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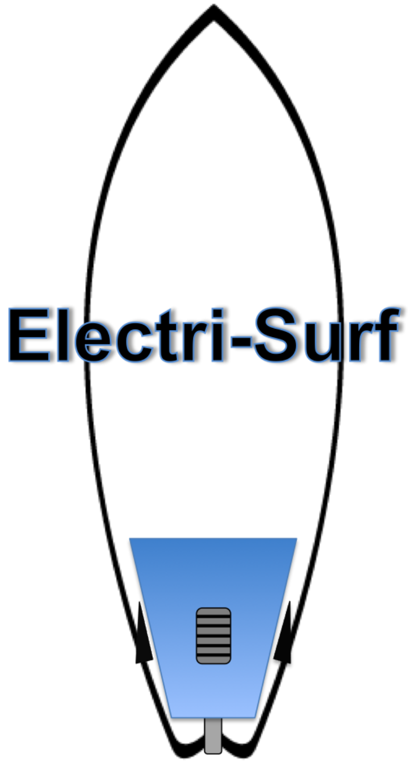

Senior Design 2 Document

May 2, 2016

Group 22 – Electri-Surf

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1.0 Executive Summary

Senior Design is a graduation requirement here at the University of Central Florida for the College of Engineering and Computer Science. The project is a two-semester process that takes place every semester. Our senior design group will design our project during the fall semester of 2015 and build our project in the spring semester of 2016. During the design phase, each group is responsible for presenting an in-depth document that is submitted at the end of the first semester describing the design plan, components, budget, and how the project will be built. The second semester is the actual build phase. Each group is responsible for building a successful project based off of the previously created design. Following in Figure 1.0 -1- represents the design ideology followed when creating this document in order to realize our project of an electric powered surfboard, Electri-Surf.

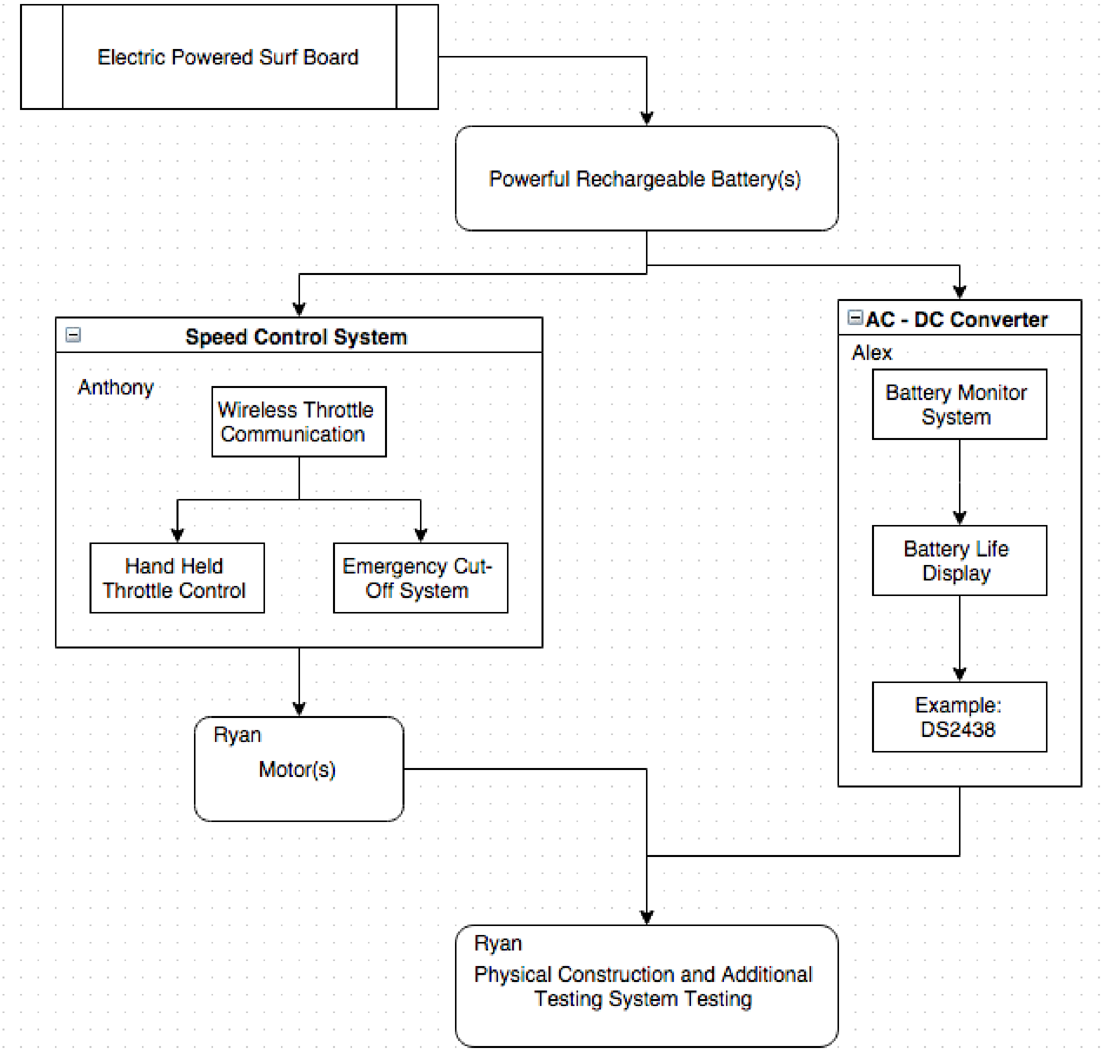


Figure 1.0 -1- Design Process

2.0 Project Description

Our project, Electri-Surf, is an electric powered surfboard that gives the rider a surfing experience without needing waves or any other natural source of propulsion. The overall concept is simple and straightforward but the design aspect is complex and intricate. A few electronic features will be added to our electric powered surfboard to make it more user friendly and safer for both the rider and nearby objects and bystanders.

Implemented in our design will be a hand held wireless throttle communication system that the rider can use to adjust the speed of the board while being able to focus on maneuvering and balancing. Not only will the rider wirelessly have control of the board's speed but it will also have an emergency cut-off system built in to protect the rider as well as nearby people and objects. The wireless cut-off system will also be implemented using the wireless communication system that will be triggered by distance. When the hand held device is too far away from the board, the engine will cut off regardless of the current throttle speed setting. Our electric powered surfboard should be operable with little to no prior surfing experience but some physical stamina and balance is required. Pictured below in Figure 2.0 -1- is the simple physical board design.

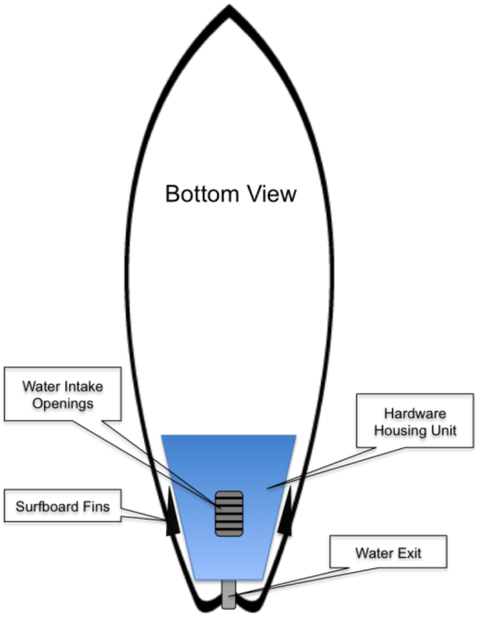


Figure 2.0 -1- Surfboard Diagram

2.1 Project Motivation

The project motivation behind Electri-Surf was to create an easy to use electric powered surfboard that could propel a rider across the water for a new enjoyable surfing experience. To be able to surf, one needs to be propelled across the water by an outside source of power such as a boat pulling someone with a rope, surfing the wake created by a boat in front of you, wind sails or a kite, or of course a wave in the ocean. But what happens during the summer months when the waves in the ocean are small or when you don’t have access to a fast speedboat and proper equipment to pull you across the water? That is how the idea of Electri-Surf came about.

We wanted to create something that could be enjoyed with relatively limited outside supplies, such as an expensive speedboat or a powerful swell in the ocean, or even the ocean in general! Ideally, Electri-Surf can be used in any body of water big enough and deep enough to allow the rider to safely use the board. Most surfers have heard of, or probably thought of such a device but never really put too much thought into it because such an item is not generally for sale to the average public and would typically cost too much money for the average weekend surfer to purchase.

2.2 Goals and Objectives

Our primary objective in this project is to give a person the ability surf on a body of water, whether it is a lake, river, or ocean, without needing large waves, sufficient winds, a speedboat, or any other type of equipment. To accomplish our overall objective, we broke it up into goals. A key to a successful goal or objective is to break it up into smaller goals. Our primary objective can be split up into three sub-goals.

The first sub-goal is for our Electri-Surf board to be easy enough to use so that the average watersport enthusiast could operate it or quickly acquire the skill to be able to operate it. Learning how to surf the old fashioned way, using ocean waves, can take years for some people to learn because of natures unpredictable ways combined with the surfer’s ability to balance and their timing on the waves. We want to eliminate as many of these factors as possibly and make a “get up and go” type of surfboard that takes little experience or little surfing knowledge to operate. However, some balance is necessary.

Secondly, Electri-Surf will give feedback to the rider. Electri-Surf is a battery-operated surfboard that can be used in just about any body of water and that adds a high level of risk and danger to the rider because of the risk of being stranded. An important way to keep the rider safe out on the water is to monitor the remaining battery life. This is important because it gives the rider an idea of how much power is remaining in the batteries and the rider can then make an estimated guess on the of riding time left. The board’s ability to float is not dependent on battery life, so if the rider saturates the batteries while out on the water, the rider can simply lay on the board and paddle to shore. Another form of feedback the board will give to the rider is through the wireless throttle control. A hand held wireless throttle that the rider uses to dictate the motors' amount of thrust will control the board's speed.

The third sub-goal is for the board to be lightweight, durable, and safe to the rider. It's imperative to have a lightweight system. The weight affects the speed and responsiveness of the board, as well as adds more strain to the motors and decreases the speed and acceleration because of an increase in drag through the water. In order to keep our rider safe, the electronics of the board must be completely cut-off from the elements. Our throttle control and battery life monitor feedback systems also keep the rider safe by keeping the rider in full control and fully away of the board's abilities.

Overall Goals and Objectives:

1. Easy to use
2. Board-to-Rider feedback
3. Light weight
4. Durable
5. Waterproof
6. Throttle controlled
7. Safe
8. Versatile

2.3 Requirement Specifications

After recognizing and defining the goals and objectives, the requirement specifications can also be defined. Requirement specifications define quantitative aspects of the design as well as some of the physical aspects.

Three simple aspects can ideally define the performance of the Electri-Surf board: does it run, how long does it run, and how fast does it go. The board should be capable of running for half an hour on a single charge and be capable of reaching speeds 5-10 miles per hour depending on the weight of the rider and the conditions of the water.

Half an hour may not seem like a long period of time but the average wave in the ocean usually only readable for a few seconds and most boat towing sessions, such as wakeboarding, usually last one to three minutes. Comparatively, 30 minutes of actual stand up surfing time is a very long period of time and the rider will more than likely start to fatigue before the batteries fully dissipate. The similar commercial products in category of watersport technology tend to run from 15-45 minutes. Forty-five minute runtime is rare and usually achievable with low speeds and very lower power output. The average running time for the few electric powered surfboards in production or that are at least in prototyping are about 25 minutes that achieve speeds upwards of 20^+ miles per hour.

A wireless handheld Bluetooth throttle control system will be used to adjust the speed of the motors. According to Bluetooth.com, Bluetooth was created in 1994 and is a powerful wireless connection tool that is used to replace physical cables between communicating units using radio transmissions. The high quality of streaming allows for a high bit rate of transmission and near real time response. Table 2.3 -1- represents the requirement specifications.

Requirement Specifications	
Ride Time	30 Minutes
Electric Powered Motor	Operating at 730 or 1280 RPM/V
Weight	40 Pounds or Less
Wireless Communication	2.45 GHz Operation Frequency
Wireless Connection Range	6 Feet Minimum
Engine Cut-Off Range	10 Feet
Battery Durability	2 Recharges in 24 hours

Table 2.3 -1- Requirement Specifications

3.0 Research Related to Project Definition

Researching related projects and topics are very important when realizing this type of uncommon, non-commercialized project. If our project idea was a common item or popular among water sports enthusiasts then there would be an abundance of information on the topic. However, our project idea belongs to a very niche category of watersports and only a few similar products are successful worldwide. Outside information will be pieced together to assist our design understanding and component necessities. Related products or homemade projects can be very helpful in avoiding problems that other people have encountered.

3.1 Existing Similar Projects

Existing electric powered surfboards are not a common product in production. In fact, we could only find 4 or 5 different models world wide that are currently being manufactured or will be manufactured soon. The three companies that produces a product that closely resembled are design are Aquila, Wavejet Propulsion, and JetSurf.

3.1.1 Aquila / Onean

Aquila is a spinoff company of Engineering Bizintek Innova and started the project of creating an electric propulsion surfboard in 2013. Aquila is located overseas in Spain and from what our research has provided us, Onean is the sister company of Aquila and they are nearly identical to one another. Aquila has yet to distribute their three different models of electric powered surfboards but they are for pre-order at about $4,000 and will be launched at the end of 2015.

Aquila offers three different models of their electric powered surfboards, the Carver, the Manta, and the Blade. Each of the three boards were designed for different types of riding. All three boards are jet boards and utilize a dual-core brushless electric motor and their own designed electric drive and electric components. Aquila's most popular and most well rounded model is the Carver. This unit's power dissipation is around 4400W and it weighs approximately 26.5 pounds without the battery. The Manta model is the slower more stable model with a top speed of 4.5 miles per hour and was designed for less experienced riders. This unit weighs approximately 35 pounds without the battery installed and can sustain battery life for up to two hours. Aquila's third model that has yet to be available for pre-order is the Blade board. The Blade board was created for more speed and able to sustain more aggressive maneuvers. This particular model can reach speeds of 33 miles per hour.

3.1.2 Wavejet Propulsion

Wavejet Propulsion is a company based out of California designed to incorporate its wavejet propulsion technology in surfboards, stand up paddleboards, and kayaks. Wavejet creates a pod type of propulsion system unit that can actually be attached or detached to any type of board or kayak with the appropriate size cutout for it. The propulsion unit is designed so that it can be used in multiple type boards and easily popped out and inserted into another wave riding structure. They also have a blank shell pod that can be used to fill the void of the propulsion pod and convert the wavejet board into a regular board if the rider does not wish to utilize the propulsion system, or if the unit runs out of battery.

The wavejet propulsion system is activated and controlled by a wireless Bluetooth wristwatch type device. This wrist control device does not have an adjustable throttle, it is an on or off type of activation since the motors are not too powerful and only propel an average size rider at about 5mph. In our design, we plan to use some type of pressure throttle system where the amount of thrust can be controlled.

3.1.3 JetSurf

According to Jet-Surf.com, JetSurf is an international company from the Czech Republic that was founded in 2008 with the intentions to expand the boundaries of watersports. They created a gas-powered surfboard that seems to be more powerful and durable than the battery powered products that the previous companies make. JetSurf makes three different models, the factory model, the ultra sport, and the pro race.

The three models can be purchased with either an 86cc engine or a 100cc engine and are used in water racing events as well as for aerial tricks. The pro race model utilizes a 100cc 2-stroke engine that can reach speeds of 35mph across the water and weighs in at a mere 30 pounds fully fueled. Despite being gas powered, these boards still use a Li-FePO4 battery for the throttle, automatic start/stop function and other various controls. The battery is not recharged by the engine so the battery must be charged manually and has a 4-hour run time. The ultra sport model is slightly heavier than the pro race mode, weighing approximately 32 pounds and is equipped with a smaller 86cc motor. Other than the engine size and the board material itself, both models are very similar and have the same external and internal features. The factory model is very similar to the pro race model and comes with a 2-stroke 100cc engine and comes in at an overall weight of approximately 42 pounds.

3.2 Relevant Technologies

3.2.1 Battery Monitoring

Several technologies were evaluated when it came to deciding how monitoring battery life would be accomplished. The technology used needed to be programmable, small and reasonably priced. The goal of the battery monitor is to be able to report how much power there is in the source as accurately as possible. The monitor should be programmable in order to be compatible with meeting the desire of displaying the battery life using LED indications. Size is an important factor due to the limited space of the design, therefore, the smaller the monitoring system the better. Finally, the price of the monitor should be affordable yet still perform well. Cost must be carefully taken into account due to a limited budget/spending plan for this design. The following battery monitors were compared in order to understand which would best suit the needs of the design requirements:

- Maxim Integrated DS2438
- Canara UPS and Battery Monitoring System
- BTECH S5
- Vexilar D-130

Each of these monitoring systems met a majority of the requirements for the design which is why they were selected to be compared. Only general qualities of these monitors were observed at first so after further evaluation, more details were revealed for the systems and helped factor out the least useful products.

Maxim Integrated DS2438

This battery monitoring system was the ideal choice in comparison to the others. The DS met every requirement desired for the monitor. It is programmable, inexpensive and fairly small. The only issue with this monitor is that it comes with its own LCD screen to display the battery life. This would be advantageous in a different situation, however, the display of the battery life was intended to be shown using LEDs. This issue is only minor because the monitor will be connected to a microcontroller which will allow the ability to design the output reading in the intended way.

Another thing that raises concern with using the DS2438 is the low input voltage range. This monitor requires the input voltage to be much less than the voltage of the battery that we want to use. This means that the monitor would not be able to read the battery life of the battery until it reached this input level which is half of the battery voltage. By this time the monitor would serve as very ineffective. In order to improvise to make the monitor be useful a voltage regulator will most likely have to be implemented before the battery and DS2438 connection.

Canara UPS & Battery Monitoring System

The Canara monitoring system was another system that would really provide a lot of benefits however it did have a few limitations that did not exactly fit the criteria of the design. This system was made more for monitoring larger scale power systems such as those in buildings. Also this system was quite large compared to the other technologies which was not ideal since space was a limiting factor for the board design.

BTECH S5

The BTECH system was very close to becoming the first option as the battery monitor of choice. This system was similar to the Canara unfortunately because it was also made to large scale systems. This monitor was small and already has built in LEDs which was ideal but it could was much more cost inefficient than the other systems. This system also required more power to operate it which was a big issue since power was very limited and is something that wanted to be conserved as much as possible.

Vexilar D-130

The Vexilar was a much simpler system compared to the rest that were analyzed. This worked by simply attaching the positive and negative ports of the battery to the monitor and the battery percentage would show up on an LCD screen. The Vexilar is just a battery gauge that can be bought in a neighborhood store and used to read a voltage. This system was very basic and cheap which made it something to consider yet not aim for. This will most likely be used if any issues were to occur when using the first option of the DS2438. There is no other use for this product except maybe implementing it for testing or analyzing voltages at certain points of the circuit but a voltmeter is most likely to be used for this.

3.2.2 Propulsion Systems

There are two primary types of propulsion systems to consider when building an electric powered surfboard. The first type to consider is a basic electric motor that can be powered by some type of lithium batter and connects to a drive shaft with an external propeller at the end of it. Secondly, a jet drive could be used which has an internal impeller. Both units require an electric motor and rechargeable battery source.

There are many types of electric motors that can be used. Primarily, we are leaning towards using the type of electric motors that are used in large RC boats because they are designed for water purposes. The type of motors that appears to be the best suited for an electric powered surfboard the Turnigy AquaStar sensor-less brushless motors. The Turnigy AquaStar T20 3T with dual operation configurations of 730 RPM/V or 1280 RPM/V water-cooled brushless motor appears to be large enough to power a strong enough jet unit or larger enough propeller. We would most likely need to utilize two motors and jet units to acquire sufficient thrust through the water. Brushless motors are ideal because they generate little to no friction. This particular model is designed specifically for large RC boat applications and features a built-in water-cooling jacket. The water-cooling system may add further complications to the design as well as a little bit of weight but some type of cooling system may be necessary with the amount of strain the load will put on the motors. The dimensions of the Turnigy AquaStar T20 3T motor have been recreated in table 3.2.2 -1- and represented in Figure 3.2.2 -2- with the permission of hobbyking.com.

Features:

- Dual Configuration Allowing for 730 RPM/V or 1280 RPM/V Operation
- CNC Machined Billet T6 Aluminum Motor Can
- High Purity Copper Windings
- Powerful Sintered Neodymium Magnet
- Precision Engineered for Maximum Energy Conversion
- Water Cooling Jacket Pre-installed

Electric Motor Dimensions: Turnigy AquaStar T20 3T 730/1280 RPM/V	
Weight	971 grams
Can Diameter	56mm
Can Diameter Including Water Jacket (A)	63mm

Can Length (B)	102mm
Shaft Diameter (C)	8mm
Shaft Length (D)	32mm
Total Length (E)	134mm

Table 3.2.2 -1- Electric Motor Dimensions – Recreated With Permission of HobbyKing.com - Refer to Appendix A

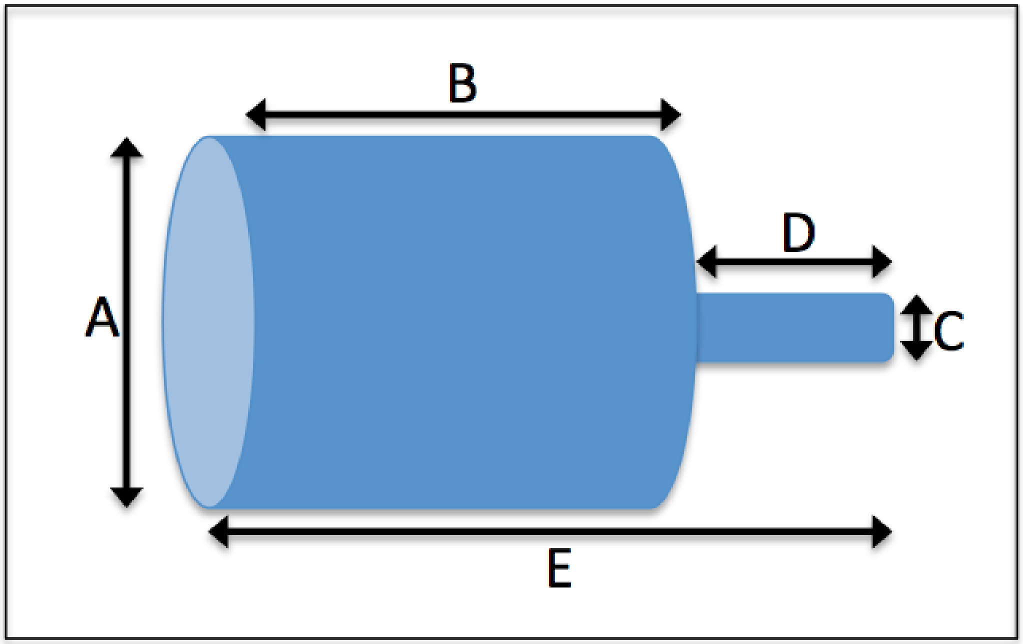


Figure 3.2.2 -2- Motor Dimensions – Recreated With Permission of HobbyKing.com - Refer to Appendix A

3.2.2.a Drive Shafts and Propellers

If an external propeller is used as the form of propulsion then the Turnigy AquaStar T20 3T 730KV/1280KV motor defined above should be suffice. In order to keep the motor out of the water, we need to connect a drive shaft to the shaft of the motor. Our drive shaft needs to be compatible with our 8mm motor shaft and approximately 8-12 inches in length. The drive shaft will then exit out the back of the housing unit through a watertight exit into the water at a slight angle to achieve maximum efficiency from the propeller(s).

