost around $600, every member will be responsible for giving $150 for this project.

In addition, as a team, we are not closed to the idea that a sponsor can help us sponsor at least part of our whole investment for this project. We want this project to be as developed and safe as possible. Every part that has been added to the table below, we can ensure, is the best among the ones that we have found for the price listed. The main idea is not to make the project extremely expensive, but if we need to pay a little more to ensure the quality on the components we are buying, we will.

Moreover, in Table 5, the components needed are listed, as are the quantity, vendor, and total cost. Currently, every part is in stock, so timing constraints are in our favor. As a result, more components can be added to this list if something breaks, is damaged, or a better way to do a certain feature is discovered.

| **Component** | **Quantity** | **Vendor** | **Total Cost** | **Senior Design 2 total cost** |
|---|---|---|---|---|
| Solarez Resin | 1 US Quart | Amazon | $53.95 | N/A |
| LEDs | 1 String (1m) | Amazon | $11.90 | 20.99 |
| PCB Print | 1 | JLCPCB | $20.00 | $20 |
| 3D Print Case for Battery | 1 | TI Lab (UCF) | Free | Free |
| Jizmo Skateboard Parts | 1 | Amazon | $30.00 | $30 |

| | | | | |
|---|---|---|---|---|
| Bamboo Skateboard deck | 1 | Amazon | 47.95 | 47.95 |
| DC Motor | 2 | Amazon | $30.88 | $30.88 |
| Motor Driver | 8 | Amazon | 10.99 | 87.92 |
| Lithium-Iron Phosphate Battery | 2 | Amazon | $36.00 | $72.00 |
| HiLetgo XL6009 Boost Module DC-DC Adjustable Module DC3.0-30V | 1 | Amazon | $5.99 | N/A |
| HC-05 Arduino | 1 | Amazon | $10.57 | $10.57 |
| Arduino UNO board | 1 | Amazon | $19.50 | $19.50 |
| Arduino UNO Wifi | 1 | Amazon | $55.40 | $55.40 |
| Solar Cells | Pack of 10 layers | Amazon | $40.00 | $40.00 |
| iOS Fee | 1 | App Store | $99 | N/A |
| Android Fee | 1 | Google Play Store | $25 | $25 |
| Electronic Speed Controller | 1 | MBoards | $110 | N/A |

**Table 22: Budgeting**

## 9.0 Project Summary and Conclusion

All in all, our project is about making traveling to campus and class easier, more affordable, and emission-free. The primary goal of our project is to develop a skateboard that is controlled through an app and is powered by renewable energy, and is able to take people from one place to another. The Soareboard we are creating will be able to harness the energy of the sun and power itself by recharging the battery that is on the board.

We are confident that our design will be easily replicable and manufacturable, as we are utilizing readily available components that can be easily sourced online. The key components of the device will include the deck, which will be used to hold the user and which will house the electrical and hardware components of the device and will be attached to our motor, battery, and microcontrollers, and the app that will be on the user's mobile device.

While we acknowledge that this project is complex and challenging, we believe that our extensive research and documentation will help us complete this task within a reasonable timeframe. Moreover, as a team, we are excited about the opportunity to learn new skills and strengthen our existing strengths in robotics and engineering. The experience we gain from this project will be valuable to our future employers, as it will demonstrate our ability to learn new things on the fly and work effectively in a team setting. Ultimately, we are thrilled to be developing the Scoreboard, which we believe will showcase the innovative capabilities of solar cells and renewable energy for students everywhere.

Even though we encountered some problems with getting components, we were able to move past it and work as a team to find a solution. We originally bought the WONDER Original Boosted Board V3 Motor, and we did not realize that it was only for that specific boosted board. When we found this out, we decided to find a different motor to test and to make sure it was able to be used on our Soareboard. After we figured this out, we were able to have all of the correct components for the board and were able to continue to develop.

For our project, we will have a microcontroller, a motor, solar cells, and a rechargeable battery. The microcontroller is used to communicate from the board to the app and it is important for the communication between the microcontroller and the app to be quick. The motor is controlled by the microcontroller and makes the board move. The solar cells are used to power the battery and are important because it is used to charge the battery, which is the only way to make the board move. The battery is used to power the motor and is a very vital part of the board. It is rechargeable and is charged from the power given to the solar cells from the sun, and is important because renewable energy is a big part of this project.