3.2.2.b Jet Drives

Jet drives appear to be the best choice when propelling our surfboard. A jet drive is similar to the type of propulsion system used on a jet ski and uses an impeller (internal type of propeller). The unit mounts inside a housing unit with a bottom vent exposed under the mounting unit that sucks in water and runs it through the impeller and out the exit that will be out the back of the housing unit, giving the board more efficient thrust than a typical propeller.

The jet drive we plan to use for our design is the CNC Precision Jet Boat Drive – X – Large. This is a jet drive large enough to support the weight of an average size rider and two could be used to significantly increase the amount of thrust. This particular jet drive is made out of aluminum so it will be extremely durable. However, such ideal features come with a hefty price tag of $403 as found on hobbyking.com. Table 3.2.2.b -1- and Figure 3.2.2.b -2- provide dimensions and features of the CNC Precision Jet Drive.

Jet Drive: CNC Precision Jet Drive Features	
Drive Shaft	8mm
Impeller Size	53mm
Number of Blades	4
RPM’s	13,900+

Table 3.2.2.b -1- Jet Drive Features Reprinted With Permission of Habbyking.com

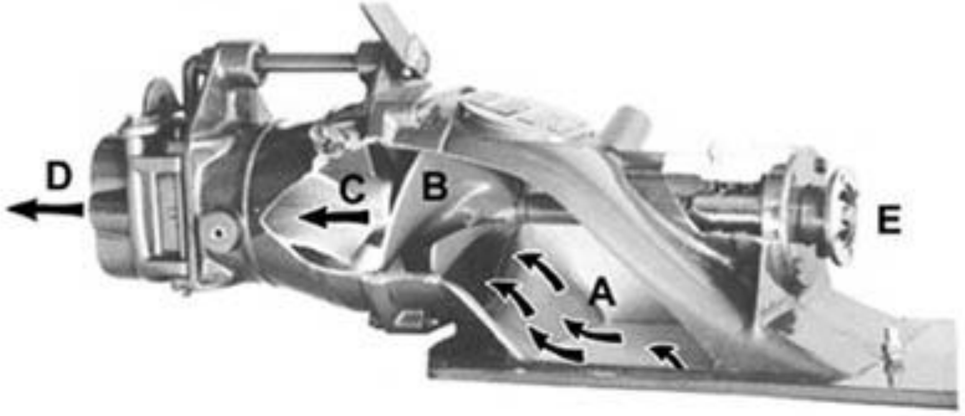


Figure 3.2.2.b -2- Jet Drive Principle Design (As Seen on Google Images)

3.2.3 Rechargeable Battery

Rechargeable batteries are very popular in the RC hobby community because they are cheap, lightweight, and economically friendly. They can be reused over and over until a decline in performance becomes evident. Because of the versatility and practicality of RC type rechargeable batteries, we will power our desired motor whether we implement a jet drive or standard drive shaft and propeller in our design. There are a few popular types of rechargeable batteries on the market for small motor type of applications as specified in section 3.2.2. The primary difference that contributes to the performance of a rechargeable battery is the material of which the battery is made up and of course the size and number of batteries incorporated into the battery pack. According to our research, the three most popular batteries used are NiCad, NiMH, and LiPo.

The NiCad battery is composed of nickel (Ni) and cadmium (Cad). NiCad batteries come in all sizes and weights for different applications. This particular kind of battery can produce a high current discharge for its size and has a very respectable power-to-weight ratio. Despite decent performance specifications, they are considered to be old technology as other types of rechargeable batteries have superseded the NiCad batteries.

Another popular choice in RC applications is the NiMH battery (nickel-metal hydride). This battery has similar performance capabilities as the previously mentioned NiCad battery. Both batteries operate using a chemical reaction using nickel oxyhydroxide but this battery uses a different alloy instead of cadmium like in the other battery. This type of battery can be very powerful but is typically very heavy when used for larger applications, such as our design, and takes a long time to charge. NiMH batteries can also be a little more temperature sensitive and could require more extensive charging and discharging temperature detection systems. A downfall for both the NiCad and NiMH batteries is that they develop what is called memory. Memory, when referring to a rechargeable battery, is when the battery “remembers” its previous charge and will then act as if its previous charge is its maximum charge and acquires characteristics of a smaller sized battery if not fully charged every single time. This can greatly decrease the battery life and performance if not properly charged.

The most popular type of rechargeable battery is the LiPo battery. This battery is composed of lithium-ion polymer and is considerably lighter weight than other rechargeable batteries. Unlike the NiCad and NiMH batteries, LiPo batteries don’t have a “memory” which improves the overall life of the battery. LiPo batteries can be used repeatedly with little to no effect on the battery itself and can be charged several times a day. Some of the other battery materials deteriorate when drained and charged repeatedly. LiPo batteries have a more efficient power/weight ratio than other batteries and are overall lighter in general, making them perfect for water applications. Due to all of the advantages of the LiPo battery, that is the type of rechargeable battery we implement in our design.

After researching many different types of batteries of various sizes and composition, LiPo batteries are the best suites our needs to power our motor(s). Hobbyking.com has been a very resourceful website with a large abundance of options and search criteria. We wanted to be able to find a battery big enough that could support running our motor and jet drive without over heating or dumping charge too quickly. We limited our search to larger batteries over 300 grams and came across the FlightMax 5000mAh 6S1P 25C made by Zippy. This particular battery is a 6 cell LiPo with a weight of 772g and is used for RC aircrafts and boat applications. It has a 5000mAh capacity and voltage of 22.2 V. Wires, plug, and shrink-wrap are included. The product dimensions and specifications are represented in Table 3.2.3 -1- and Figure 3.2.3 -2-.

Battery Specifications: Zippy Flightmax 5000mAh 6S1P 25C	
Weight (Including Wires and Plugs)	772 grams
Length (A)	143mm
Height (B)	50mm
Width (C)	51mm

Table 3.2.3 -1- Electric Motor Dimensions – Recreated With Permission of HobbyKing.com - Refer to Appendix A

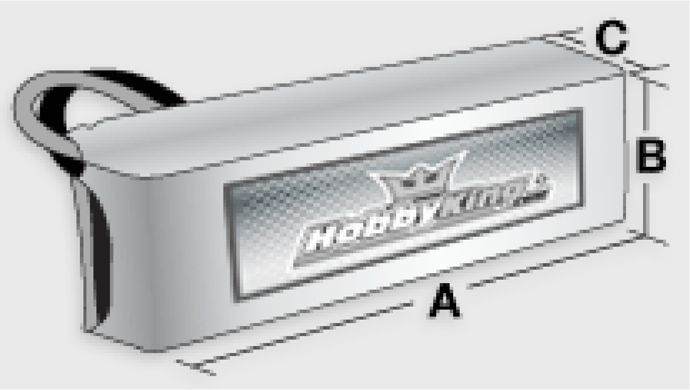


Figure 3.2.3 -2- LiPo Batter Dimensions– Refer to Appendix A

Even though rechargeable batteries are relatively safe and user friendly, they still can potentially pose a safety hazard while being charged or to the operator of our electric powered surfboard while in use. Because of the large amount of power output these batteries are capable of expending, heat will always be a concern. The chemical makeup of LiPo batteries pose the possibility of combustion if overcharged or punctured and the use of a fire retardant bag is recommended. The risk of being punctured is relatively low for the type of solid battery we will implement in our design and is a greater risk when using a pouch type of LiPo battery. Short-circuiting the battery can also quickly cause the battery to ignite. Though rare, an internal short inside the battery itself could be catastrophic. Another thing we must keep in mind in terms of battery safety is that if our LiPo battery catches on fire, it is a chemical fire and requires a class D fire extinguisher that is recommended for combustible metals.

3.2.4 Battery Charger

There are a couple of components necessary to charge a LiPo battery like the one we are going to implement in our design. An AC power source is needed, such as a wall outlet, and an AC-DC converter to charge the actual battery. A sufficient charger for our purposes is an IMAX B6 AC-DC charger. This particular charger is standardized for the United States or Europe and can utilize 100-240V AC voltages and convert it to DC voltage. The charger itself is microprocessor controlled and can charge 1-6 cells with individual cell balancing. This specific IMAX charger package conveniently comes with the appropriate cables required to charge our desired model of LiPo Zippy battery. Overcharging can damage or destroy a rechargeable battery but according to the charger specifications, this microprocessor-controlled charger has the following safety features to help prevent overcharging:

- Terminal voltage adjustment
- Data storage
- Input voltage monitoring
- Charge current limit
- Delta-peak sensitivity

3.2.4.a Battery Charger Safety Bag

LiPo batteries have a chance of igniting when charging if over charged or if an internal short happens. A LiPo fire can be very dangerous because it is fueled by combustible metal. The risk of a fire is greatly limited by the fact that we will be using a microprocessor-controlled smart charger with voltage and current monitors and individual cell balancing but a LiPo battery safety charging bag is highly recommended, especially if the battery will be charging while unattended. Safety battery charging bags are made of fireproof thread and are simply used to house the battery while plugged into the charger to contain a fire if one were to erupt within the battery.

3.2.5 Throttle Design and Speed Control

Since the board needs to be controlled wirelessly, the motor needs to be regulated to operate at multiple speeds using a potentiometer. Without the potentiometer the throttle will not serve much use and the board will operate as either on at full power or off. The potentiometer provides the capability to regulate how much power is being sent from the battery to the motor. This will need to be regulated by the throttle which is connected via Bluetooth. In order for the throttle to be able to send information to the potentiometer, the potentiometer must be controlled by a program that will be constructed and stored in a microcontroller. The microcontroller that will be used for this process will be the Arduino. The microcontroller will be formatted to control the speed according to the specifications found in Table 3.2.5 -1-.

Speed range	Potentiometer resistance	Vout
0-5 mph	10 k	2-10V
5-8 mph	6 k	15-19V
8-10 mph	0	20-22V

Table 3.2.5 -1-

Each speed increment should be defined by a range due to the prediction of having a user with a different weight. This may cause the board to function slightly different in a way that for a heavier user more power will be required to push the board at the speeds listed. The potentiometer connected to the circuit board can be found in Figure 3.2.5 -2-. Because the potentiometer requires the user to physically turn it, it cannot be just connected to the board. In order for this to function properly, two Arduino boards must be used. These boards will send information to each other via Bluetooth. The first circuit board would contain the Bluetooth receiver to obtain the message from the throttle of what the speed will be. The second board would contain the potentiometer and be installed in the throttle. Based on whether the user wants to increase or decrease the speed the potentiometer will adjust the resistance accordingly. The second board will send a signal to the circuit board installed on the surfboard, this is the one that does not contain the potentiometer, so that the speed of the motor can be adjusted to either increase or decrease depending on whether the user is trying to increase or decrease the speed from the throttle.

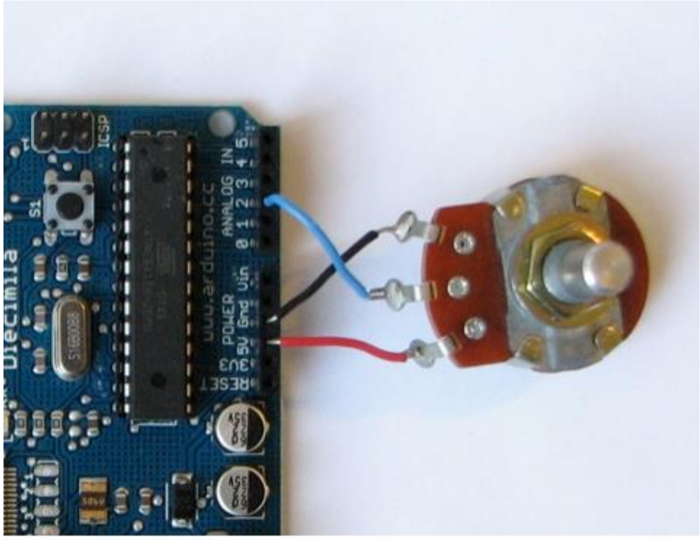


Figure 3.2.5 -2-: Potentiometer Connection

Specifications:

- Tolerance: ±25%
- Temperature coefficient: ±250ppm/°C @ -20°C~+80°C
- Taper: linear
- Operating voltage: 20VDC or AC RMS, max.
- Resolution: essentially infinite
- Contact resistance variation: .5% nom.
- Adjustment range: 15%~85% of rotation
- Power rating: .1W @ 70°C max.
- Rotation torque: 15~170gfcm
- Rotation: 1 turn, 260°±20°
- Weight: 0.11gm
- Temperature range: -20°C~+85°C
- Rotational life: 20 cycles
- Load life: ∆R≤5% after 500 hrs.
- Sealing: sealed for dip and wave soldering until silicone seal is removed
- Values: 500, 1K, 2K, 5K, 10K, 20K, 50K, 100K, 200K, 500K, 1M

3.2.6 Voltage Regulation

Since the voltage source being used supplies a voltage greater than 10 V, a regulator needed to be implemented. The converter used will be a DC to DC converter because nothing is being changed except for the amount of voltage that passes through the circuit after going through the regulator. This is so that the components in the circuit would not be fried because they require much less of an input source voltage in order to operate. To power these components a voltage of around 3-8 V is all that is required, depending on what the final design will contain. However with such a high voltage source the only way to reduce the amount being used by the printed circuit board and the components in it, a step down voltage converter will be used. This type of converter is also known as a buck converter. A buck converter uses what is called a trimmer which will choose what level of voltage the converter will output to the circuit. One problem faced with having to use a regulator to make this adjustment is the efficiency. Because the voltage supply is so high, the efficiency of the regulator is expected to drop since it has to produce such a low voltage. The lower the input voltage, the more efficient the converter is because it has to do less work to lower the voltage and lowers the chance of any losses. A few regulators were evaluated in order to obtain the one that would best fit the requirements of the design. The two regulators evaluated were the LM2596 and the TPS54239E. The specifications of these two converters are listed, which were obtained from the Texas Instruments datasheets.

LM2596

This converter is very good because it provides such a wide range of input voltage values. This is very useful due to the large voltage supplied by the battery. In addition it gives room to experiment in case the battery chosen is not powerful enough and a battery with a higher voltage is required. This converter is very efficient and its cost is pretty cheap; it ranges around $2-$3. A few of the features this converter has are listed.

- Input voltage range up to 40 V
- 3.3V, 5V, 12V and adjustable output versions
- Adjustable output voltage range, 1.2V to 37V
- Ensured 3A output load current
- Requires only 4 external components
- 150 kHz fixed frequency internal oscillator
- TTL shutdown capability
- Low power standby mode
- Thermal shutdown and current limit protection

The specifications reveal that this product is very versatile and simple. There are a few different versions of the LM2596 that are produced however only the simplest form is needed to meet the requirements. An image of the LM2569 can be found in Figure 3.2.6 -1-.

Figure 3.2.6 -1-: LM2596 Step Down Converter

TPS54239E

The TPS54239E compares almost identically to the LM2596. There are a few specifications that make it more effective however there are also some unfavorable specifications. One benefit that really makes this converter stand out is its Eco-mode function. What this does is identify when there is a load that is not requiring a high amount of power, or a light load, resulting in the device going into a power saving type of mode. This allows the device to produce very efficient results. Another productive quality is the adjustable soft start ability. This is very beneficial because it prevents the motor from being easily stressed when the power is turned on. This aids in extending the lifespan of the system. A few of the features provided by the Texas Instruments datasheet for this converter are listed.

- 4.5V to 23V input voltage range
- 600 kHz switching frequency
- .76V to 7V output voltage range

- High efficiency, less than 10 µA at shutdown
- Operates from -40°C to 85°C
- FETs optimized for lower duty cycle applications
    - 140mΩ to 70mΩ
- Adjustable soft start
- Cycle by cycle over current limit
- Low output ripple
- High initial bandgap accuracy

The TPS54239E fits most of the requirements of the design and it is very efficient which make it difficult to resist using. However the limitation of this device is that it does not regulate high enough voltages. The battery used for the board is expected to range from 20 to 30 V and the TPS54239E can only regulate up to a maximum of 23 V which limits the design to using a smaller power source. This is not ideal since the source voltage is intended to be higher than 23V.

In addition to using regulators to reduce the voltage, regulators will also be implemented to increase the voltage. This will be done using a boost converter. The boost converter will be used for a case where the voltage was reduced by the regulator but may need to be given a little more voltage to operate a device in the circuit. This is because the boost regulators, or amplifier, most of the time only bring up the voltage by a small amount therefore it is ideal to raise the voltage by a miniscule amount. Most amplifiers do not increase the voltage input greater than 3V so they are only good for these small adjustments. If a larger adjustment is needed, the amplifiers can be cascaded to increase the voltage output.

A few of the amplifiers that were evaluated were the XL6009 and the LM2587. Both amplifiers contained useful specifications to help with the design. The XL6009 and the LM2587 are capable of increasing the input voltage by almost double. Both amplifiers will most likely be used in testing because the specifications of both products do not give enough information to rule one as being better than the other. After testing has been done, one of the amplifiers will be chosen to be implemented throughout the circuit. Most likely the LM2587 will be chosen due to its availability. The XL6009 is a foreign product so it may take an extended period of time for arrival and because time is crucial in completing the design it may be too much of a risk to use that component.

3.3 Strategic components

3.3.1 Emergency Cut-off

When using the Electri-surf board the user must be able to try new things without risking losing the product or causing injury to himself. Whether the user falls off or jumps off the board there should be no risk of the board to continuously run resulting in creating distance from the user. These things can be avoided by implementing a system to cut off the boards power supply when the user is no longer on the board. In order to implement this aspect a few approaches were studied. The first of the ideas was to implement a leash that would remain on the user's ankle as they use the electri-surf. This leash would be connected to the board so that if the user were to fall off the leash would disconnect from the board and shut down the motor. This is similar to how jet skis work. Jet skis have a kill switch that will turn the Jet Ski off in the event that the rider were to be knocked off of the Jet Ski.

The other approach to implementing an emergency shut off would be to simply program the connected range of the throttle and microcontroller to a certain distance. If the throttle was to exceed the maximum distance then the motor would cut off. This design is very simple since the throttle will be using a Bluetooth connection. The connection range of the Bluetooth can be modified so this will eliminate the need to install a physical kill switch. The only problem with this is that the user can fall off the board and still be close to the board causing to motor to keep running. This creates the risk of the user being injured by the propeller on the bottom of the Electri-surf. However, this method also works better than the kill switch leash because if the rider was to drop the throttle in the water the board would keep running since the leash is still connected. Limiting the connection range makes dropping the throttle a non-issue because once the board passes the lost throttle by a certain distance, the board will stop.

4.0 Related Standards

4.1 Connectivity

This project relies on wireless connectivity and thus some knowledge must be searched via the Internet to make the best decision on which wireless connectivity to choose. Due to some of the requirements that has been implemented within the project, looking into the range of the wireless communication is key with keeping in mind also battery life. Having knowledge of the devices that are going to be used would have a better decision in which devices to use and what's the most ideal way in terms of expenses and time.

4.1.1 Wireless Communication

There will be three wireless communication systems that will need to be implemented into the surfboard. For this implementation, a wireless communication is needed to send the corresponding data that is needed to and from the handheld throttle device and the electric surfboard. The wireless device module should be ideally low power with no specifications on how fast data is sent due to the small data being sent at any given time. Due to the simplicity of the data that is being sent and received from both end point and the low power required, a Bluetooth or ZigBee device would fit good for the project.

Another module that would be implemented would be a RFID chip and sensor. This will sense that there is someone on the actual board due to the proximity range of the RFID chips, which is about 1 meter. The RFID chip would ideally work as a sensor that would be either attached to the rider or the handheld throttle to check that the user is in the same area as the board. Anything outside would trigger the system to shut down the board.

The third device that would be implemented on the surfboard would be a GPS module, which would help track the location of the user to help determine how fast the person riding the electric surfboard is going. Looking at the table at the bottom gives a general idea of their characteristics.

Looking at the Table 4.1.1 -1-, it shows the three different wireless devices that would be considered into this project, though we are only using one for our project. One particular part we are looking

Technology	Bluetooth	RFID	ZigBee
Range	Up to 100m	Up to 10m	Up to 75m
Power & cost	Very low	Low/Low	Very low/ low
Application	Android connectivity	Read sensor values	Sensor and remote controls, mesh networks
Data Rate	0.7 – 2.1 Mbps	40-640 Kb/s	250Kb/s

Table 4.1.1 -1- shows the differences between each wireless technology.

4.1.2 RFID

An RFID, or radio frequency identification, is a term for any technology that uses radio waves with a frequency bands of from around 125 KHz for a low frequency, to 13.56 MHz for high or for ultra-high frequency would be between 850-900 MHz; to automatically identify people or items. RFID can potentially be used with the handheld throttled or the user to sense if the user is potentially on the surfboard or not. This is done by having an RFID reader within the surfboard send signals to the chip within a period to retrieve a value from the chip. The signals that are sent from the reader to the chip and if the chip is within the responding range, the chip would send back a signal to the reader which would be used as a confirmation that the user is still on the board. The RFID communications are divided into three classes, which have their own specifications with respect of data, power, and range distance. Table 4.1.2 -1- displays the differences between each RFID that are out.

RFID	**LF**	**HF**	**UHF**
Range	~30 cm	1.5 m	Up to 12 m
Price	medium	medium	medium
Data Speed	low	Low/moderate	High/moderate
Power	Medium/high	Medium/low	Low

Table 4.1.2 -1- Shows the differences between the three different classes of RFID.

RFID is implemented by having two electronic devices; this would be the RFID reader and the RFID tag. Essentially what the two of them do is, when they are close enough in range, the RFID reader would send a strong signal and if the tag were close enough to be powered by the incoming signal, the tag would send back a signal with data. This sort of device would be ideal to use in the project, as it would provide a shorter range of when to have a cut-off emergency if the person using the surfboard falls off the board. Since the frequency at which the signal is sent is continuously, this could potentially be a faster way of turning off the surfboard than relying with the connection of the Bluetooth, since the RFID range is a lot shorter than the Bluetooth.

If choosing the RFID later down the road for the project, there are a few factors that are to be considered. One of the few factors to be considering is, the complexity of integrating an RFID into the surfboard. If it were too much time consuming, opting out of it and having the Bluetooth instead do the emergency stop would be more ideal. Another factor to look at would be how price, if the reader that is needed is a bit too much out of the budget that is set, then it would be scrapped and instead stick to the Bluetooth. An important factor that would be as important as budget would go would be how much power running the device would impact on the battery we use for the surfboard. One of the requirement is to have a set minimum run time, and if the RFID is drawing too much power to meet this requirement, it would not be added since its not part of the specifications that are needed.

4.1.3 ZigBee

The obvious advantage of using ZigBee devices is the low cost and power efficiency. Many of the ZigBee technology is perfect for short distance data transfer applications ie., reading wireless sensors, monitoring, and remote control. Due to the low power needed to operate a ZigBee product in conjunction with products that have a small range distance and low data transfer, it makes it an ideal product to consider to be interfaced. The ZigBee could potentially be used in a Hand-held Throttle, which would be made separately. This could be used to potentially communicate to the Electric Surfboard to send the simple data between the Hand-held Throttle and the board itself. Looking at the Table [kjlkja] shows two potential ZigBee Products that could be used, but only one should be chosen for the project. Looking at the two products, one of the few disadvantages that this product has is its range of transmission. In our project we are looking for a short-range distance in which if the user falls off the board, the board can engage the emergency mode real quick, thus having the Electric Surfboard in close proximity of the user. Another part that one needs to consider is the amount of current that is being drawn to receive and transmit. This is somewhat of a lot of amp and power that is being used to communicate with the Electric Surfboard. Lastly, the prices of the products are a bit expensive, thus we might consider other products for wireless data if there is cheaper alternatives. Comparative specifications are shown in Table 4.1.3 -1-.

Model	**XBee® 802.15.4**	**XBee® ZigBee**
Frequency	2.4 GHz	2.4 GHz
Range	30 m	60 m
Data Rate	250 Kbps	250 Kbps
Operating Volt	2.8-3.4 V	2.1-3.6
Power Output	1mW	1mW
Current Tx	45 mA	33 mA
Current Rx	50 mA	28 mA
Price	$59	$89

Table 4.1.3 -1- shows the comparison between two ZigBee Products

4.1.4 Bluetooth

Bluetooth is a wireless device, which operates similar to the Zigbee standards, which has a frequency band of around 2.4 GHz for short distance data sending, low power usage, and low costs. Using Bluetooth could be a potentially good candidate to use to communicate between the handheld-throttle and the surfboard. The handheld throttle could potentially be a smart phone that could use Bluetooth to connect to the hardware of the surfboard. While using a smart phone would seem problematic, a simple user interface within the application on the phone is good to help aid control of the surfboard. Due to the Bluetooth modules having a rather range of operation, it would be ideal to use a Bluetooth module for the project as one can find a Bluetooth module to work up to a certain distance. Bluetooth modules are generally divided into three categories in which they have their own characteristics in power and baud rate, how fast data is being transferred. Table 4.1.4 -1- shows the difference between Bluetooth classes.

Class	Max power (mW)	Max Power (dBm)	Range (m)
1	100	20	100
2	2.5	4	10
3	1	0	1

Table 4.1.4 -1- Differences between the Bluetooth classes device

Bluetooth connections are implemented using a master-slave structure to control the flow of data. In a Bluetooth connection, the device that is responsible for controlling the transfer data is usually referred to, as the master, and the device that retrieves the data would be called the slave device. Even though master devices could have up to seven slave devices, potentially transferring data to them, slave devices could only talk to the master device and thus have no form of communication with other slave devices. The Bluetooth connection would work great into our handheld throttle if the decision of using a smart phone as a handheld throttle. In this case, the smart phone would be the master device and the surfboard would be the slave device. The master device would send commands to the slave device in terms of controlling the speed of the surfboard and turning the motors on or off.

If going the road of using Bluetooth technology, a lot of factors would have to be considered such as how much power is drawn, the cost of the module, and how complex the interface module is with the system. Due to the minimum requirement of distance needed for a connection and the simplicity of the Bluetooth module needed to send data, a more narrow search has been done to simplify in which Bluetooth module is best fit for the project. The differences between Bluetooth modules are displayed in table 4.1.4 -2-.

Bluetooth module	CC2564MODN	BT900	HC-05
Operating Voltage	-.5-4.8 V	3.6 V	3.3-5V DC
Size	7.1 mm x 7.1 mm	2.5mm x 12.5mm x 19mm	27 mm x 13 mm x 2 mm
Signal range	10 m	100m	10 m
Data speed	2.1 Mbps	3 Mbps	3 Mbps
Price USD	13.97	15.35	5.25
Complex Interface	easy	easy	easy
Max Baud Rate	9600	3 Mbps	9600

Table 4.1.4 -2- Differences between Bluetooth modules chosen

Taking a glance at the table and carefully considering the requirements and restriction within the project, there are two Bluetooth modules that are considered in this project. These two Bluetooth modules are the CC2564MODN and the HC-05. Looking at the sizes of these two, the CC2564MODN seems a lot smaller than the HC-05. The two modules seem to have the same signal of range. The cost of the modules, the HC-05 seems a lot cheaper to the CC2564MODN, and this might be highly considered due to the budget constraints in the project. Even though the CC2564MODN might have a smaller size than the HC-05, due to the many support of the HC-05 and the price of the module would make it an ideal Bluetooth module to use to integrate within our hardware system of the surfboard.

4.1.5 Mobile Phone

One of our options that we have, which seems like a better option, is using a smart phone device for our Hand-Throttle Device. Due to how advance smart phones have become, and the simplicity of the project, it is very desirable to have. In addition, since one can make an application for the given phone, we can code in our application what could be in the Hand-Throttle Device saving us crucial time for development and building. The main focus we look for a smart phone is ability to carry a reasonable charge, and have access to Bluetooth.

4.1.5.a Apple Platform

One way of building our Hand-Throttle Device would to use an Apple smart phone. Apple IDE to make applications is XCode. The language primarily used to make applications is swift and Ojective-C. With a great community support if there is any help at a given time, one item that catches our attention is Apple’s one-time initial fee of $99 to actually make apps to put into your phone. With the very little to no experience, this path is not very ideal to us.

4.1.5.b Android Platform

Another platform that came into our mind was the Android platform to build our application and device. Android language that is used to create applications is Java. There are many IDE’s out there such as Eclipse which can be used to create applications. Other IDE’s could potentially make applications too with little knowledge of coding. One of the things that draw my attention is one can create applications and use them on the phone for free and there is a huge community that can be used for any help that might arise. In addition to having one of our members be knowledgably in java, this would be a very considerable choice.

4.2 Microcontrollers

Looking at the specifications of our project, a few components the microcontroller would need to support. Since we are dealing with a Bluetooth module, one of the components that the microcontroller needs to have is a UART connection pin. Another component not required but more considered is to have support for PWM. Due to the fact that we have a DC motor used on the Electric Surfboard, having support for a PWM pin would save space, time, and money on our project.

C2000 Launchpad: The C2000 from Texas Instruments family is a great processor for the price. When you order the C2000 LAUNCHXL-F28027, you get: TMS320F28027. One of the perks of the processor is the tool's that are provided, which makes downloading code onto the chip very simple. Since the only interface the development board has is a USB port, it provides power and a way to the processor to burn the code into its flash memory.

Looking at the Table 4.2 -1-, it gives a glimpse of the specs of the microcontroller. The microcontroller seems like an ideal MCU to go with for our project, though the code space to run seems a bit low and might reconsider other microcontrollers to use. The reason for the low memory space is cause this microcontroller is more focused for hobbyist to tinker with. The power supply though is ideal, which is 3.3 Volts to operate. Having this is mind is ideal due to we want to conserve most of the battery power towards the DC motor. Another part of the processor that brings the attention is the support of UART and PWM. Due to using Bluetooth module in our project, the use of a Bluetooth module on this processor would be supported. Having a PWM, Pulse Width Modulation, support is also good since is needed to control the speed of the DC motor that will be connected. With an outstanding support of the TI community, if there are any issues that creep up, help could be managed through forums or TI itself. The IDE that TI uses for its microcontroller is Code Composer; through there are alternatives to use that are open source. GCC has a nice perk, that is it has a package that supports linking, compiling of the code, and loading of the program used by the C2000 through the USB connection interface. It also has a lot of command line tools that makes it easier to debug the C2000 by dumping the information within the C2000 processor, though this would limit the space of the microcontroller to use.

CPU	C28x
Frequency (MHz)	60
RAM(KB)	12
Flash(KB)	64
PWM(Ch)	8
ADC	12-bit

12-bit A/D (#Channels)	7/13
I2C	1
UART	1
SPI	1
Timers	1 watchdog & 3 32-Bit GP
GPIO	20/22
IO Pin Voltage	3.3

Table 4.2 -1- Specs of the C200 processor

ATmega328P: The next microcontroller in mind was the ATmega328P, which is made by Atmel Corporation. This microcontroller seems ideal for the Electric Surfboard since the specs support the requirements that we have. Looking at table 4.2 -2-, gives a overall glimpse of the spec of the ATmega328p microcontroller. One aspect to look at for this microcontroller is the operating voltage, which can be as low as 1.8 Volts. This is something to look at since we want to have most of the power used by the battery for the electric surfboard. Another aspect is that it supports Bluetooth, UART connection, and has a couple of pins for PWM which is ideal for using for the DC motor on our project. One part to remember for the processor though there’s not much forum or community that is willing or provide support for this chip, thus a greater amount of our resource would be trying to Figure out any problem that may persist. While it being an 8-bit processor, our specifications and task that we do should be sufficient using an 8-bit microprocessor.

CPU	8-Bit AVR
Frequency (MHz)	20
RAM(KB)	2
Flash(KB)	32
PWM(Ch)	6
8-bit A/D (#Channels)	6
I2C	1
UART	1
SPI	1
GPIO	14
IO Pin Voltage	7
OP Voltage	1.8-5 V

Table 4.2 -2- specs of the ATmega328P

EFM8BB31F64G-QSOP24: Another processor that was considered was the C8051 microprocessor from the EFM8 Busy Bee family made by Silicon Lab Corporation. This was another microcontroller to be considered to specs it has which meets the requirements we are seeking. Looking at the Table 4.2 -3- gives you a general spec of the processor. One of the good perks of this processor is that you need between 2.2-3.6 volts for operating, which is something we want. Another part it has two UART connections, even though it would be overkill, since we only need one. Another part of this microcontroller is the speed, which is a lot faster than the other microcontrollers, which is good. In addition, this microcontroller has adequate space for our code to run on. With a good support community and an active community, this microcontroller seems to be another ideal microcontroller to choose from. Silicon Labs also provides great documentation, tools and libraries to mess around with the microcontroller. Such tools available would save us resources, which is time.

CPU	8-Bit 8051
Frequency (MHz)	50
RAM(KB)	4.25
Flash(KB)	64
PWM(Ch)	6
12-bit A/D (#Channels)	13
I2C	1
UART	2
SPI	1
GPIO	21
IO Pin Voltage	7
OP Voltage	2.2-3.6

Table 4.2 -3- Specs for EFM8BB31F64G-QSOP24

TMS320F28PLC84: The last microcontroller that was considered was the TMS320F28PLC84 is from the C2000 family by the TI Corporate Company. This microcontroller was highly considered due to the specs it has. Looking at Table 4.2 -4-, it gives a general aspect of the specs the microcontroller it has. One aspect of the microcontroller that caught our attention was the space we get for coding. This microcontroller has 100KB of RAN and 256KB of Flash. This is pretty nice, since one does not worry about optimizing our code for space. Another nice part of this microcontroller it runs at a 90 MHz, which is a nice speed for us if we need run into any issues that require more speed. Another part that it has is two UART connections and two PWM channels, which are needed for our projects. One last part which is nice on this microcontroller is, there a lower voltage mode, which is nice to have since we want to focus our power for the battery to use.

Coming from the TI company and being a C2000 family processor, there is a lot of support from the TI and the community, in which there are a lot of projects that use these kind of microcontrollers. With this is mind, we can use in our advantage if we run into any hiccups and get any answer in a timely manner. This is ideal since we want to waste the least amount of time, since time is short. With a strong community and TI, there is a lot of tools which can be used to debug our project. These tools can help stop at a certain point, take the values of registers and stack pointer and every other nifty part of debugging. Though all of this perks is done through the USB port.

CPU	C28x
Frequency (MHz)	90
RAM(KB)	100
Flash(KB)	256
PWM(Ch)	2
ADC	12-bit
12-bit A/D (#Channels)	4
I2C	1
UART	2
SPI	2
Timers	1 watchdog & 3 32-Bit GP
GPIO	40
IO Pin Voltage	-.3-4.6

Table 4.2 -4- specs for the TMS320F28PLC84

4.3 FPGA

While there was a couple of microcontrollers we consider for our project, we also did some research if FPGA would be an ideal choice for us. Some advantages that the FPGA has is that it focus on concurrency. Meaning, one can control any kind of input/action in real time. This would ideal if we relied heavily on the input from the user at real time, though this is used in our project. Another advantage an FPGA has is its versatility. While this might look like an advantage due to the fact you can create any platform in mind, for this project it would cost us more due to the fact that one has to purchase the overhead to make it work. When having the microcontroller, one only has to Figure out which hardware pieces one need at ease. Even though the FPGA provides versatility within its board with real time results, the versatility of it makes it too much. Another disadvantage of using an FPGA is that it uses HDL to get things going, at which no one in the group is experienced at doing. Another consequence of messing with FPGA is the power consumption; they use a lot more power than microcontrollers, and this is one part we want to keep low. In addition, having to use an FPGA, even though its doable having to do Bluetooth modules with UART connection is pretty hard work and difficult to do, which is something we don't the resources within the project. Overall, the versatility and real-time results, even though a great advantage is not part of the niche we are looking for.

4.4 Possible Architectures

4.4.1 Hardware Diagrams

4.4.1.a Hand Throttle Diagram

Figure 4.4.1.a -1- displays a diagram that visualizes the process of when the user is connected to the Electric Surfboard and is changing the speed with the Hand-Throttle device. Looking at the diagram, the Electric Surfboard will not commence any action unless there is a connection going between the Android Device and the Bluetooth module. Once a connection has been established, the user has control of the speed of the board. When the user presses the Vol + key on the Android Device, the application will check if the current speed is the maximum and if not, send the new set speed through Bluetooth to the Electric Surfboard. If the user reaches a maximum speed and is trying to increase the speed, it will not do anything and instead will send a blank message, which the microcontroller will read as a do not change speed. If the user presses the Vol – key, the application will check if the current speed is not minimum, if not adjust the speed and send the signal via Bluetooth to the Electric Surfboard. Though if the application see's that the current speed is the minimum, it will send to the Bluetooth module of the Electric Surfboard a blank message to have the current speed not changed. If the user happens to be distant from the board, the application would notice the user that Emergency mode has been tripped, and since the Electric Surfboard lost connection, it will go to Emergency mode, which will shut down the motors so the board can stop.

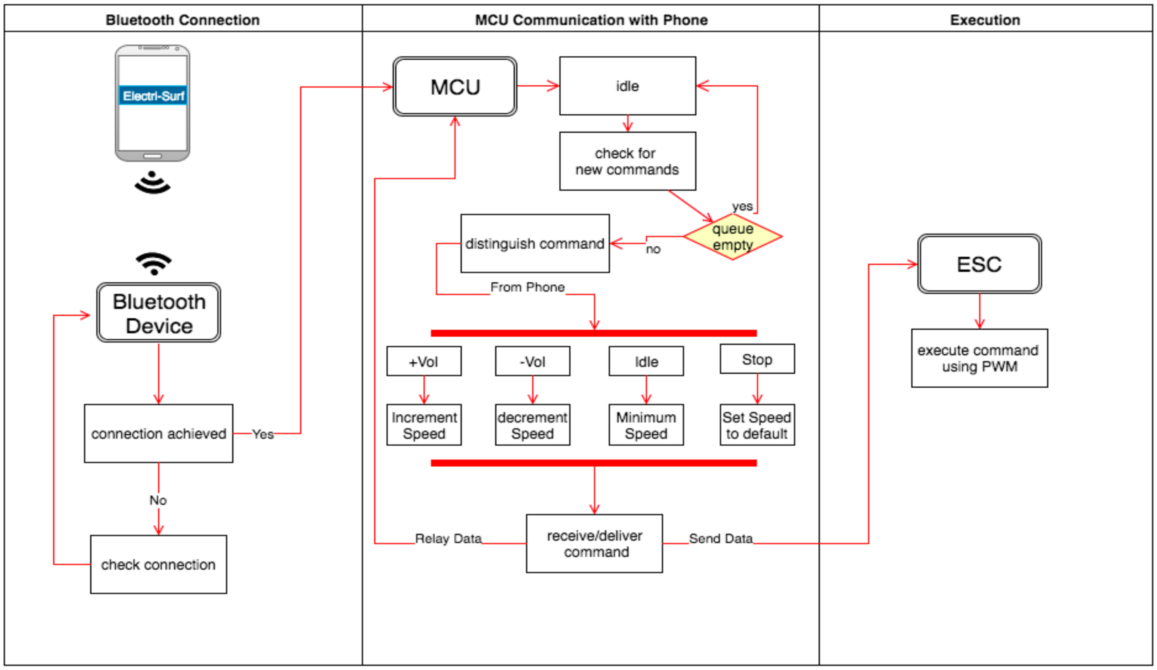


Figure 4.4.1.a -1- Diagram showing how the Hand-Throttle inputs control the electric Surfboard

4.4.1.b Electric Surfboard

The main core of the Electric Surfboard is within, the hardware that is built inside, and what helps it navigate is the Hand-Throttle device. In Figure 4.4.1.b -1- displays the hardware block diagram and the flow of control, power and data. The battery will go through a step down converter inside the esc for the MCU to use. It will also be connected to the motor and the Smart Battery Display. In addition there will be a voltage divider to power the Bluetooth module that will help send data to the Android device. The connection that is between the MCU and the Smart Battery Monitor is to display information about the battery for the Hand-Throttle device. From there data would flow from the Bluetooth module to the MCU through the UART serial connection, which would control the Electric Surfboard. The Bluetooth module would also send data back to the Android device depending on what is requested.

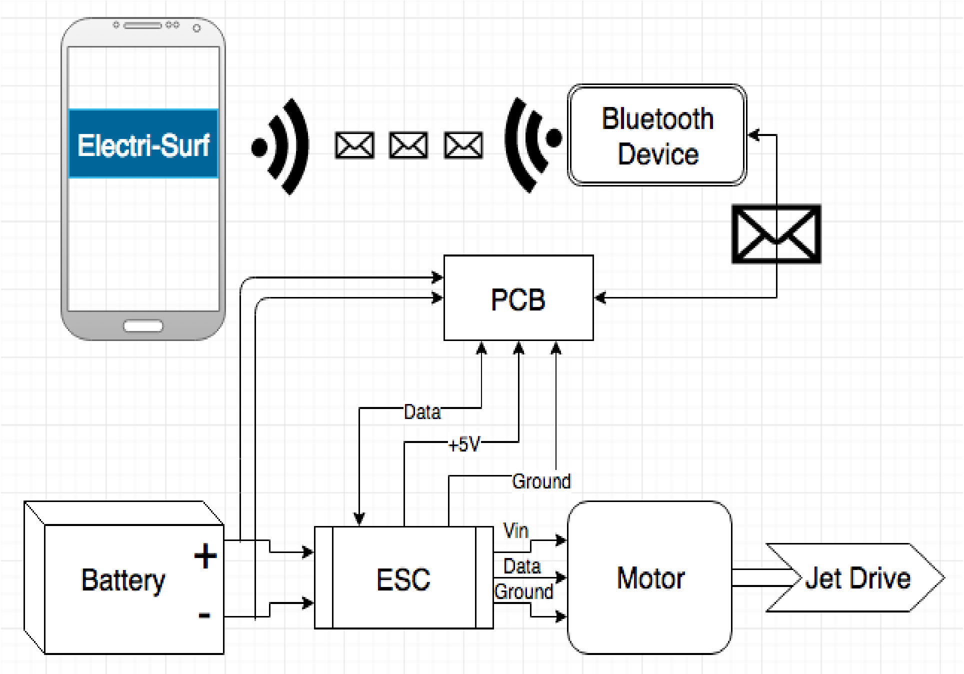


Figure 4.4.1.b -1- shows the flow of power, data, and signals across the Electric Surfboard hardware.

4.4.2 Software Block Diagram

Figure 4.4.2 -1- shows a block diagram of the surfboard software. The diagram shows how the data flows within the whole system of the surfboard and the handheld- throttle. From the handheld-throttle the data is sent to the MCU to the motors and battery and back delivering the appropriate information.

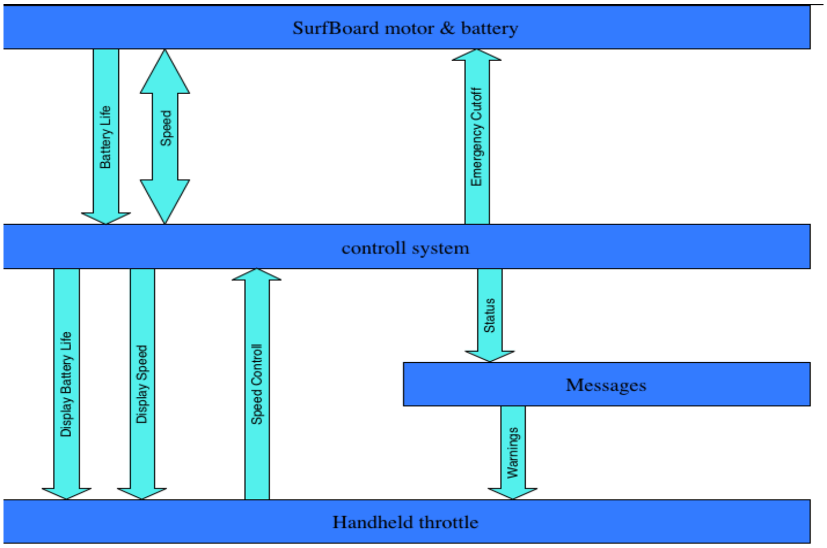


Figure 4.4.2 -1- Block diagram of the Electric Surfboard software.