In essence, the purpose of this project is to create a Soareboard, a skateboard powered by solar energy. Our group members are excited to work on this project because it allows us to utilize our individual strengths and develop new skills that are crucial to the creation of such a device. While we recognize that building the Soareboard may present certain obstacles, we are confident that we can overcome them with the help of this document and the comprehensive research that we will conduct.

Furthermore, this project offers a unique opportunity for us to gain valuable experience that would be highly sought after by future employers. By showcasing our ability to quickly acquire new knowledge and collaborate effectively with others, we can demonstrate that we possess the qualities that employers value most.

We are looking forward to embarking on this project because it is an innovative way to showcase the potential of renewable energy sources such as solar power. We believe that the Soareboard has immense potential to revolutionize the transportation industry by providing a clean and sustainable mode of transportation. Our group is excited to play a role in this transformation and create a device that can inspire others to embrace renewable energy.

After the rigorous and rewarding journey of completing both Senior Design 1 and Senior Design 2, the group stands at the triumphant culmination of their collective efforts. The entire project, which has been a labor of love, has finally reached its much-anticipated completion. With a sense of accomplishment and pride, the team now eagerly awaits the moment when they can unveil the final product to the world, showcasing the fruits of their hard work, dedication, and ingenuity.

Throughout the entire process, the group has faced numerous challenges, ranging from conceptualizing the initial idea to navigating intricate technical complexities. It was a journey filled with highs and lows, requiring perseverance, teamwork, and unwavering determination to overcome obstacles and push the boundaries of their creativity.

In Senior Design 1, the foundation was laid, and the seeds of innovation were sown as the team embarked on the initial stages of the project. They delved into intensive research, meticulously analyzing existing technologies, and brainstorming ideas that would eventually take shape as the building blocks of their grand vision. Collaborating closely with their mentors and faculty advisors, they honed their project's scope and set ambitious yet achievable goals.

Transitioning into Senior Design 2, the team embarked on the implementation phase, where their ideas materialized into tangible prototypes. They dived deep into designing and developing the intricate components that would breathe life into their creation. Countless hours were spent in labs and workshops, soldering, programming, and assembling, as the team navigated through the intricate maze of engineering challenges.

At times, the path ahead seemed daunting, and setbacks tested their resolve. Yet, the group stood resolute, learning valuable lessons from each hurdle and using the setbacks as stepping stones towards excellence. Collaborative problem-solving sessions became the norm, fostering an environment where creativity thrived, and out-of-the-box thinking flourished.

The sense of camaraderie among team members grew stronger with every shared success and hurdle conquered. They supported each other through late-night brainstorming sessions, celebrated breakthroughs, and offered encouragement during moments of doubt. This bond not only strengthened their project but also forged lasting friendships and memories that will be cherished long after the project's completion.

Finally, after an arduous yet gratifying journey, the moment arrives when the group can showcase their masterpiece to the world. The final product stands as a testament to their passion, resilience, and relentless pursuit of excellence. Their hearts brimming with excitement, they eagerly anticipate the moment when the curtains are drawn back, and the world gets to witness their creation in all its glory.

As they step forward to present their hard work to an audience of peers, mentors, and industry experts, the group feels a sense of anticipation mixed with nerves. But they know that they are armed with knowledge, expertise, and the pride of knowing that they have given their best to the project. They are ready to demonstrate not only the capabilities of their creation but also the strength of their determination and the spirit of innovation that guided them throughout the journey.

In the end, the project was never just about creating a final product—it was about the experience of growth, the joy of discovery, and the thrill of bringing an idea to fruition. As the group stands on the cusp of presenting their hard work to the world, we are filled with gratitude for the opportunities they've had and excitement for the impact our creation may have on the lives of others. The journey has been transformative, and the future holds endless possibilities as they continue their pursuit of knowledge, innovation, and making a positive difference in the world.

## 10.0 Appendix

This segment is utilized to present the bibliography which encompasses all the sources cited throughout the paper.

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