4.5 Hardware

4.5.1 Hand-Throttle Device

Due to the simplicity that an Android device has, it is a better choice to choose an Android device as our Hand-Throttle device for the Electric Surfboard. In addition, due to the hardware that an Android device has, it is sufficient enough to what we want, instead of building our own Hand-Throttle Device from scratch. Our choice of the Android Device was the HTC-One M9 phone. One of the qualities of this phone is that it runs Android OS 5.1 and has Bluetooth connectivity. Other specs of this phone are that it has a multi-touch touchscreen for the user to interact, a Qualcomm Snapdragon 810 Quad Core, 1.5GHz processor.

To verify that in the testing phase data is being sent and received through the Bluetooth module, the Android device will have access to the BlueTerm application, which is a Bluetooth emulator that could send data to the Bluetooth module of the Electric Surfboard. The BlueTerm application will be used to send data to the Bluetooth module to verify that, the Android device is able to transmit data to the Bluetooth module, and that the Bluetooth module receiver is able to receive data. This application is found in the Google Play Store, at a free cost.

Looking at the Figure 4.5.1 -1-, it illustrates a simple block diagram showing how the Android phone will be able to control at the Electric Surfboard's micro-controller. Looking carefully at the block diagram, it takes a couple of processes for the data sent from the M9 to reach the micro-controller. First of all, an application needs to be created for the Android phone to use the Bluetooth function to get the data registered by the user to be sent. This data sent should be in the form of ASCII characters. Once the data is sent, the HC-05 Bluetooth module would receive the data, triggering the micro-controller to read the data through the UART serial, where the ASCII character read from the UART will determine the course of action the micro-controller will do.

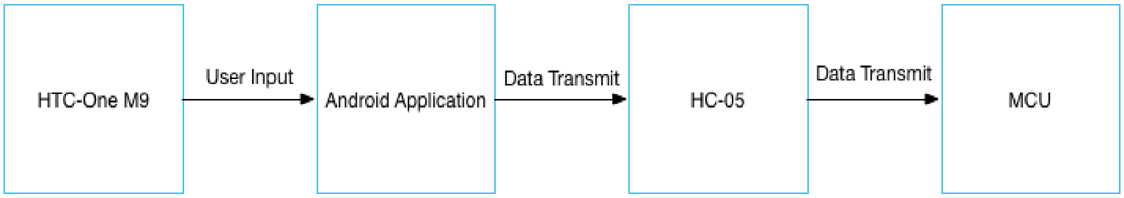


Figure 4.5.1 -1- Block diagram displaying the Hand-Throttle using the HTC-One M9

4.5.2 Microcontroller

The microcontroller that was chosen for this project is the ATmega328p from Atmel. Looking at table 4.5.2 -1- shows some of its important features that correspond for the project.

Frequency (MHz)	20
RAM(KB)	2
Flash(KB)	32
PWM(Ch)	6
UART	1
Timers	1 watchdog & 3 32-Bit GP
GPIO	14
IO Pin Voltage	5 V

Table 4.5.2 -1-

The microcontroller processor was made for all the features that the Electric Surfboard could utilize and a bit more. The frequency of the microcontroller is high enough to keep up with the code that is dumped into the microcontroller and still be adequate in executing instructions. The flash space is adequate enough to hold any code coded in C/C++. In addition to this, it gives an advantage to use useful tools that would need more room, such tools include operator overloading, some functions and libraries. The PWM, or Pulse Width Modulation, channel will be used exclusively by the DC motor that's mounted on the Electric Surfboard. Since a Bluetooth module is used in the project, the UART pins will be used to transmit and receive that accordingly. The connection pin of the UART is the soul place that would control the Electric Surfboards speed. The GPIO pins makes it possible to connect any external devices that one might find useful. The pins would be connected to LED's to serve as feedback and debugging purposes.

4.5.2.a Pin Settings

There are only a few pins that are important that will be used for the Electric Surfboard device. One of those pins is the UART(SCI) pins for the communication between the Android device and the Bluetooth module. UART connection is done with two separate pins on the ATMega328P microcontroller; one pin is for transmitting and another one for receiving. For receiving data, pin 30, RXD will be used for the Bluetooth module. For transmitting data, pin 41, TXD will be used for the Bluetooth module. These pins are tied to register controls TXD and RXD. GPIO pins 1, 2, 10, 11 will be used for turning the LED and Bluetooth on. Using three specific colors, green, yellow and red will be used on pins 1, 2 and 10, respectively to tell which mode the board is on. Pin 11 would be used to turn on the Bluetooth module on from the microcontroller. For the PWM channels, PWD will be used for to control the motor on the Electric Surfboard, which will be tied to pin 21.

4.5.2.b Algorithm

Many algorithms are used commonly over and over, one of them being the handling of messages created. When the message arrives, the message will be sent into the MessageCreator, there it'll check that the message that came is valid and perform the corresponding action. The MessageCreator would then return a new message, with a function unpackmessage(). When the whole message is retrieved, a function within messagerun() will be called to perform any action that the message received intended to.

With the runmessage(), it is a function on each mode that is in. With having runmessage() call, it also calls, checkmessage() function. This happens to know what kind of message it is and what to do at the beginning. What the checkmessage() does is checks with the hardware class to see if there's an available message. If there is no available message, the Electric Surfboard shuts down. Otherwise, the message would be handled, this would continue what the board is doing or do a different action.

Since modes tend to change on the Electric Surfboard, it is wise to know which was the last mode that was used just to verify that everything is going well. So in the class Mode, there are two private variables called curMode and prevMode. When a new mode is changed, prevMode would get the current mode that the board is in and curMode would get the value of whatever the new mode would be on the board. After the variables are set, then the current mode can start. If there is any error that prompted, the curMode would be given the prevMode values and continue to run meanwhile.

4.5.3 Connection Mode

Since it is convenient to use the Android device as a form of communication between the Electric Surfboard and the Android device, the best approach to having this is to use a Bluetooth module; communicating through Bluetooth. Due to the specifications of our projects, the Bluetooth approach provides a cost effective and a simple interface that helps with connection. The Bluetooth module will be used to connect to the Android device to receive and transmit data through UART serial connection.

While Bluetooth being a very good choice of cost effectiveness within hardware level, integrating it into the system makes it ideal to do so. In a day and age within our technology, Bluetooth has been engraved into many devices especially a lot of mobile phones. With this in mind, the system of our project will be designed within an application where the person only has to open up the application and connect to the Electric Surfboard to start.

4.5.3.a Connection Application

The Bluetooth module that will be used in this project to interface with the Android device and the Electric Surfboard will be the HC-05. This Bluetooth module hardware dimensions are 26.9mm*13mm*2.2mm, which wouldn't hinder or obstruct any other part of the hardware inside the encapsulation. The Bluetooth module also has a simple to use protocol to connect. The Bluetooth module uses Bluetooth version V2.0+EDR and a 2.4 GHz baseband with an enhanced 3Mbps data rate. The Bluetooth module hardware features a UART interface, IO programmed control, a 3.3 Volt to operate 1.8 Volts being the minimum to function. The IO pins has 1.8-3.6 Volts and have a modifiable baud rate. Some other features of the Bluetooth module is it can be programmed to be a slave or master device, but for the Electric Surfboard, it will be a slave device since we are only sending instructions to the Electric Surfboard via the Android device. The rate at which the baud will be set is at 9600, which is pretty standard for most Bluetooth.

Looking at Figure 4.5.3.a -1-, it gives a general view of how the HC-05 Bluetooth module will be connected with the ATmega328. The connections is very simple, the ground pins should be connected to the ground. The power pins of the HC-05 Bluetooth module and the MCU, ATmega328, shall be connected to the same power supply of 3.3 V, since they both take in an operating voltage of 3.3 Volts. The pin TX of the HC-05 shall be connected to the RX pin of the MCU, since it is receiving the data that the HC-05 is transmitting. The RX pin of the HC-05 should then be connected to the TX of the MCU, since the HC-05 Bluetooth module is receiving the data that is being transmitted by the MCU.

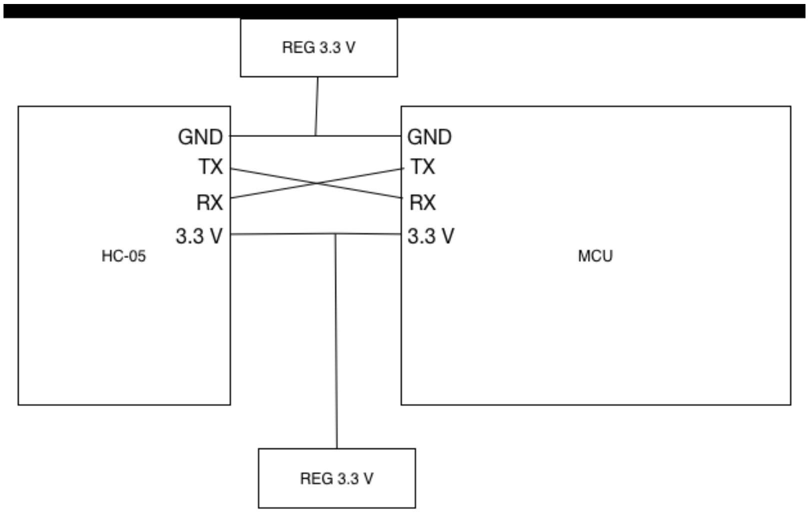


Figure 4.5.3.a -1- General view of how the Bluetooth module and MCU are connected.

To make sure things are working during our project, we will have the HC-5 Bluetooth module and the ATmega328 microcontroller set up in a bread board since it will simplify the work for us and help us change anything up if a problem rises up. To verify that data is being at the Bluetooth module, an Android device will used to send data through the application BlueTerm. Once the connections and pins are verified and the MCU and HC-05 is communicating, the connections will be integrated in a PCB layout with the correct pins connected. This not only saves spaces within our working space, but also simplifies and makes it look more professional without all the wiring that is around in a breadboard setup and mess.

Due to the many baud configuration the HC-05 Bluetooth module has to be interfaced into the system, in order to conFigure the certain mode that needs to work, a use of AT commands is used. Configuring a HC-05 with the correct configuration mode that one chooses, the Bluetooth module would need to communicate with the MCU through UART serial connection and have the MCU connected to the computer. Serial communication software is then needed to conFigure the modes with AT commands.

5.0 Realistic Design Constraints

As time progressed during developing an idea as to how to build our design, there were a few limitations that were faced which caused much thought before finalizing a design approach. Each of these limitations, or constraints, were taken into consideration in order to optimize our product to overcome as many barriers as possible. The constraints taken in regard consists of economic constraints, time constraints, environmental constraints, safety constraints, and manufacturability and sustainability constraints.

5.1 Economic and Time Constraints

5.1.1 Surf Board/Hardware arrival

The constraint that should be taken most into consideration when developing a product is time. This is something that really needs to be used wisely because this is the one constraint that is constantly moving. When deciding what to build, being able to finish it and be fully functioning before the deadline was a major requirement. Because of this, the design chosen was decided in order to provide a realistic time span to finish the complete project. Not every desired specification could be implemented with such a short time period to get the product finished therefore sacrifices needed to be made and the product needed to be versatile so that way, if needed, additional accessories could be left out if time became an issue. With that in mind research had to be done in a timely manner.

A few ways time was predicted to cause setbacks were for ordering parts. Many of the required parts come from all around the country so there is no way of knowing exactly how long it would take to receive them. The arrival of the products ordered can be approximated but not certain, therefore, proactivity must be practiced. One of the time constraints that caused a waiting period was customizing the surfboard design. This needed to be specifically modified to adapt with the requirements of our intended product design which meant no timetable could be predicted until the design was finalized. Multiple different approaches were considered as to how to modify the board in order to properly house the units as well as keep them from being damaged by the water. In addition, the placement of the propeller was dependent on where the power supply and motor were placed. The limiting factor in this dilemma was whether or not the propeller should be mounted on the board or attached at an angle being directly connected to the motor. The difference between these two would make the difference between having the motor and power always attached or be removable.

Outside sources were not the only time constraint to take into consideration. The availability of each team member also was a factor. All three team members are full time students working part time jobs so finding the time to fit in research and design while managing all other responsibilities was not an easy task. This is something that required each of us to make sacrifices as well as develop strategic time management skills. At least twice a week, over the span of six weeks, research was conducted on the required parts for the design. This was necessary to be as efficient as possible so there were no delays when it came time to putting everything together. As for the actual design of the board there is no way to predict how long it will take to achieve the intended goal so milestones may be somewhat inaccurate. However, starting as early as possible is the main objective in order to troubleshoot and make the necessary adjustments.

5.1.2 Mechanical Hardware Pricing

Our mechanical hardware makes up for approximately 65-80% of our project budget. The mechanical aspect of the design can be broken into four main purchases. Of course smaller support parts will be needed, they do not impact our project budget as significantly as the others. First and foremost, the propulsion unit, jet drive, will be the most expensive piece of hardware necessary at just over $400 and nearly wipe out our entire Boeing and Leidos funding. Our motor used to power the jet drive unit can be found for roughly $97 online. The third main mechanical purchase is the battery because without sufficient voltage to power the entire system, all other parts are useless. Our battery chosen will roughly cost us $40-$50 and may be necessary to purchase another later in the future. The largest and second most expensive purchase will be our surfboard itself. Our surfboard can cost anywhere from $100-$500 but will probably be purchased in the $150 range.

In some cases the sacrifice of paying the higher price needed to be made because if not there would be more of a risk of the final product not functioning in the desired fashion. An example of when this happened was when comparing the prices of propellers. Table 5.1.2 -1- shows a comparison of the options that were considered.

Material	**Cost**	**Weight**	**Reparability**
Composite	Lowest	Light	Not possible
Aluminum	Middle	Middle	Easy
Silver	Highest	Heavy	Difficult

Table 5.1.2 -1-

The aluminum and the composite propeller were the two mainly being compared because silver was too high in cost. The composite was desired because not only was it cheaper but it was lighter, however, the aluminum propeller is more durable and is easily repairable whereas the composite propeller cannot be fixed if something were to happen to it; it would need to be completely replaced. Unfortunately, the performance of all the propellers is generally the same so there is not much benefit to paying the higher cost other than the increased durability of the propeller.

When it came to spending money on hardware there had to be a cap set that was followed in order to make sure any unnecessary spending was avoided. Setting this cap would help make sure resources were being used efficiently. This cap limit was almost completely covered by generous funding from Boeing and Leidos who supplied $490 of funding. Having a limit on spending meant research needed to be carried out so that the best possible, yet affordable, components were being used so that no excess spending would arise. Unfortunately, this method of financing can only be effective to an extent. There may not always be a way of knowing if a product ordered is going to be compatible with the rest of the components so having to reorder a different part can cause setbacks. In addition, something may not work the way it was predicted to work, hence, a new part must be ordered driving the cost of production up.

In terms of hardware, the biggest concern was the price of the battery. The preferred battery type is a Lithium Ion battery however these tend to be rather expensive due to its recharge capability. In addition the power required by the battery needed to be higher than an ordinary battery in order for the board to move at a reasonable speed. This is an important feature for the design so it could not be avoided. The main difficulty with hardware spending was deciding on what sacrifices had to be made in order to prevent over spending.

Waterproofing and unit enclosures will also make an impact in our budget. Though these types of materials are not as expensive as the jet drive and surfboard but they are just as important to having a functioning design. Most enclosures, especially the large main component housing unit, will most likely needed to be made by hand which not only costs money, but will also cost us time as well. Waterproofing will consist of liquid epoxy, hard plastic sheets that can all cost around $45.

5.1.3 PCB

5.1.3.a Pricing

Printed circuit boards were one of the necessary components that did not cause much worry in terms of price since they are generally inexpensive. PCBs range at around $1-$5 which is pretty reasonable. Adding the components would not be an issue either since that is something that can be done manually as since the team members have access to soldering materials and know how to use these materials. The only area that will cause limitations is deciding how the PCB will actually be printed. In order to best get an idea of what the PCB needed to look like EAGLE CAD software was used to simulate the PCB construction. This software allows the user design a PCB with all the required components and run tests to make sure the PCB will properly function. This helped save money from ordering a PCB and realizing it would not fit the design requirements preventing the need to buy multiple boards. It also saved time because there was no need to wait for a PCB to be made.

5.1.3.b Manufacturing

Deciding on whether to use a punchboard or custom designed PCB came down to understanding how to implement the device in the board. The punchboard is cheaper than having a custom designed PCB however the punchboard is larger. This would take up too much space and with only so much space to work with it is difficult to be persuaded to use the punchboard. The PCB is must more size efficient because it is designed specifically to fit the components listed in the design.

Obtaining the completed schematic of the PCB needs to be done as soon as possible due to the time it takes to have the PCB manufactured. Generally it can take up to 2 months to receive the custom PCB. Such a long waiting period means tests cannot be done to troubleshoot any issue on the PCB. The time for prototype testing will only be about 5 months and waiting for the PCB is already half of this time. In order to account for this delay the punchboards will be used to do testing but the final design will only contain the custom made printed circuit board. When it comes time to having the PCB made the schematic for the PCB layout will be created using EAGLE CAD software. This software allows the user to customize a

PCB layout and export the schematic to a company that can design the circuit board exactly how it is constructed in EAGLE.

5.1.4 Surfboard Pricing

Furthermore, certain product pricing could not be avoided and spending had to be adjusted in order to accommodate. For example, the surfboard was expected to take up the majority of the spending due to fact that they generally have a high price. The board type length is a limiting factor as well because although a longer board is preferred, the price rises with the length of the board as shown in the comparison of Figures 5.1.4 -1- at 8 feet long and 5.1.4 -2- at 7 feet long. This needed to be highly considered because the price difference is $72 for just one foot longer of a board. The brand of the board is another factor to consider as affecting the price of the board, however, most boards seemed to be generally around the same price for similar lengths.

Figure 5.1.4-1-8ft.

Figure 5.1.4-2-7ft

Other than the battery, each of the other components were not predicted to use as much of the funding so it was considered an acceptable purchase. This left over half the budget to be spent on the necessary parts as well as extra cosmetics that can be added given the product is completed on schedule. As shown in Figure 5.1.4 -3-, the distribution of spending is displayed. About 89% of the costs are absolutely necessary in order to meet our design requirements. Which, in turn, leaves 11% leftover for additional features. This 11% is not necessary so if anything were to go wrong with the components there is some cap space to make up for any losses. This is very beneficial because it provides a little freedom to experiment on the prototype. Also because the board will be in the water the hardware can easily be damaged so in case anything gets ruined due to environmental damages it can be replaced. In addition this limits any out of pocket spending since the 89% of expected cost is covered by the funding being received.

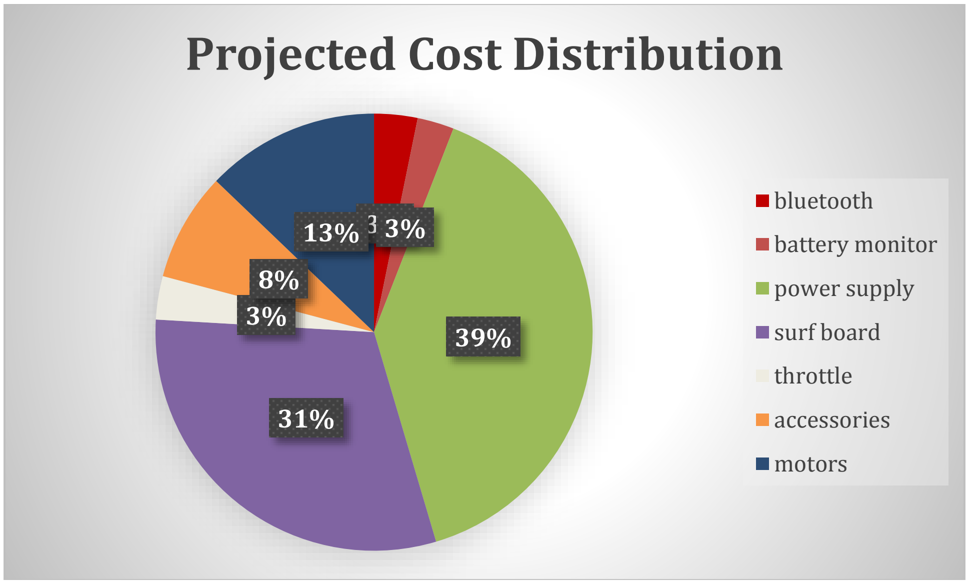


Figure 5.1.4 -3-

5.2 Environmental Constraints

5.2.1 Waterproofing

One of the main issues this product has to overcome is surviving in its environment. This product is designed to constantly be surrounded by water and may even become submerged at times so making sure no damages occur whenever this happens is extremely vital. In order to prevent such occurrences the hardware will be encased within a sealed containment and attached to the top of the board. Water testing will need to be done in order to determine if the board is ready to withstand the conditions of its environment. As a precautionary measure, the casing will be lined with a caulk or expanding foam to further decrease any leakage. However, the battery needs to be removable in order to be recharged so there will need to be a compartment that is not sealed so preventing any water from entering here may be an issue. Not only does the water pose an issue but the fact that it is salt water calls for even more adaptations to ensure product safety and longevity.

In addition, the controller, or throttle, will also be affected by the environment. The handheld throttle will be wireless so it will need batteries which means it will need to be waterproofed as well. Because of the unpredictable environment the throttle can easily be dropped so accommodations need to be made to address this. In order to do so the throttle will be given a strap to be secured around the user's wrist as well as be made to float in case the strap was not enough to keep the throttle at a safe distance.

Signal loss is also going to be affected by the environment. If at any point the receiver on the board becomes submerged the signal from the throttle to this can be interrupted causing the user to no longer control the speed. This is something that can really limit the effectiveness of the board so in order to keep this from happening, an antennae will most likely be implemented that will stay above the water in order to prevent this signal loss from occurring.

The components inside the case will need to be made waterproof. As mentioned earlier the case will not be 100% waterproof so measures must be taken to accommodate. The components can be made waterproof by simply spraying them with a protective coat that prevents water from bonding to the materials. The only problem with this is that these sprays usually are permanent. This is a major problem if something goes wrong because the circuit boards cannot be edited if something were to go wrong. However, there are some waterproofing sprays that can be removed. This also poses a problem because then caution must be used when applying the waterproof coat remover so that the components to not get damaged. The waterproofing coat is also highly flammable so it can be very dangerous after removal if all of the coat is not taken off because soldering will most likely need to be done.

5.2.2 Bodies of Water and Complications

As previously stated, our electric-powered surfboard should be able to operate in any body of water large enough and deep enough, at least 3 feet, to comfortably maneuver the board. The 3 types of water we have access to perform riding performance testing are lakes, rivers, and the ocean. Of all the bodies of water available, a lake that is somewhat protected from wind would be the best testing environment because the water will be calm and flat, also refereed to as glassy.

Rivers are not ideal for prototype testing or performance testing because of the many outside variables. Rivers are harder to access than lakes and the ocean and involve more hazards. The most obvious and one of the most dangerous hazards are boats in the water. Boats can be present in larger lakes and off the coast of the ocean but it is rare to have boating traffic in small lakes and near the coastline. When in the presence of heavy boat traffic, such as in a river, boating rules and laws must be followed on the electric powered surfboard as well because it could be classified as a water vehicle and the potential dangers of fellow nearby boaters must be considered. A danger or hazard to consider is the weather conditions. The weather can change quickly and drastically when on the river because of the warm water temperature and close proximity of the land.

The ocean will be a great place to ride the board when the design and performance testing is finished. We are not going to conduct our prototype testing, functionality testing, or performance testing in the ocean because of multiple factors. The most important factor taken into consideration is the effect of the natural elements in the ocean; this includes the tides, rip currents, sea life, waves, salt water, and the unpredictable water depth at which the rider is in. Waves and rip currents make the ocean a very difficult riding and testing environment. The rider could lose the board, capsize much easier, drift off course, or become disoriented in the ocean and that is very dangerous when testing a new device. We are going to minimize the outside factors as much as possible. Eventually, the ocean is the ideal place to ride the finished product because the motor can help ride waves and maneuver through the different wave breaking points in the ocean. The sea life in the ocean also causes a safety hazard. Ocean creatures, such as sharks and jellyfish, can cause physical harm to the rider or even to the electric powered surfboard itself. These hazards are part of the risk involved in creating an electric powered surfboard and will be faced but will be avoided as much as possibly.

Windy conditions can create rough non-deal water surface conditions, creating a “choppy” and unstable body of water; which increases the amount of drag when riding. Windy air and choppy water conditions significantly increase riding difficulty, making it harder to balance and maneuver the surfboard. Along with difficult riding conditions, choppy water also adds additional strain to the board itself because of the rough riding surface and impact of the waves on the bottom of the board and the hardware-housing unit. Keeping the integrity of our waterproof housing is very important while riding to avoid damaged parts and component failures. This is why a lake isolated from the wind as much as possible is out desired testing environment. Hazards in a lake environment include unknown water depth, alligators, and waterweeds. Unknown water depth could possibly end in board damages if the rider “bottoms out” on the bottom of the lake. Alligators can pose a threat to the safety of the rider, just as sharks do in the ocean, but alligators are defensive animals and would rather escape human interaction than become aggressive. Waterweeds can be a hazard to the hardware because it could get caught in the propulsion system of our board and cause failures or permanent damages.

5.2.3 Wireless Connectivity Interruption

One of the biggest complications that make the wireless throttle difficult to implement successfully is the connectivity issues. Not only does the water serve as a threat to signal loss but the actual board can serve as a jammer between the throttle and MCU. The wireless signal will already have a difficult time maintaining a connection through the water but in order to ensure the board will not cause an interruption the materials of the board must be known. This is because there are some dielectrics that make it difficult for a signal to pass through. This can be avoided by finding a surfboard that contains a dielectric that does not cause any interference.

Surfboards are generally made from a substance called polystyrene foam. Polystyrene has a dielectric constant of 2.6. This is pretty good because air has a dielectric constant of 1. Air is very good in maintaining signals due to its low dielectric constant. This causes less worry when determining how the surfboard will affect the connectivity between the throttle and the MCU.

5.3 Safety Constraints

Safety is a primary concern or constraint when designing any project and all potential dangers must be taken into account. Our electric powered surfboard will be used in water and that adds a new element of danger that must be taken very seriously, especially during the testing phase. Both the surfboard rider and the hardware itself are at risk and certain equipment and technology can help keep the rider safe. Dealing with the natural elements involved and the electricity on board the system can be dangerous.

5.3.1 Rider Safety

The safety of the rider is much more important to our team than the safety of the hardware. Water sports can be very dangerous because of the obvious risk of drowning. Getting injured and/or suffering head trauma from the surfboard, water, or bottom of the body of water riding in can causing the rider to not be able to swim properly if capsized, running the risk of great bodily harm. One safety approach that could be taken to greatly reduce the risk of great bodily harm is to utilize a like jacket when riding. Whether the rider is laying down on the board or standing up, going fast or slow, the risk of a head injury in water is a very serious risk and the life jacket will help keep the rider afloat regardless of their conscious state or swimming ability. Of course the ride should not solely rely on the life jacket itself to stay safe, it is highly recommended that the rider stretches and warms up the body before attempting to ride the electric powered surfboard. Incase of an emergency the rider will more likely be capable of physically supporting themselves in that type of situation.

Water life inside the riding environment also poses a threat to the rider. We will most likely test our complete product in a lake because of the low pH level and because of calmer and flatter water surface. Alligators are very common here in central Florida in any body of water and can potentially be very dangerous. Single celled organisms called amoebas can also be very deadly in the warmer months of the year as they thrive in warm temperature waters.

The safety feature implemented into the design of the surfboard is the Bluetooth emergency cut-off system. As previously mentioned, this system will be incorporated into the PCB inside the mounted hardware system and is designed to cut the motor off after the board and rider are separated by a certain distance regardless of the throttle’s speed setting. This safety feature will help reduce the risk of being stranded in a body of water, being drug through the water by the surfboard if using a leg leash, or from causing damage to the board or nearby people.

5.3.2 Hardware Safety

Keeping the hardware safe from the elements is essential to our design functioning. Our product environment is the water and as we all know, water, or electrical hardware, and electricity doesn't mix. Our primary defense against the water is using conventional waterproofing techniques to isolate our electronics from the outside elements, especially the water. Our housing unit that will contain all the hardware will be made out of a hard waterproof type of plastic or semi-glass material in order to keep the hardware safe. For minor leaks or solid material connections, epoxy resin can be used. Epoxy resin is a low weight liquid material used in waterproofing application such as surfboard repairs and is applied to areas that are susceptible to water leaks and solidified to block water leaks. Hardware safety and waterproofing is important to keep cost down and the functionality of the electric powered surfboard functional and responsive to the rider's commands.

5.4 Sustainability Constraints

Sustainability Constraints are usually orientated towards a company's ability to sustain production, distribution, and business prosperity. Companies must find a custom formula or set of guidelines to follow to enable longevity of the company and distribution of goods or services. However, our circumstances are a little different. Our interpretation of sustainability is to keep our project functional for the duration of building, manufacturing, and testing. The success of our project is not measured in economic value or product distribution but in terms of functionality. In order to guarantee a sustainable working project we must focus our energy on the following constraints.

5.4.1 Custom Manufactured PCB

Custom manufactured PCB's are important in any unique project that does not necessarily involve typical store bought hardware. Many companies manufacture PCB's for customers and the PCB's can be created online using personally developed schematics. As a general rule, one should give about a month or sometimes longer to produce the desired PCB. Depending on how busy the company is or how limited of resources the company has access to, pricing and turn around time may vary. PCB's are a great way to cut down on space and increase reliability in the design.

The price of custom PCB's are very low in comparison so our other equipment. We can order 5 custom made PCB's for $30-$60 and utilize one at a time with 4 extras. Extra PCB's are very important for our type of project incase of waterproofing failures. If water breaches our housing units and comes into contact with our electrical hardware, the board could be fried instantly.

Reliability of a PCB is much greater than using a breadboard or punchboard and manually soldering all the components by hand. Connections could come lose and cause a short or electronic failures and the only way to achieve functionality would be to check every component on the board or reconstruct the entire circuit by hand again in hopes of fixing the problem. There is still a small chance that a printed circuit board has an internal short or open connection but the success rate is reasonably high and we will purchase extras with that in mind. Along with the reliability of a PCB, the actual size of it is much smaller and compact. Weight is a primary limiting factor in our design and a breadboard or punchboard takes up much more space and weighs a multitude more than a PCB because it needs to be conFigured by hand. PCB’s are manufactured primarily by machine and uses solder masking applications that are very hard, if not impossible, to do by hand. Breadboards or punchboards are perfect for part testing, circuit analysis, and prototyping but a PCB will be made once our design is finalized.

5.4.1.a Manufacturing Companies

Many different companies make custom printed circuit boards all around the country, most of which, all the design process is done strictly online and no face-to-face meetings are required. One of the group members worked directly for a local PCB manufacturing company called QueteQ, based out of Sanford, FL. The owner, Kurt Storey, may be willing to help with the schematic design and manufacturing process as a small sponsorship. Sunstone Circuits is an online company with a quick turn around of 5 business days to 5 weeks. The schematic can be uploaded online and quoted in little time. OSH Park is another online company that can manufacture custom PCB’s by uploading your own design via an Eagle Board file or Gerber CAM file.

5.4.2 Salt Water Corrosion Danger

Ideally, our electric powered surfboard will be ride-able in any body of water large enough and deep enough to be able to safely maneuver the board in, which includes lakes, rivers, and the ocean. However, salt water from the ocean and some rivers with brackish water can be very corrosive on nearly all types of materials, non-metals and especially metals.

Different types of water can have a different pH level which affects the severity of water exposure to devices and different types of materials. Pure water, which is not commonly found in nature, is neutral with a pH level of 7. Ocean water has a pH of about 8.2, which is slightly basic in concentration. Corrosion due to ocean water is an electrochemical process referred to as aqueous corrosion and occurs in materials that lack a protective oxide film layer. A way of slowing down the amount of corrosion on the board is to use materials or coatings that have an oxide film that’s more resistive to the corrosion. The chloride content in ocean water will attack any material after a certain amount of time, regardless of its protective coating, so it’s very important to rinse off all the hardware with fresh water to rinse off the corrosive compounds found in ocean water. Protective coatings simply delay the corrosion process and do not hinder it completely.

Freshwater lakes corrode and wear down materials much slower than salt water does. Lakes generally have a slightly basic pH level concentration and aren’t as harsh. For this reason we will conduct our initial project testing in a freshwater environment.

5.4.3 Board size and weight limitations

Surfboards come in many different shapes and sizes depending on the weight of the load being applied to the board and the speed at which the board will be moving. In a wave surfing environment, the choice of surfboard size depends on the size of the waves on that particular day. Typically, larger more buoyant surfboards are utilized on days where the waves are smaller and small less buoyant surfboards are used on larger waves where more speed can be accumulated. A surfboard that is 7-9 feet in length would be considered a larger surfboard and from 5-7 feet would be considered a short board. Because of the increased size and weight, larger surfboards are slightly more difficult to maneuver. The electric powered surfboard will need to propel up to about 200 pounds through the water, including the weight of the board itself with the mounted hardware and of course the weight of the rider.

If the additional resistance and drag from the water proves to be much greater than expected, a larger more buoyant surfboard will be a better option for our design. A larger surfboard will be easier to balance at slower speeds and could support a larger rider. A surfboard between 7-9 feet is considered a larger surfboard and is often referred to as a longboard. With the increased stability and ease of balance, the rider loses maneuverability and speed because of the overall size of the board. Longboards often times have a reduced level of drag because they sit on top of the water rather than drag the rear of the board in the water.

If our design is capable of reaching speeds of 20-25 miles per hour then a wide short board will be in our best interest. A board about 20 inches wide and 6 feet and 6 inches long will have enough buoyancy for all the equipment as well as allow the rider the amount of maneuverability they would desire. However, the rider must be going at least 13-15 miles per hour to be able to stand up with the enough stability on a smaller board. If the water resistance and drag prove to be a more hindering speed factor than predicted, a very wide surfboard approximately 26 inches wide and 7 feet 6 inches tall will be ideal. A board of this would be able to operate effectively at speeds less than 10 mph.

5.4.4 Component Incompatibility Constraints

Compatibility is a concern when designing a project that incorporates multiple electronic and physical systems. Its vital that all the physical components are compatible with each other, and the Bluetooth wireless throttle communicates with the transmitter and functions appropriately in controlling the throttle and dictating the speed of the board. One constraint is the battery power driving the PCB. A voltage regulator and multiple other hardware components are going to be necessary to regulate the current flow and voltage into the PCB to prevent failures or damage. Our Zippy LiPo battery can operate at a maximum of 22V and our battery monitoring system operates at about 10V maximum so regulating will be necessary to prevent damages. The wireless communication operating frequencies must also be compatible between the transmitter and the receiver to achieve functionality. Whether we use Bluetooth, RFID, or ZigBee, the data rate and transmission frequencies need to be compatible to communicate with one another efficiently and effectively.

Our PCB will consist of many parts, voltage regulator, battery monitor, a pulse-width modulator (PMW), to be used as a power modulator and operate as a throttle, our transmitter, and of course basic resistors and capacitor type components. Connection and solder locations must be accurate and efficient in order to have a functioning PCB that will perform our desired tasks.

Some common forms of incompatibility in the system could greatly vary. Anywhere from incorrect transmitting frequencies in the wireless communication to incorrect pin size on the hardware. Bluetooth commonly communicates with frequencies of 2.45 GHz, which means the transceiver must also communicate at the same frequency to ensure compatibility. Conveniently, for designing purposes, 2.45 GHz frequency is Bluetooth standard. Similar to Bluetooth, ZigBee wireless communication also operated at a 2.45 GHz frequency but is usually used for longer ranges and the extra power consumption may not be suitable for our needs. RFID operates at lower frequencies than both the Bluetooth transmitter as well as the ZigBee transmitter and are usually used for specific short-range applications.

The easy part of component compatibility is the physical mechanical type of hardware such as the motor, propulsion device, battery, and the surfboard itself. Its uncommon for RC motors and jet drives to be incompatible to the point of not functional. A clamp type of connector will be used to connect the drive shaft of the motor to the jet drive so those two components are compatible because of the additional hardware selection flexibility for the connection. One possible issue in the compatibility of the design between the motor and jet drive would be if the motor is not powerful enough to turn the jet drive under a load (water), that can easily be avoided by purchasing a motor and battery source large enough to achieve thrust through any medium.

5.4.5 Inspectability

The term inspectability is a term referring to the ease at which different stages of our project can be inspected for electrical function, water leaks, and wireless communication. We will conduct tests periodically as each part of the system is developed, both individually and integrated.

Electrical function inspection will be conducted at each stage of our circuit design. The battery monitor, voltage regulator, capacitors, and resistors will all be tested individually before integrated together into one system. As parts of the system are brought together, each stage will be inspected with and tested for functionality and performance using a test power source. A failed inspection would result in a short circuit or open circuit, possibly frying or damaging our individual components before fully integrated.

Water leak inspections will be done with each waterproof housing unit individually without any components inside them to make sure the units are waterproof. The individual waterproof housing units consist of but are not limited to: battery pack and safety fuse unit, Bluetooth communication transmitter unit, and the motor and jet drive housing unit that will house most, if not all parts. A failed waterproof inspection would obviously result in a leak and water being inside the desired housing unit. It is important to inspect the durability at different depths as well.

Wireless communication can fail due to many different reasons. The first inspection would be to check the power. Both the Bluetooth transmitter and receiver need to have a consistent power source to function. After power is achieved, it is important to check the connectivity between the transmitter and receiver. Failed communication inspections would consist of no connection, a loss of connection, or connection inconsistency and result in failed throttle communication. All the individual inspections must be passed before combining all the components to work in unison.

6.0 Project Hardware and Software Design Details

6.1 Initial Design Architectures

6.1.1 Battery Specification/Capabilities

Our rechargeable LiPo battery that will be implemented in our design should be capable of powering our electric motor as well as our onboard electronics such as the battery monitoring system and wireless Bluetooth throttle system. As previously mentioned in section 3.2.3, the Zippy Flightmax battery is a 6 cell battery with a capacity of 5000mAh meaning it will last roughly twice as a long as a 2000mAh capacity LiPo battery. However, this battery was not available when it came time to order so we had to opt to using the Zippy Flightmax 6 cell battery with a capacity of 4500 mAh. According to the specifications listed on hobbyking.com, the Zippy LiPo battery can discharge at a constant rate of 45C with bursts of 50C. The discharge rate and capacity denote the amount of current the battery is able to deliver. At 45C, our 4500mAh battery can deliver a constant (4.5A*45) 202.5A and short bursts of 225A. This battery would serve just as efficient as the original battery and maybe even better. The official specifications as listed on hobbyking.com are as follows (refer to appendix for website link referencing):

- Capacity: 4500mAh
- Voltage: 6S1P / 6 Cell / 22.2V
- Discharge: 45C Constant / 50C Burst
- Weight: 778g (including wire, plug & shrink wrap)
- Dimensions: 143x50x51mm
- Balance Plug: JST-XH
- Discharge Plug: HXT4mm

6.1.2 Electric Motor Specification/Capabilities

Originally, powering our Jet drive or drive shaft was going to be the Turnigy AquaStar T20 3T 730KV/1280KV (RPM/V) water-cooled brushless motor. This high-powered motor is designed for large RC racing boats and would suffice in propelling our electric powered surfboard. This motor comes equipped with two wiring configurations depending on desired output, the “Y” configuration and the “delta” configuration. Each wiring configuration is for different output performance specifications and a feature like that is quite uncommon in RC boat motors but can be very useful as we will essentially have two motors in one. If the motor is wired in the Y configuration, it operates at 730kV and if the motor is wired in the delta configuration then it operates at 1280kV. The max voltage the motor can endure is nearly double that of our battery output with less than an ohm of resistance at either operation configuration due to the brushless motor’s low internal resistance.

When the time came to finalize our motor purchase, the Turnigy AquaStar T20 3T was out of stock and slight changes in design needed to be made. So that we would not need to alter our overall design, we chose a similar motor; the Turnigy AquaStar 4084-620KV (RPM/V) water-cooled brushless motor. This motor is similar maximum current and voltage values but is slightly smaller and lighter than our originally selected motor, which will cut down on the weight. Unlike our originally selected motor, the 4084-620KV (RPM/V) Turnigy AquaStar only has one mode of operation that worked sufficiently for our purposes. With the permission of hobbyking.com, the motors specifications are shown in table 6.1.2 -1-.

Motor Specifications: Turnigy AquaStar 4084-620KV (RPM/V) Water-Cooled Brushless Motor	
RPM/V	620KV
Max Voltage	37V
Max Current	105A
Max Watts	3050W
Resistance	0.03**Ω**
No Load Current	.7A
Can Diameter	39mm
Can Diameter w/ Jacket	49mm
Length	84mm
Shaft Size	5mm
Weight	508g

Table 6.1.2 -1- Turnigy AquaStar Motor Specification Reprinted with Permission of Hobbyking.com

6.2 Bluetooth Communication

Looking through our research it was ideal and convenient to do Bluetooth as a mean of communication between the Hand-held Throttle and the Electric Surfboard. Going with a Bluetooth module meant that it was going to be cheap and convenient in terms of time and interfacing as a whole. What made this choice very convenient is the age of technology now a days. Due to how every mobile phone having Bluetooth enabled in their phone, we decided to have an Android device for our Hand-Held Throttle. This would save us time from making our own Hand-Held Throttle from scratch. Due to many people owning a Smartphone, it would be ideal to make an application in which anyone can download from the App store and use it with a simple and friendly GUI.

6.2.1 Hand Throttle Specifications

Using the Android device as a Hand-Throttle, it needs to display at least 2 important items, that is the percentage of the battery and the speed, RPM, at which the DC motor is running at. This would be done through a UI via an Android application run on the Android device. The volume keys of the android device would serve to change the speed of the Electric Surfboard, + would potentially increase the speed and – would potentially decrease the speed. The Android device should be able to have enough charge for the board to run a whole charge or its current charge. For example, if the phone is at 10%, and the board is fully charged, it shouldn’t run since ideally, there is not enough power on the phone to run for one hour. Ideally, it should run when the phone has adequate charge.

6.2.2 Power Consumption

The Bluetooth device requires very little power to operate. With that in the mind the power consumption it will initiate is minor when compared to the rest of the components. The voltage required to operate the Bluetooth that will be installed on the board is around 3V. In addition, the Bluetooth that will be in the throttle will not consume any of the source power at all. This is because the throttle will contain its own battery to power the Bluetooth. This battery will only need to be used for the Bluetooth and the LCD screen on the throttle. The intention for this is to save as much power as possible. Keeping the battery life up directly relates to the run time of the board. The run time is an aspect of this design will most likely be shorter than an expected so conserving power in any way possible is a must. Furthermore, Bluetooth was mainly chosen because it does consume the least power when determining what to use to establish a wireless connection.

6.2.3 Connection Range

Looking at the HC-05 Bluetooth module, it has a signal range of 10m, which is about 33 feet. Even though that is an adequate range to have, we have to consider that the connection of the Bluetooth module runs at 2.4 GHz, which is about the same frequency of microwaves. With this in mind, we have to consider also the environment in which the Electric Surfboard will be in, which is water. Since water has a very severe effect on Bluetooth frequency, we have to plan what would be the most beneficial position in which to have the Bluetooth module at and in addition if the water that splashes on the encapsulation would have a severe effect on the Bluetooth module’s way of communication with the Android device.

6.3 Designing RFID

RFID stands for radio-frequency identification and is a from of wireless data transfer using electromagnetic fields. According to technovelgy.com, this type of data transfer is typically used for quick object or people recognition. It is argued that RFID technology may replace barcodes for product distribution because this type of data transfer can recognize objects much easier and quicker without having to be in direct positioning relative to a scanner. The object which contain passive tags do not need to have an outside power source and are good for close range recognition but active tags require their own power source and can be picked up at greater distances. However, because RFID chips don’t need to be in direct “view” or positioning of some sort of scanner, information collision can occur when multiple signals overlap and cause inconsistency.

6.3.1 Connection Range

Connection range is important for our design because it will also be used for the emergency cut-off system. There are two types of communication tags for RFID, passive and active. Passive tags do not require their own power source and are used for short-range detection applications and typically have a 20 foot connection range. Since the passive tags do not require their own source of power, they are ideally good forever, but of course the elements will affect the tag and materials can deteriorate depending on the environment at which the tag is being used.

Active tags require an outside source of power and are used in long-range applications. The longer range tags typically use higher-frequencies and can reach up to 300 feet and are used in common recognition applications such as electronic tolls. Unlike the passive tags, these tags have a much shorter lifespan due to the slow dissipation of power. A range of 20 feet is sufficient for our design but we fear that a programmable RFID tag may not be dynamic enough for our needs.

6.3.2 Connection Consistency

According to gathered research, RFID chips could be used as a method of detecting if the rider is still in close proximity to the board by simply relaying information to the receiver and a constant fixed rate. Connection consistency of an RFID tag is very high, especially when there is only one tag in the area at a time because there is no risk of interfering signals. The signal transmitter and tag would not be permanently connected. To save power, the transmitter would search for the tag at given intervals.

6.3.3 Power Consumption

RFID identification is a relatively low power system compared other types of wireless connection applications. A typical RFID tag scanner is what consumes the most power and the RFID tag consumes little power, if any. Typically speaking, an RFID scanner needs a constant power supply of 50-100mA and would be more efficient with a scanning timer in place to limit how often the scanner searches for a tag. Some energy will be lost through the inefficiency of the antenna, but only having one tag within reach of the scanner saves energy because the scanner doesn’t have to cycle through the frequency anti-collision sequence. Maximum power consumption will occur when the antenna is internally shorted due to external reasons and operating in water can and will increase power consumption due to a possible lack of frequency transmission. The lower amount of times the scanner is activated and searches for the tag the lower amount of power consumed in the system. Figure 6.3.3 -1- displays the power consumption to running time ratio when using traditional RFID readers as apposed to the Nordic ID Stix RFID

USB reader. The Nordic ID Stix reader is a low power consumption alternative to standard RFID readers.

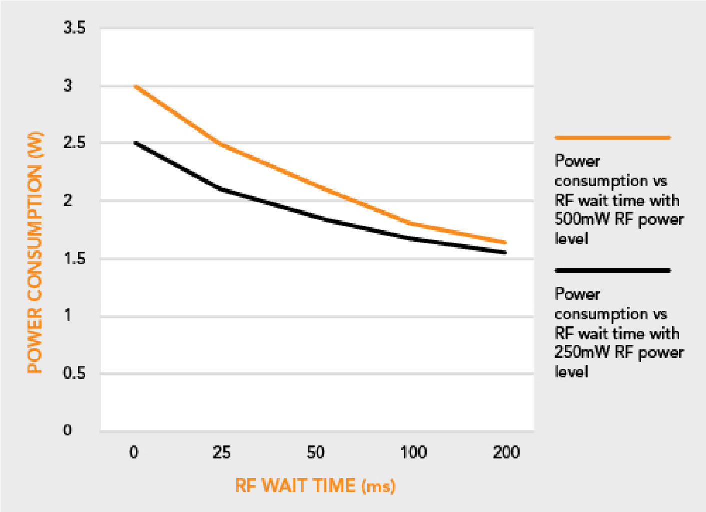


Figure 6.3.3 -1- Power Consumption with Respect to Wait Time – Reprinted with Permission from Mirva Saarijärvi

6.4 Battery monitoring system

6.4.1 Smart Battery Monitor

The original idea of implementing the battery monitoring system consisted of using the Maxim Integrated DS2438 smart battery monitor. The specifications of this product in DS2438 datasheet, revealed the monitor can only support a power supply in the range of 2.4 to 10 V. However, a design could be used to adjust the battery monitor so it could support higher voltages exceeding 10 V. A few of the important specifications of the DS2438 that made this the product of use consists of the following specifications listed, obtained with permission by Maxim Integrated.

DS2438 Specifications:

- 64-bit lasered rom
- Temperature sensor
- Battery voltage A/D
- Battery current A/D
- Current accumulators
- Elapsed time meter
- 40-byte nonvolatile user memory

In order to make the battery support this criteria, the circuit diagram in Figure 6.4.1 -1- must be realized. The main component aiding in this voltage reading is the Zener diode D2. This diode prevents the DS2438 from receiving the voltage out of its capable range. The datasheet for the DS2438 recommends using a diode value that can regulate 5.6 V since it is within the range the battery monitor is required to operate in. The circuit values for the schematic are labeled in Table 6.4.1 -2-.

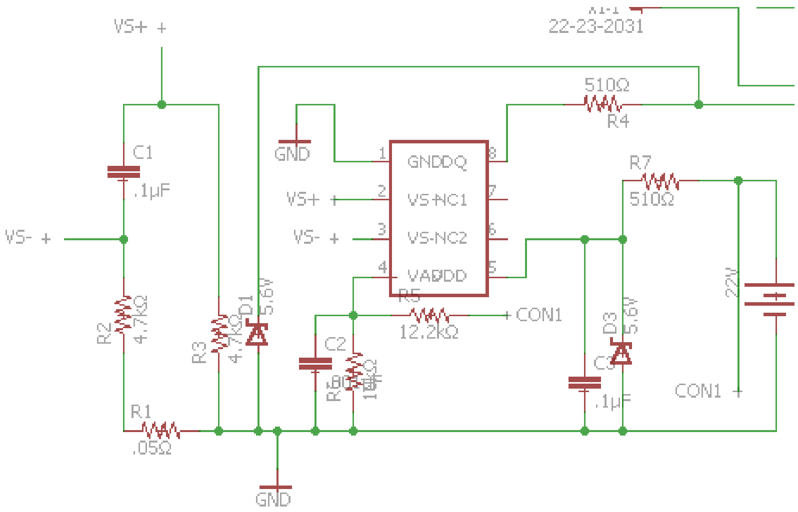


Figure 6.4.1 -1- DS2438 schematic

Component	Nominal Value
R1	.05 Ω
R2	4.7 kΩ
R3	4.7 kΩ
R4	.05 kΩ
R5	6.8 kΩ
R6	10 kΩ
R7	6.8 kΩ
C1	.1 µF
C2	1000pF
C3	.1 µF
D1	5.6 V
D2	5.6 V

Table 6.4.1 -2-

The battery monitor is represented by the square in the middle of the diagram in Figure 6.4.1 -1-. The circuit is connected following the pin assignment for the DS2438 which can be found in Figure 6.4.1 -3-. The functionality of the DS2438 pins are defined in Table 6.4.1 -1-.

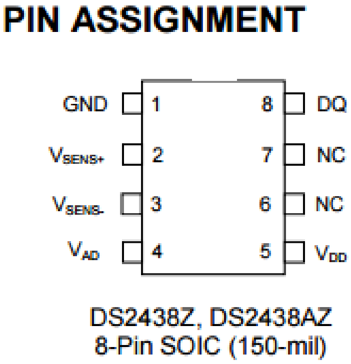
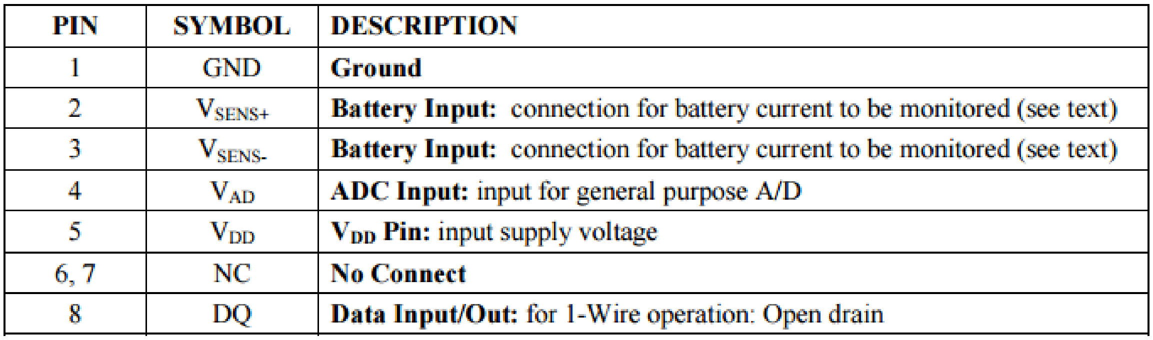


Figure 6.4.1 -3-



PIN	SYMBOL	DESCRIPTION
1	GND	**Ground**
2	V_{SENS+}	**Battery Input:** connection for battery current to be monitored (see text)
3	V_{SENS-}	**Battery Input:** connection for battery current to be monitored (see text)
4	V_{AD}	**ADC Input:** input for general purpose A/D
5	V_{DD}	**V_{DD} Pin:** input supply voltage
6, 7	NC	**No Connect**
8	DQ	**Data Input/Out:** for 1-Wire operation: Open drain

Table 6.4.1 -1- DS2438 pin description

Although it would be possible to use the DS2438, an alternative option that could provide exactly what was needed was chosen as a backup in the event that a limitation occurred with the DS2438. After months spent on trying to get this chip to work an alternative route had to be taken. Due to the lack of time remaining to complete the project adjustments had to be made that could be implemented quickly and easily. In order to monitor the battery a voltage divider was used to drop the voltage being supplied to the PCB to 5 V. This 5V drop was then routed to an analog pin on the microcontroller to read and portray the battery voltage in our battery. The PCB had already been manufactured by this point so in order to do this a hardwired connection needed to be made from the voltage divider to the analog pin on the microcontroller. The only issue with this approach is that now our battery representation does not display battery life but the present voltage of the battery.

6.4.2 LED Display

Keeping the user informed about the status of the product is very important in this design. To make sure this can be fulfilled a display of how much battery voltage is left in the power supply is to be implemented with an indication of colored LEDs that represent different levels of battery life. The representation of the battery voltage of the LEDs is described in Table 6.4.2 -2-. LEDs were chosen because they are extremely cheap and easy to implement. They are also very bright which is beneficial to the user since the product is made to be used outdoors. This makes it easier to see and read the battery voltage in comparison to an LCD screen if the user was to be in a bright environment. Each of the LEDs that will be used will require different forward voltages based on color. The required voltage for each LED can be found in Table 6.4.2 -1-.

Color	**Forward Voltage**
Green	2.9-3.1V
Yellow	1.9-2.0V
Red	1.9-2.0V

Table 6.4.2 -1-: Forward voltages

LED battery voltage representation:

LED color	**Voltage level**	**Battery Voltage**
Green	4.5-5V	22-24V
Yellow	4.0-4.5V	18-20V
Red	3.5-4.0V	15-18V
Red (blinking)	0-3.5V	<15V

Table 6.4.2 -2-

To make this work effectively the voltage divider will need to send voltage to the MCU. This is necessary because the voltage divider cannot power the LEDs directly. The MCU will have the three LEDs connected and based on the voltage read from the analog pin the corresponding LED will be powered. The LEDs will be assigned to pins in the memory which will be programmed to be active when specified conditions are met. The designation of the LEDs being controlled by the MCU pin locations can be found in Tables 6.4.2 -3- to 6.4.2 -6-.

Battery discharge: 22-24V

A	**Green**	**Yellow**	**Red**
Pin	4	5	10
Status	hi	low	low

Table 6.4.2 -3-

Battery discharge: 18-22 V

	Green	**Yellow**	**Red**
Pin	4	5	10
Status	low	hi	low

Table 6.4.2 -4-

Battery discharge: 15-18V

	Green	**Yellow**	**Red**
Pin	4	5	10
Status	low	low	Hi

Table 6.4.2 -5-

Battery Discharge: <15V

	Green	**Yellow**	**Red (blinking)**
Pin	4	5	10
Status	low	low	hi

Table 6.4.2 -6-

This also adds safety to the design so that the user is not unaware of how much battery is left in the case they were thinking of taking the board out far in the water. When the battery becomes dangerously low, the system will enter a power saving mode and be restricted to certain applications in order to conserve power. The maximum speed allowed will be set to lower than the standard allowed at full charge in order for the user to have enough power to safely return to dry land.

6.4.3 Hand Throttle Display

Having the user aware and in control is key for this design and what better way to provide feedback to the user than to have it in the palm of their hand. Since the user must always be holding the throttle to control the board it only makes sense to add features to this control to provide immediate feedback. The additional features included in the wireless throttle consists of displaying the speed, battery life of the board, battery life of the throttle, and approximate remaining run time of the board. All of these features will be displayed on an LCD installed in the throttle.

The dimensions of the LCD screen will be approximately 1.5 in. x 3 in. This will be the size in order to provide the user with the capability to hold the throttle in one hand with ease. A visual of how the throttle will be constructed is found in Figure 6.4.3 -1-.

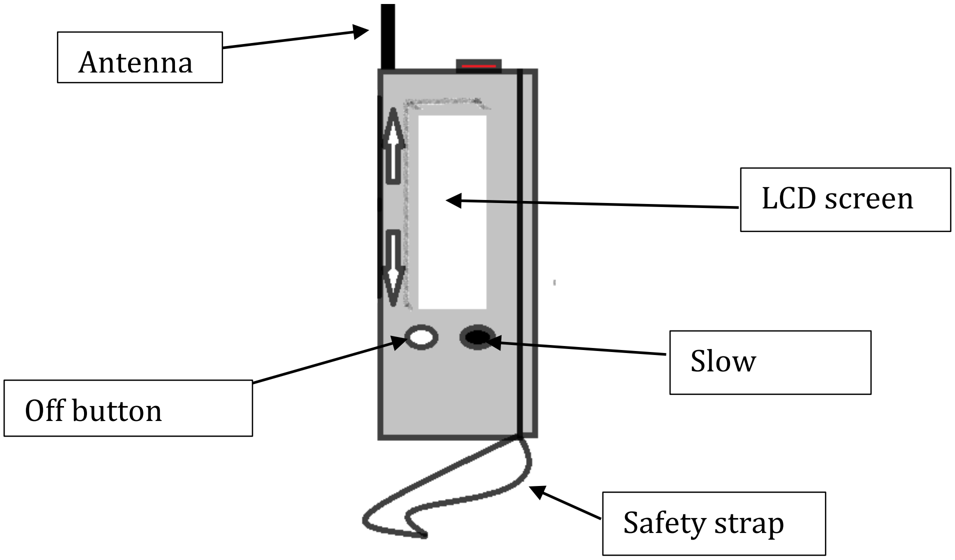


Figure 6.4.3 -1-: Throttle display

6.5 Waterproofing

6.5.1 Protecting Circuit Boards

Keeping the components from damages due to water is the biggest concern for this project. In order to prevent such damages from occurring a housing unit will be used to protect the hardware from the water. This will not be 100% water proof so some of the hardware will need to be dipped in a waterproofing solution. This will further protect the components in the event the housing unit were to become damaged and cause a leak. This will be done by using Fine-L-Kote™ AR by TechSpray. This is an acrylic spray and it is very good because there is no need to worry about the hardware being permanently waterproof. This would cause major issues if something were to be made incorrectly and no changes could be made because the spray was permanent. The spray can be removed which helps in case for any reason something needs to be modified. This spray comes in a few different coating types which have different benefits. These sprays are labeled by different numbers which relate to the category each spray specializes in. These numbers are 2102, 2103, 2104 and 2106. The coating type that will be used for this project will be type 2102. This coating type has the best resistance to water when compared to the others and that is the main concern. It also has the best resistance to temperature which is also a plus. Carefulness must be taken when applying this coating, however. The chemicals can be hazardous to skin so in order to avoid any dangerous physical injuries gloves made of Viton, Solvex, Butyl, Buna, or Neoprene must be worn when applying. This spray is designed to protect only the circuit board and components inside it so additional waterproofing methods need to be considered.

6.5.2 Hardware Housing Unit(s)

In addition to waterproofing hardware components, the battery must also be protected from water. This component will require a little more precaution since it is one of the main components of the design and it is much bigger which makes it more likely to get wet. Two housing units will be used for this and will be referred to as the primary and secondary units. The pcb will be encased in the secondary container which will be inside of the primary housing unit that will contain all of the board components. This is to ensure that if any water were to enter the primary unit, the pcb will be protected by a secondary unit making water much less likely of reaching it. The primary unit will be mounted at the tail of the board because that is where the motor and jet drive will be. This placement was chosen in order to provide the user with as much space as possible on the board to use for standing. This also is the best location to receive the best possible speed. The primary unit was custom made using clear Plexiglas in order to display all the components. This will be designed to fit on the board and hold all the components in the most efficient way as possible. Inside the unit all of the components are held down with Velcro strips. This is so the battery can be easily removed whenever the user needs to recharge it as well as keep everything from moving around. Before the housing unit was placed in the board the inside of the unit was caulked to prevent water from breaking through. A square hole was then cut out of the surf board and the unit was slid in very snug. The unit was then bolted to the top of the board to ensure less possibility of the housing unit detaching from the board. A few images of this process of making the unit and fitting it into the board can be found in Figure 6.5.2 -1- and Figure 6.5.2 -2-.


Figure 6.5.2 -1-

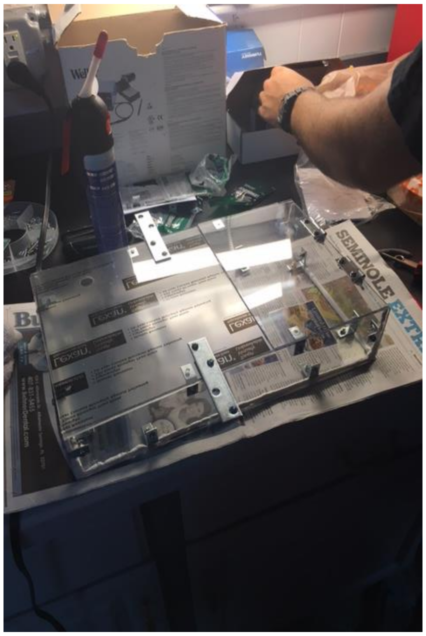


Figure 6.5.2 -2-

6.6 Voltage Regulating Components

6.6.1 Step Down Converter

After evaluating multiple options, the converter that best fit the design and will be used is the Texas Instruments LM2596 step down converter. This device is very cost efficient and meets exactly what is needed to enable the circuit to be properly powered. This converter can be used even though the voltage source being used is rather large because it can operate with a wide range of input voltages which makes implementing it much easier. It is also very small and size is one of the main qualities to consider due to the limited space of the hardware location. Due to the complexity of the design there will most likely be more than one of these converters needed since not all the components will require the same voltage to operate. The current design will require 4 of these converters, however, may be subject to change. A visual of the schematic for this converter can be found in Figure 6.6.1 -1-.

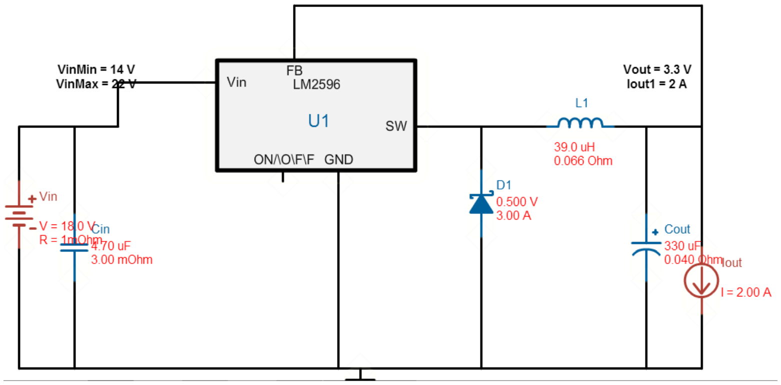


Figure 6.6.1 -1-:LM2596 Schematic

6.6.2 Boost Converter

In order to successfully supply the desired power to every component in the design a boost converter will be implemented. This will be used to amplify the voltage reduced by the step down converter so that the correct amount of power can be distributed amongst the different components. This enables the design to decrease and increase the voltage wherever needed making the overall circuit design a bit simpler. The downside to using such a method of constantly dropping and raising the voltage can cause some losses so this method is not 100% effective. One of the boost converters that will be used is the XL6009. The XL6009 is commonly used in applications such as car adapters, automotive and industrial boost, inverting converters, and portable electronic equipment. This converter will be used to make small adjustments wherever an increased input voltage is required to power a device. This is an inverting DC/DC converter which means it is able to produce a positive output voltage or a negative output voltage. This converter uses two op amps to produce the voltage boost. Figure 6.6.2 -1- displays the block diagram of the XL6009. The main concern when deciding on the boost converter was how much it could output.

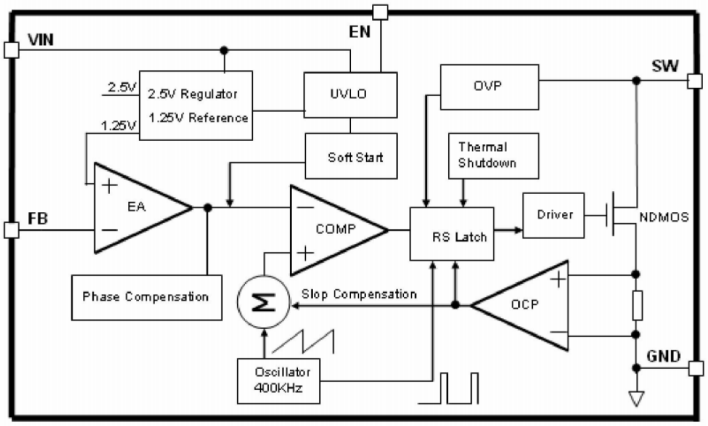


Figure 6.6.2 -1-: XL6009 block diagram

Based on the example schematic, obtained from the datasheet for the XL6009 by Kylinchip, in Figure 6.6.2 -2-, the boost converter can output a voltage of 1.25 x the input voltage. This can be improved by simply modifying the resistors used in the diagram. The formula for output is denoted by Equation 1. If the value of R2 is increased, the output of the converter will increase as well. However, the amount of power that can be dissipated by this converter is limited. The output can only be increased to an extent. The XL6009 is capable of converting an input of 5V to a 32V output. This amount of voltage amplification will most likely not be necessary but it is good to have versatility. In order to reach this amplification level does not involve using equation 1. This can be done by turning a node on the XL6009 that overrides its output limit. However, this tampering can cause harm to the product as well as what it is connected to therefore it is not advised to do so.

(1) $Vout = 1.25 * \left(1 + \left(\frac{R2}{R1}\right)\right)$

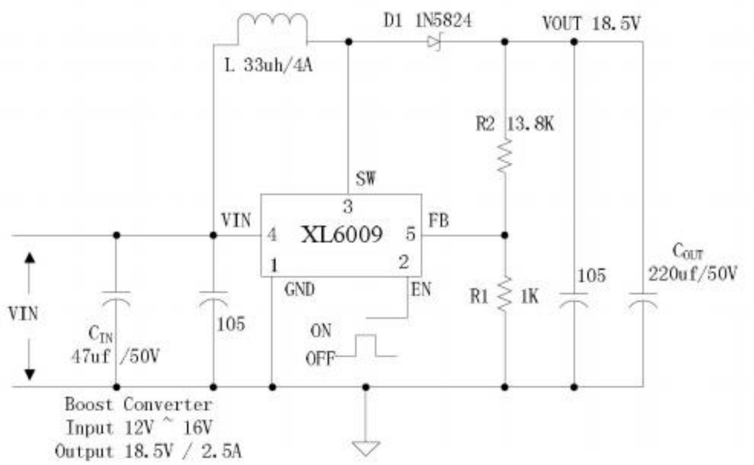


Figure 6.6.2 -2-

XL6009 Specifications:

- 5V to 32V input range
- Fixed 400kHz switching frequency
- 94% efficiency rating
- Max 4 Amp switching current
- Built in soft start function
- Built in thermal shutdown function
- Built in current limit function
- 1.25 reference adjustable version
- SW pin built in over voltage protection

The LM2587 converter will also be used. This converter will be used to amplify the voltage when a large boost is needed. The LM2587 can produce an output voltage of 3.3V to 12V greater than the input while taking in an input of up to a maximum of 40V. This converter can take an input voltage of 12V and convert it to output 24V using the circuit diagram in Figure 6.6.2 -3-. Figure 6.6.2 -3- was obtained from the Texas Instruments LM2587 datasheet. To change the range of the produced output voltage, the only components that will need changing are R1 and R2 in Figure 6.6.2 -3-. The values of R1 and R2 needed to satisfy this requirement can be found in Table 6.6.2 -4-.

LM2587 specifications:

- 100 kHz switching frequency
- Internal soft start function reduces in rush current during start up
- System output voltage tolerance of ±4% max over line and load conditions
- 4V to 40V input voltage range
- Output transistor protected by current limit

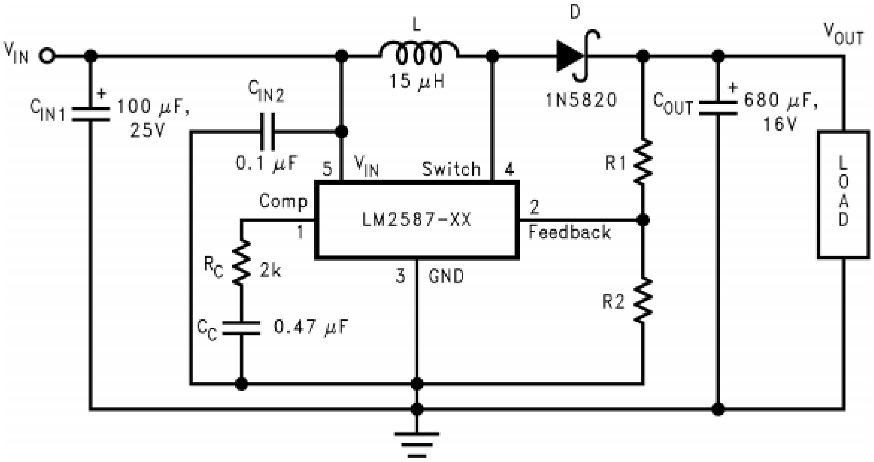


Figure 6.6.2 -3-

R1	R2	Vin	Vout
36.9 kΩ	2 kΩ	12V	24V

Table 6.6.2 -4-

6.6.3 Electronic Speed Controller

After further research on how to best design the board, we noticed that an electronic speed controller (ESC) could make a lot of the voltage conversions much easier. The ESC is equipped with a universal battery eliminating circuit (UBEC). This means the ESC contains a step down regulator that will take any input voltage and drop it to 5V. This is very beneficial because this eliminates the need to have another source just to power the microcontroller or to design our own step down circuit. In addition, the ESC is also connected to the motor and outputs the full voltage input to the motor. This eliminated the need for both the boost and step down converters. The ESC outputs the 5V to a port that is connected to the microcontroller. This port also include the ground and data line. The ESC uses the data line to read from the microcontroller. The purpose of this is for the ESC to be told how much current to output to the motor.

The speed controller that was used is the Swordfish pro as shown in Figure 6.6.3 -1-. This is a 120A speed controller which we chose since the battery being used is capable of outputting 202 A so we wanted to limit the maximum current. This ESC proved to be very useful in controlling the motor from the received Bluetooth commands however it was expensive. Here the benefits outweighed the cost so it was worth it.

Figure 6.6.3 -1- Swordfish ESC

6.7 Safety Devices

6.7.1 Hard Kill Switch

Having a way to cut power directly is a major concern in this design. In the event the rider were to fall off the board, it is important that the motor stops running. In order to account for this situation a hard kill switch was installed. The kill switch used is the Seadog Universal Kill Switch which can be found in Figure 6.7.1 -1-. This kill switch was chosen because of the method it uses to cut the power. This switch is equipped with a lanyard that clips into the kill switch that is connected in the circuit. The kill switch is installed directly between the esc and the battery. This is necessary in order to prevent any power flow in the system. When the lanyard is detached from the kill switch, an open circuit is formed causing no current to flow resulting in the motor, mcu and esc all to turn off. The lanyard can be attached to the rider so that whenever they fall off the board this switch is disengaged. This method of cutting the power was added since relying on the program to cut the connection based on signal is not completely safe or guaranteed so we needed to implement something that will directly cut the current of the battery from flowing to the rest of the system.

Figure 6.7.1 -1-

6.8 Mobile Application

While using the app the display is shown in two different formats. The first format shown in Figure 6.8 -1- displays the home screen that the user will see after opening the Eletri-surf app. This screen provides the user with two options. These options are labeled “Get Surfing” and “Advanced settings”.

Figure 6.8 -1- Home screen

The “Get Surfing” option will connect the app to the Bluetooth on the surf board and then display the throttle screen. This screen is the screen that is displayed when the user wants to control the board, shown in Figure 6.8 -2-. On this screen the user can now control the motor by pressing up to increment or down to decrement on the volume keys of the phone. As the speed is increased, a progress bar shows the relative speed by displaying a color: red for slow speed, yellow for medium speed, and green for maximum speed. In addition, to the speed bar a battery progress bar is also displayed which is intended to let the user know how much voltage is remaining in the battery. There are also two buttons that are labeled “off” and “slow”. These buttons are accessed using the touch screen and when pressed they do exactly what they are labeled to do. “Off” turns off the motor and “slow” brings the motor to a slow speed.

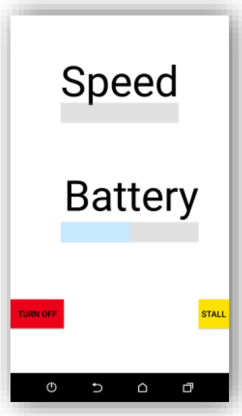
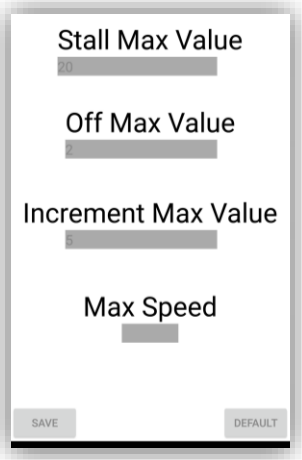


Figure 6.8 -2- Get surfing screen

The second option the main screen is the advanced settings option. Under advanced settings the user is given the ability to change the maximum speed allowed, how big the increments and decrements are initiated and what the slow speed is. This was implemented so that the user can customize the way they use the board. Once the changes are made by the user they have the option to save them and use them to control the board. If they do not like these settings there is also a default button in the advanced settings screen which will restore everything to the original settings. The advanced settings screen is display is shown in Figure 6.8 -3-.



Stall Max Value
20

Off Max Value
2

Increment Max Value
5

Max Speed

Figure 6.8 -3- Advanced settings

7.0 Project Construction and Materials

7.1 Parts Acquisition

In order to stay on budget and use our resources as effectively as possible, prices of many different distributors will be compared to find the best deal and prices on all hardware. We will order parts and equipment as early in the build phase as possible to ensure we stay on schedule without falling behind due to a backorder or part scarcity. If possible and especially if time is of a greater issue than cost, we will try to purchase parts from local stores to speed up the building process which will also allow us to quickly return or exchange parts if necessary in a reliable way.

7.1.1 Surfboard Acquisition

Given our geographical location in central Florida, it is very easy to acquire the appropriate surfboard for our project. The ideal solution would be to create our own custom deep shell surfboard, similar to thin kayak, with a removal top surface that could house our hardware, as well as enable easy access for recharging the battery. Unfortunately due to time and monetary constraints, getting our own board shell constructed is not a likely option and we will need to purchase a used surfboard from local surf shop on the east coast, near Cape Canaveral, FL.

One of the group members already owns a 6 foot 2 inch foam top surfboard; if our power output is predicted to achieve speeds close to 20 miles per hour then this will be the most economical and resourceful option. If the predicted power output is not expected to reach those speeds then there are many surf shops along the Space Coast and just south of Cape Canaveral that sell used surfboards of all sizes that are fairly priced anywhere from $100-$500 depending on the size, brand, and material. The board that we will purchase, if necessary, will cost approximately $150 and most likely be a “foam top” surfboard, as pictured in section 5.1.4 labeled “Surfboard Pricing”. That means the board will be very buoyant and the top of the surfboard will have a soft cushion foam top, much like a boogie board. This will be a good surfboard to use instead of the traditional fiberglass or epoxy construction because they are relatively cheap, softer material, and will be easier to manipulate and integrate our components. Traditional fiberglass surfboards have a soft foam inside and a hard fragile fiberglass outside. This type of construction is easily damaged and if not repaired or sealed from water immediately, can become waterlogged and ruined, making it difficult to attach outside components to it without compromising its durability and buoyancy.
When it came to using a surfboard for the design we decided to use an old surfboard that we already owned in order to save money. There was no need to buy a new surfboard that was just going to be cut into to hold the housing unit and the components so using one that was no longer being used was much more beneficial.

7.1.2 Battery, Motor, and Jet Drive Acquisition

Simply put, the Zippy Flightmax LiPo battery, the Turnigy AquaStar motor, and the CNC precision jet drive will all be purchased online. Hobbyking.com has the three desired components at fair prices and could conveniently be shipped to a location of our interest. Our desired battery can be purchased at a price of approximately $45. The high-powered RC motor, the Turnigy AquaStar, can also be purchased off of Hobbyking.com and can be purchased for just under $100. Our most expensive piece of hardware will be the precision jet drive that can be purchased for $400. It is beneficial to have to be able to order our large components online from a large distributer.

7.1.3 Wireless Communication Technology Acquisition

Our wireless communication technology will require multiple stages and electronic components to achieve a desired reliable wireless connection. As previously discussed in section 4 of this text, Bluetooth technology will ideally be used to wirelessly control the amount of thrust achieved. The technology will consist of, but not limited to, the Bluetooth transmitter, Bluetooth receiver, and a microcontroller.

Our Bluetooth technology will consist of a transmitter that will be located in the electrical hardware on the board itself and the part has been narrowed down to the CC2564MODN and the HC-05. Both can be ordered online, the CC2564MODN is a dual-active Bluetooth evaluation board that takes the place of the Bluetooth transmitter and the microcontroller and can be purchased directly from TI for $20. The HC-05 chip must be soldered to a microcontroller and can be found on amazon or other online distributors for $3-$6. An Arduino or Texas Instruments family microcontroller can be used with the HC-05 Bluetooth transmitter and purchased online from multiple different distributors for anywhere from $10-$25. The price depends on how complete the microcontroller board kit is. Development boards are incomplete and therefore cheaper, while the complete kits cost closer to $25.

Ideally, the Bluetooth receiver used will be an android smart phone with a Bluetooth receiver built in. The acquisition of an android smart phone will not impact our budget because two of the group members already have one. However, a waterproof case will be necessary to ensure the safety of the device. One of the most trusted and well-known waterproof phone cases is the LifeProof case. This phone case costs around $100 online but a generic waterproof phone bag with a lanyard, called a Dry Pak can be purchased for as low as $10 online from Brookstone and is capable of waterproofing just about any cell phone and includes a small flotation device.

7.1.4 Battery Monitor Acquisition

A battery monitor is an important component regardless of price because it is an important safety feature for the rider. There are a few battery monitors that we could choose from and possibly test but the DS2438 Smart Battery Monitor is fairly cheep and can easily be ordered from eBay for $3.50 per unit or for slightly less per unit of purchased in bulk. However, this part was easily acquired from the Maxim Integrated website. We requested free samples of this product and were given 4 of these chips for free giving us the ability to heavily experiment with it. This particular component is discussed in detail within this document.

7.1.5 Voltage Regulation Device Acquisition

Many different types of technology can regulate the voltage or current flow of a DC power supply, including simple passive components such as varying resistors and a potentiometer. Voltage regulation will be used in unison with are Bluetooth wireless connection to act as a throttle and control the speed of the motor. The most effect way to regulate the DC motor speed is to use a pulse-width modulator (PWM) and integrate it into our circuitry. Pulse-width modulators designed for DC motor speed control can be found online for $3-$8. Gearbest.com has a durable “do it yourself” pulse-with modulator for $7.96 plus shipping. Often times, microcontrollers may have pulse-width modulation built in.

8.0 Project Prototype Testing

The electric surfboard has various subsystems that work together in order to function as a propulsion surfboard in which a user would be riding and controlling through a handheld-throttle that would be sending inputs that the user has chosen. Each part that makes up the surfboard will be tested as it is put together, completed, and integrated with other parts of the surfboard system hardware. These tests could be as anything simple from checking the connection between the surfboard and the handheld-throttle to the inputs from the handheld-throttle and the appropriate actions happen based on the input of the user. Testing at last minute is not a goal for this project, but to test every small aspect of the project that is completed, test to verify that it works and integrate the system with other parts and verify that every semi-integrated works also together. By doing continuous testing based on the tests that we do, lowers the chance that there would be a hiccup in the system.

8.1 Hardware Test Environment

The testing for the electric surfboard will be place both indoors and outdoors even though the electric surfboard was meant to be outdoors, where large masses of water would be located. Most, if not all, of the electric components for the electric surfboard will be conducted exclusively on indoors. Since the Senior Design Lab will be available for us throughout the semester, it would be ideal to examine all of the electronic parts in there and conduct any testing. Once most of the electronics is hooked up and are wirelessly connected and responding, testing will be conducted outside to test with the ideal conditions that the electric surfboard will be going with. One of the most crucial parts of the testing would be the behavior of how data is transferred due to the fact that there is water around. In addition, constant observation would be needed to verify that the system does not get water encapsulated inside the housing unit. Any full run of the electric surfboard used in a mass of water, i.e. lake, beach, and will be recorded and examined for future testing and modifications if needed.

8.2 Hardware Specific Testing

For this section, close observation of the different features and the integrated electronics encapsulated of the electric surfboard will be discussed. These test that are conducted will measure how closely the progress of the electric surfboard has come from the initial goals. These tests will ultimately show if the integrated electronics and connections are working and behaving as expected. Looking at the test results gathered, one would judge on what will be the next course of action. These actions will be prioritized based on the requirements of the project and resources at hand; money, time, manpower.

The process of hardware testing was pretty basic. Once the pcb was acquired all of the components were installed on it and tested. This testing revealed that there were some issues in the design. One of the issues was that the Bluetooth would not turn on. This was because of the resistors that were being used to drop the voltage of 5V coming from the microcontroller, to 3.3V to power the Bluetooth. The current may have been too low because after further testing the Bluetooth worked just fine when no resistors were used to drop the voltage to turn on the Bluetooth. Another issue that was faced during testing was that the pin the code for the entire system was programmed to come out of was incorrect. This error was in the code and not on the pcb however no changes could be made to the code due to not having a bootloader on our pcb. In order to fix this a connection had to be hardwired from the pin that the mcu had the data routed to on the pcb to the pin on the mcu that was programmed to output the code.

8.2.1 Hand-Held Throttle Control Test

The hand-held throttle control test will test the parameters that are involved when the user is using the hand-held throttle with the electric surfboard. Due to the fact that the only way to use the electric surfboard is through the hand-held throttle, all the tests will revolve around the Bluetooth module and the Android application. The tests that will be involved would be: Bluetooth range testing, Android response testing, button control testing, and many other test procedures. One major aspect that will be tested would be the controlling of the speed of the electric surfboard due to the fact this would be the only aspect the user can control on the electric surfboard.

8.2.1.a Android/Bluetooth Connectivity Testing

The Android/Bluetooth connectivity testing will be testing the connection between the Bluetooth module on the electric surfboard and the one with the Android device. To run these tests, there a few items that will be needed to assure the testing occurs and accurate. The items needed for this procedure would be a development board with UART connectivity, in this case we chose the Arduino UNO, a computer that is able to display serial read results, and a Bluetooth serial emulator on the Android device to send data to the development board via a Bluetooth module such as ASCII characters, BlueTerm. After having this setup, the Android device will send specific ASCII characters to be tested through the BlueTerm, and if the response is right, the ASCII character sent through the BlueTerm should be displayed at the screen through the UART serial connection via USB between the computer and the Arduino UNO. To assure that every character works, as it should, a bunch of ASCII characters will be sent by the BlueTerm.

8.2.1.b Bluetooth Range Testing

The Bluetooth Range Testing will test how far can the signal be casted to control the electric surfboard through the Android device. Looking through the specifications of the HC-05 module, it is stated that the Bluetooth module has a line of sight range of 30 feet, though is changes depending on the environment and conditions the Bluetooth module will be in. The testing will verify through a set of tests, at which distance does the Bluetooth module stop working due to the signal not reaching at the other end, the electric surfboard and the Android device or vise versa. Due to the fact that the electric surfboard is going to be used outside where water is present, we have to mimic the similar conditions at which the electric surfboard components will be encapsulated with the Android device. Doing so would give us the most optimal data to assure when the Electric surfboard is ready for prime time; there would not be any problems with the connections between the electric surfboard and the Android device.

The way in which the test will be conducted is by having a enclosure similar to what the hardware will be kept and mimic the conditions at which the electric surfboard will be. To test the Bluetooth module without integrating it within the whole entire system, we will connect it to a development board, which would be the Arduino UNO due to the tools given to program are simple and the simplicity of the I/O. To make it easy on the testing and keep it simple, a simple program will be developed in the Arduino IDE software to basically set a certain pin output high when the micro-controller reads in a serial input from the UART. Getting data to the Bluetooth module, the Android device will use BlueTerm to be used as a

Bluetooth emulator. The Android device would send then through the BlueTerm application, data to the Bluetooth module in which if the data is get received, would turn a green light on the micro-controller and display the corresponding character through the computer screen. The testing would be conducted at different feet intervals to verify the distance the signal can be read. Table 8.2.1.b -2- displays the results the distance at which data is sent. We believe that the HC-05 Bluetooth module will be able to read data of up to 15 feet and out of range within 20 feet.

Distance (ft)	**Character Sent**	**Character Received**	**In range? (sent = received?)**
1	“0”	“0”	Yes
5	“9”	“9”	Yes
10	“A”	“A”	Yes
15	“Z”	“Z”	Yes
20	“a”	n/a	No
25	“z”	n/a	No
30	“.”	n/a	no

Table 8.2.1.b -1- Results for the data being sent to the Bluetooth module mimicking the conditions the electric surfboard will be in.

Depending on the results that are gathered, we might choose to keep the antenna within the encapsulation of where the electronic components are or outside just to keep the design simple. Even if the antenna encapsulated distance to receive is shorter than having outside, if its within a certain distance to receive data, it would still be encapsulated inside due to the shorter range would help with the emergency break of the board if the user ever falls off the board. Table 8.2.1.b -2- displays the test data from when the Bluetooth module and the Android device are used in the ideal environment.

Situation	**Module Responding? (Results expected)**
Antenna inside the encapsulation	Yes, the Bluetooth module is receiving data
Antenna outside the encapsulation	Yes, the Bluetooth module is receiving data

Table 8.2.1.b -2- Results from the antenna inside/outside the encapsulation.

8.2.1.c Speed Control Test

The Speed Control Test will test the electric surfboard from any abnormal behavior that should happen trying to go over a certain speed limit. The test should test that when the speed is in changed via the Android application, it doesn't pass the two limits that are set, minimum speed and maximum speed. In addition, whenever there is a change of speed, the speed is change at a fix rate through the device. To achieve this testing, we will use the Arduino UNO, which is the development board, and set up two pins with LED colors a green, for the speed was changed successfully, and a red one where the speed changed did not happen. In addition to this, the speed chosen would also be displayed on the screen through the development board. The way that the user would change the speed of the electric surfboard would be through the +/- Volume keys using the Android device running the application, sending data to the Bluetooth module. Once the data is sent to the Bluetooth module, the micro-controller would read the UART serial data and send the corresponding signal to the motor to change the speed accordingly. Table 8.2.1.c -1- and Table 8.2.1.c -2- shows the behavior due to the user input through the Android device.

Serial Input Recieved	Results
Vol +	Turn LED Green, display change speed at Screen accordingly
Vol -	Turn LED Green, display change speed at Screen accordingly
null	Turn LED Green, no change of speed, display current speed

Table 8.2.1.c -1- shows the results when the electric surfboard can change speed accordingly since the new speed change is less than the maximum/minimum speed.

Serial Input Recieved	Results
Vol +	Turn LED Red, display change speed at Screen accordingly
Vol -	Turn LED Red, display change speed at Screen accordingly
null	Turn LED Green, no change of speed, display current speed

Table 8.2.1.c -2- shows the results when the electric surfboard cannot change speed since the new speed would be lower or higher than the Maximum/Minimum speed set-up coded.

Another aspect that will be tested in this test would be the powering down of the electric surfboard. The user should be able to press the power button on the phone, and once that is registered, the Android device would send a signal to the Bluetooth module to the micro-controller to shut down the engines manually.

8.2.1.d Emergency Control Test

The Emergency Control Test will test the emergency mode of the electric surfboard. Due to the fact that the only way to physically control the electric surfboard is through the Android device, there must be an emergency stop when the user falls off the electric surfboard while at use, since we don't want the board to keep on running. To do this test, we will connect our development board, the Arduino UNO board with the micro-controller and connect it to the computer to display the results in the screen. The test would consist of the micro-controller reading data from the UART serial connection. Whenever the microcontroller doesn't receive data from the UART serial connection from the Bluetooth module, it is assume the user with the android device is out of reach and must deploy the emergency motor stop. In this case, we will increase our distance from the Bluetooth module, and once the connection is lost, the micro-controller would set a output pin high to turn on the red LED and display on the screen, "Connection Lost, Emergency Stop Engaged". This would signal the micro-controller to turn off the motor for the electric surfboard. Once this signal is trigged in the micro-controller, the micro-controller would then disengage power to the motor. The Figure 8.2.1.d -1- below shows a simple diagram of what happens when the Android device should loose connection to the electric surfboard.

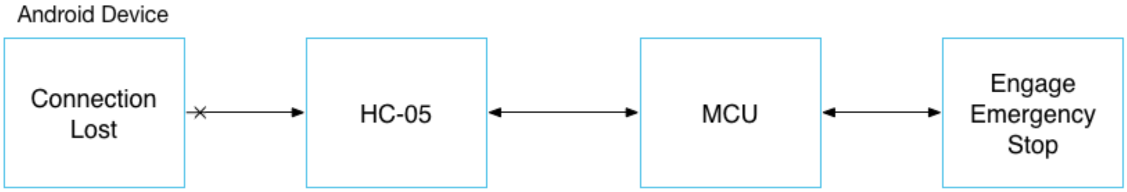


Figure 8.2.1.d -1- shows the results when connection lost happens.

In addition to testing the emergency cut off based on connection

8.2.2 Battery LED Display Test

The battery LED Display Test would test the LED display that is mounted with the smart battery monitor. To test the smart battery monitor to check it works with our electric surfboard, we will discharge accordingly the battery and get the readings from the smart battery monitor and compare it with the readings of the volt and amps coming out of the battery. The intervals that are read would be every 15-minute and should be compared to the readings that the smart battery monitor displays. Table 8.2.2 -1- would show the data read at the given intervals from the battery.

Time Interval (minutes)	Smart Battery Monitor Display	Volt(V)	Amps(A)
15	95	21.5	50
30	90	21.5	45
45	85	21.5	40
60	80	21.5	35
75	75	21.5	30
90	70	21.5	25

Table 8.2.2 -1- shows the results after operating the battery for a 90 minute period.

After a long period of testing it seemed the battery monitor would not work the way we intended. In order to save time we opted out of using the battery monitor and instead use a voltage divider to read the voltage of the battery. This voltage would be sent to the analog pin of the microcontroller. At this point, however, the pcb had already been ordered so adjustments had to be made since there was no time to order a new one. Luckily the design had an existing voltage divider where the battery monitor went so we were able to use that by hardwiring the voltage divider output to an analog pin on the microcontroller. The schematic of the voltage divider used from the battery monitor is shown in Figure 8.2.2 -1-.

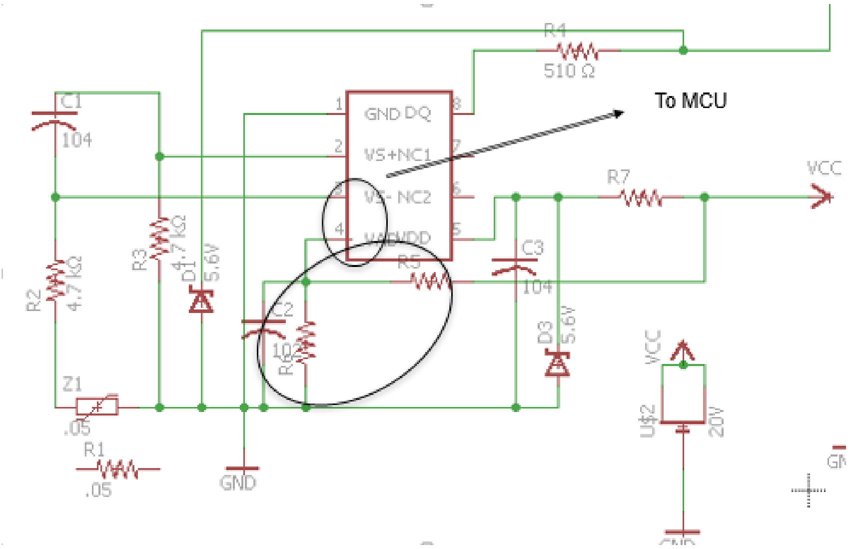


Figure 8.2.2 -1-

8.2.3 Power Distribution Test

For the Power Distribution Test, we will measure the power the main components of the electric surfboard, the micro-controller and the motor power impact against the battery. Due to the specifications of running at least 30 minutes, it is crucial to optimize how much power each component uses and finding optimal ways in which each component uses the least amount of power. It is important within this test that we minimize the power each component take and maximize efficiency throughout the electric surfboard to increase the running time of how long the electric surfboard can be used.

The goal is to have all of the internal components such as the Bluetooth, the LEDs, circuit boards and other technical components consume as little power as possible in order to preserve the majority of the power for the motor. The motor is expected to consume the most therefore reserving as much as possible is the main objective. The testing will be done in the following steps:

1. Bring power source to full charge
2. Let the power run while operating only one unit (e.g. the motor)
3. Stop the power after 20 minutes
4. Measure the remaining battery
5. Return power to full charge and repeat for additional unit

Once the testing is completed an analysis of the results will be taken in order to have a better understanding of how the power is being distributed. After knowing how much power each unit will use, troubleshooting can be done in order to acknowledge if something is using more power than it should be. Based on the specifications of the hardware that was chosen the expected results of power consumption are predicted to replicate Table 8.2.3 -1-.

Ranking of power consumption (high to low)	System	Percent of power consumed
1	Motor	70-80%
2	Jet drive	12-18%
3	Circuit boards and components	10-15%
4	Bluetooth	2-5%

Table 8.2.3 -1-

8.2.3.a Micro-Controller Power Test

The micro-controller power test shall test how much power does the micro-controller is consuming. The way to do this is by using the battery and having to use only the micro-controller and read the beginning voltage of use and reading the voltages off of the smart battery monitor in intervals of 2-minute. Table 8.2.3.a -1- shows the data that would be collected in determining our results. One important factor that will determine how much power the micro-controller is using is how efficient the coding is done. Based on the results gather, we will try to maximize our code, so that the least amount of power is used.

Trial	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0-minute	100	100	100	100	100	100	100
2-minute	99	99	99	99	99	99	99
4-minute	98	99	99	99	99	99	99
6-minute	97	98	99	99	99	99	99
8-minute	96	98	98	99	99	99	99
10-minute	95	97	98	98	98	98	98
12-minute	94	97	98	98	98	98	98
14-minute	93	96	97	98	98	98	98
16-minute	92	96	97	98	98	98	98
18-minute	91	95	97	97	97	97	97
20-minute	90	95	96	97	97	97	97
22-minute	89	94	96	97	97	97	97
24-minute	88	94	96	97	97	97	97
26-minute	87	93	95	96	96	96	96
28-minute	86	93	95	96	96	96	96
30-minute	85	92	95	96	96	96	96

Table 8.2.3.a -1- shows the voltages at every 2-minute results from the test. The intervals would show the new modifications run with the test.

8.2.3.b Motor Power Test

The Motor Power Test should test how long can the motor run for. The way we will be conducting this test is by powering the motor at full speed in ideal conditions, meaning having the motor inside the water. The test would be finished when either of the two conditions is met; the battery runs out of charge or the motor has run for 30 minutes. While we are testing, we will be collecting data in increments of a 2-minute period and put into our table shown at Table 8.2.3.b -1-. After the test is done, we will take appropriate action based on the results gathered. This data would determine what would be the ideal RPM we can set up on the motor to have enough power to run the other components in the electric surfboard.

Trial	1(set RPM)	2(set RPM)	3(set RPM)	4(set RPM)	5(set RPM)	6(set RPM)	7(set RPM)
0-minute	100	100	100	100	100	100	100
2-minute	90	92	93	94	94	95	96
4-minute	80	84	86	88	88	90	92
6-minute	70	76	79	82	82	85	88
8-minute	60	68	72	76	76	80	84
10-minute	50	60	65	70	70	75	80
12-minute	40	52	58	64	64	70	76
14-minute	30	44	51	58	58	65	72
16-minute	20	36	44	52	52	60	68
18-minute	10	28	37	46	46	55	64
20-minute	0	20	30	40	40	50	60
22-minute	-	12	23	36	36	45	56
24-minute	-	4	16	30	30	40	52
26-minute	-	-	9	24	24	35	48
28-minute	-	-	2	18	18	30	44
30-minute	-	-	-	12	12	25	40

Table 8.2.3.b -1- shows the results of the board running at a specific RPM, shown at different RPM values.

8.3 Software Specific Testing

8.3.1 Android Software

The application that shall be used by the Android device can be tested through a PC using the Android integrated testing framework. While having also the use of a USB Bluetooth module, every aspect of the application can be simulated. If all the tests conducted for the Android application pass, the application will be able to conduct the Electric Surfboard without any issues.

Speed Change Test: A very crucial aspect of the Android application is to be able to change the speed/RPM of the Electric Surfboard. To test this, we shall simulate through the Android application with the use of the USB Bluetooth module. We then would read the signals that come from the micro-controller and compare the data read to what is expected. There should be two buttons on the application, which mimics the ones that the device should have the Volume +/-. Pressing the

Volume +/- shall change the speed accordingly to the device; + making the Electric Surfboard speed, - making the Electric Surfboard slow down. The test should check that the application doesn’t let the user exceed the programmed RPM that the electric surfboard can run. The test shall pass if the signals read from the micro-controller sustain the same signal after a certain RPM passed, which shall not pass that RPM limit.

Bluetooth Detection Test: When the Electric Surfboard is on and has been set via the Android device, the Android device shall be able to automatically connect to the Electric Surfboard when the application starts up. Assuming that everything passes and the appropriate checks done by the system pass, the application shall display a message that everything is good to go.

Battery Life Detection Test: This test should check the battery life of the Android device the application is used on. This should check the phone’s battery when the application is started prior to the user interacting with the electric board. Doing this check should prevent almost all the time from the user’s Android device shutting down from lack of battery in the middle of a run. If everything’s good with the battery life of the user, the user would get a green check mark, if not a warning will prompt, preventing the user from using the electric surfboard.

Safety Engage Test: This test should check the emergency test of the electric surfboard. To conduct this test, the user should slowly increase its distance ‘til a disconnection happens between the Electric Surfboard and the Android device. When a disconnection happens, it should prompt that the user would be in an emergency mode ‘til the user comes into a distance of the Electric Surfboard. The test would pass when this message comes on.

8.3.2 Electric Surfboard

The Electric Surfboard will have three modes that the software can be used in: RELEASE, DEBUG, MASTER. The MASTER mode will simply give master status to the user, having complete control of the system, primarily meaning having full control of what speed the user wants and also over looking any warning or messages that the system would throw to the user.

Hardware Interface Test (ID: 0): The hardware test is a very crucial part of the Electric Surfboard. Since all the hardware in the Electric surfboard is being used, we have to test everything since it’s a crucial part that everything works fine and correctly. Thus we are going to toggle all of the General Purpose I/O inside the hardware. We will also carefully test our Driver Motor’s PWM. Since the PWM will be what will be controlling our motor, it would be wise to test the system with an oscilloscope to determine the duty cycle is correct duty cycle. We will also have fake bytes that will be filled into the UART send and receive byte registers and the data entered shall be written and read, then check that the data is correct.

Emergency Stop Test (ID: 1): This test shall test the Electric Surfboard. Within the system, once the Bluetooth connection has been lost, the system should signal the Driver Motors to shutoff. Doing so would stop the Electric Surfboard from operating any more. This test makes sure that the Emergency mode of the surfboard works, since we don't want the board to keep on running while there's no way of controlling, making it hazardous until the charge dies.

Mode Test (ID: 2): Since there are three different modes, it is ideal that we test all the modes of the Electric Surfboard. Since the modes vary greatly to each other, this test will be very in-depth. The most important part of this test is to see that every mode works and is changing correctly. We will change modes, and verify that's the correct mode is running. For the modes, the mode class would be able to invoke a get_current_mode() function that would get the current mode that's running which would then be compared to the mode that is running at the moment. When there's a mode change, there would be another function invoked called get_last_mode(), which should state which was the last mode that was on. This would give assurance what was the last mode used prior to the new mode changed to.

Message Creator Test (ID: 3): The messages that arrive will contain a specific bits represented as the first byte. The following bytes should follow the message that is being sent through the MessageCreator, in which then the MessageCreator would return the appropriate type of message to send over. To generate the message being sent by the MessageCreator, it needs to be registered by the MessageCreator. To assure that this aspect is working, when the message is being generated, we compare the size of the list that was generated to the number of messages that were made.

Message Test (ID: 4): The messages that come into the system is important within the system. It is crucial that the messages are functioning right, if not the system would not perform correctly and would potentially injure the user. To test this, a set of bytes of a test message with certain values shall be created and sent, in which the unpack_message() function will be invoked that the data of the message is the same one as the ones we set. To test that the message sent is correct, a set of bytes would be made and then invoke the pack_message() function and assure that the bytes made equal to a certain value chosen. Afterwards an function called run_message() would be invoked to make sure the message sent runs while executed.

8.3.3 Bluetooth Software

Bluetooth Name Test: The Bluetooth receiver/transmitter on the electric surfboard should be called "Electric Surfboard", and the Android device shall broadcast under the name "Hand-Held Throttle". Both devices should be able to identify each other and connect.

Valid Message Test: The Bluetooth receiver/transmitter on the Electric Surfboard shall receive two bytes before it assumes a complete message has been sent. The device shall check the received two bytes to verify it by asserting some of the bits are a valid message index. The Android device used shall do the same thing to verify the data being received comes from the Electric Surfboard.

UART Communication Test: The Electric Surfboard's transmitter and receiver shall send received messages to the main processor via UART communications. To test this, the processor shall send fake messages to the Bluetooth receiver, commanding it to make a new valid message and send it back, with all of the data fields equal to 0Xfff. This should be acknowledge by the Bluetooth module and checked for correct values, if there are any discrepancies, an error should be alarmed, else the test conducted is considered to pass.

8.4 Mechanical Function Testing

Mechanical function testing is directed towards the motor and jet drive. The two most preliminary tests can be categorized as unloaded and loaded testing. Unloaded testing means that the test will be conducted out of water to simply check the functionality of the motor and jet drive. Correspondingly, loaded testing will be conducted with the jet drive in a simulated water-testing environment without being mounted on the board. Both the unloaded and loaded tests will be done multiple stages. As each stage of the project is added and the complexity of the project design develops, the functionality of the mechanical systems will be reevaluated. Mechanical function testing will be conducted in two stages. Figure 8.4 -1- represents the simple mechanical functionality of the system.

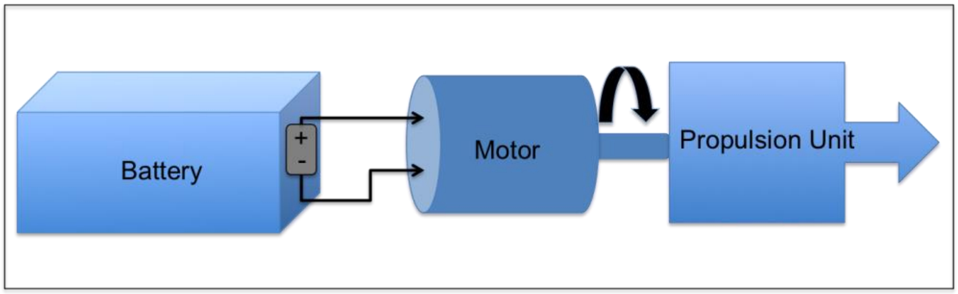


Figure 8.4 -1- Simple Mechanical Functionality Testing Diagram

8.4.1 Stage One – Without Environmental Load

The first stage of testing is a very simple unloaded test with a direct battery to motor connection. This test will be done as soon as the motor and battery are acquired to check functionality of the motor and make sure it rotates. Prior to the initial functionality test, a preliminary test is to charge the Zippy LiPo battery to full capacity and check its voltage with a hand held voltmeter or with equipment found in the lab. This test incorporates no regulator and will demonstrate the full capacity of the motor with no load. Part two of stage one testing is to securely fasten the jet drive to the motor's drive shaft and test the functionality of all three components working together in a simple linear manner. Once again, no throttle control is integrated and the max output will be represented in an ideal environment with no load.

8.4.2 Stage Two – With Environmental Load

Stage two of mechanical function testing is to repeat stage one part two testing but incorporates load testing by using a simulated water environment. Our simulated water environment will be a bathtub or a swimming pool. The point of this is to see how the jet drive will operate with the water resistance, as well as get a physical real-world feel for the amount of thrust our components can produce. This test environment will also allow us to test the water-cooling system capabilities of our motor. This test will be done with the three components, the battery, motor, and jet drive all in direct connection. Once connected, we will safely separate the battery and motor from our water environment and shield the dry components with a temporary barrier as the jet drive's water intake makes contact with the water. As we temporarily wire the battery to the motor we will experience the capability of the system in an ideal scenario.

9.0 Related Diagrams

Diagrams are an important role in any project design. They are helpful to realize ideas as well as physical models and representations. Diagrams were used throughout our design process to help plan and depict our ideas. Figure 9.0 -1- is a simple power output represents used to determine efficiency.

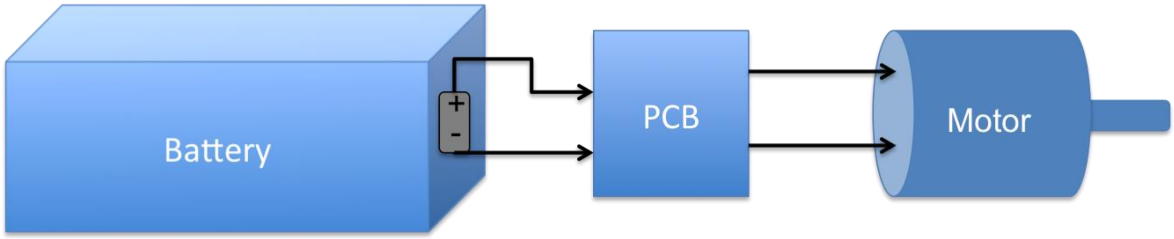


Figure 9.0 -1- Simple Power Output Representation

9.1 PCB

This section contains the complete schematic and board design for the board. The schematic shows the intended connections of the battery, PCB, motor and jet drive. The following schematics were created using the EAGLE PCB building software. The schematic and board design for the PCB are found in Figure 9.1 -1-

and Figure 9.1 -2-. Not all of the parts that will be used in the design were in the EAGLE library so some had to be imported. The microcontroller, Bluetooth and battery monitor all had to be downloaded and imported in order to use them in the schematic and board layout.

The pcb is a two layer board and is about 1.56 in. x 2.3 in. This pcb mainly consisted of 0603 surface mount parts with the LEDs, Bluetooth and header being the only through hole parts. Our pcb was fabricated by OSHpark. The pcb was ordered through this company because they provide 3 copies of the pcb which was very helpful when it came to troubleshooting with our pcb. One pcb was used as the test pcb to make sure all the functions worked properly and the other two were used as the final pcb and backup pcb.

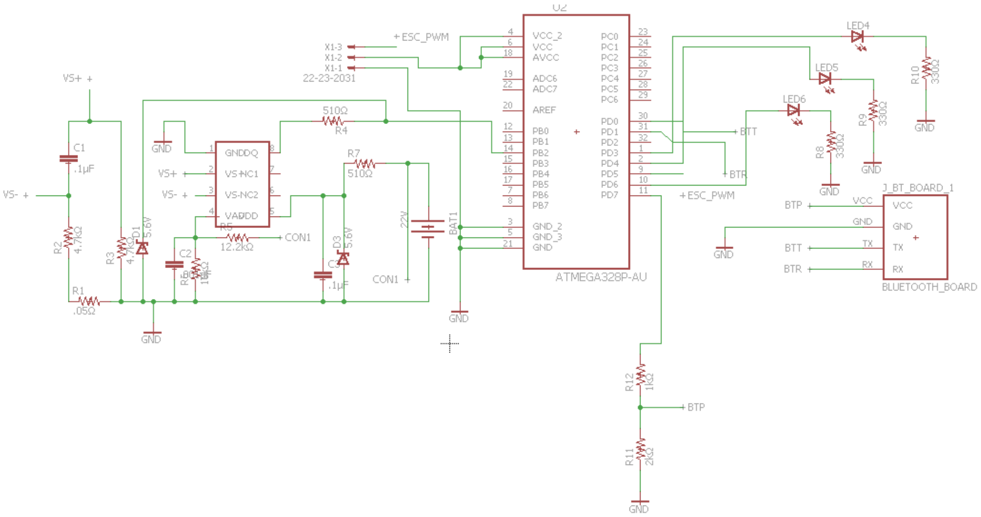


Figure 9.1 -1- PCB schematic

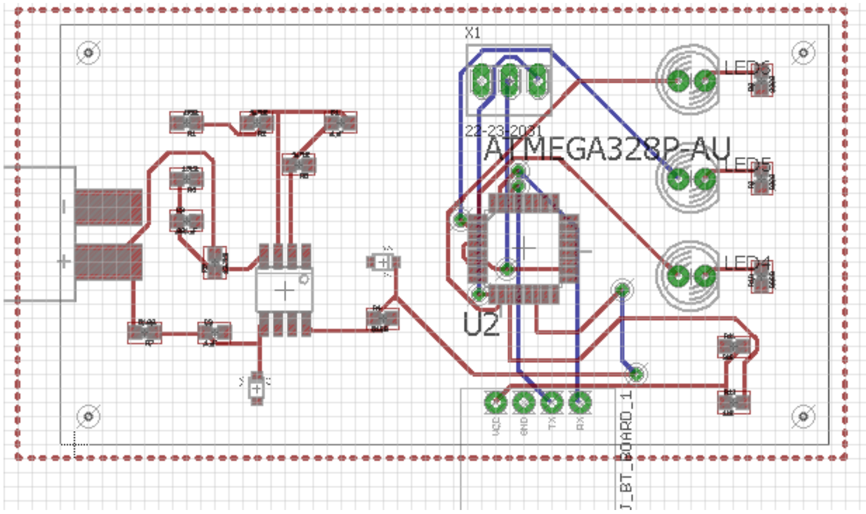


Figure 9.1 -2-: PCB board layout

10.0 Administrative Content

Administrative content consists of but is not limited to financial information, the development timeline, and project completion rate.

10.1 Semester Timeline

The first semester is officially the design phase. Milestones are very important during the design phase so the team could stay on track and so that we can complete our goals on time. Table 10.1 -1- displays the strict design timeline followed for the Fall 2015 semester.

Objective	**Estimated Time Period**
Group Identification	Sept. 3, 2015
Determine Project Idea	Sept. 10, 2015
Divide and Conquer Document	Sept. 15, 2015
Research Phase	Sept. 3, 2015 – Nov. 30, 2015
Preliminary Table Of Contents	Oct. 15, 2015
Document Progress Check	Nov. 12, 2015
Individual Work Submission	Dec. 6, 2015
Page Compilation and Formatting	Dec. 7, 2015
Document Finalization	Dec. 8, 2015
Bind Document	Dec. 8, 2015 – Dec. 9, 2015
Senior Design Document Submission	Dec. 10, 2015

Figure 10.1 -1- Senior Design 1 Developmental Timeline

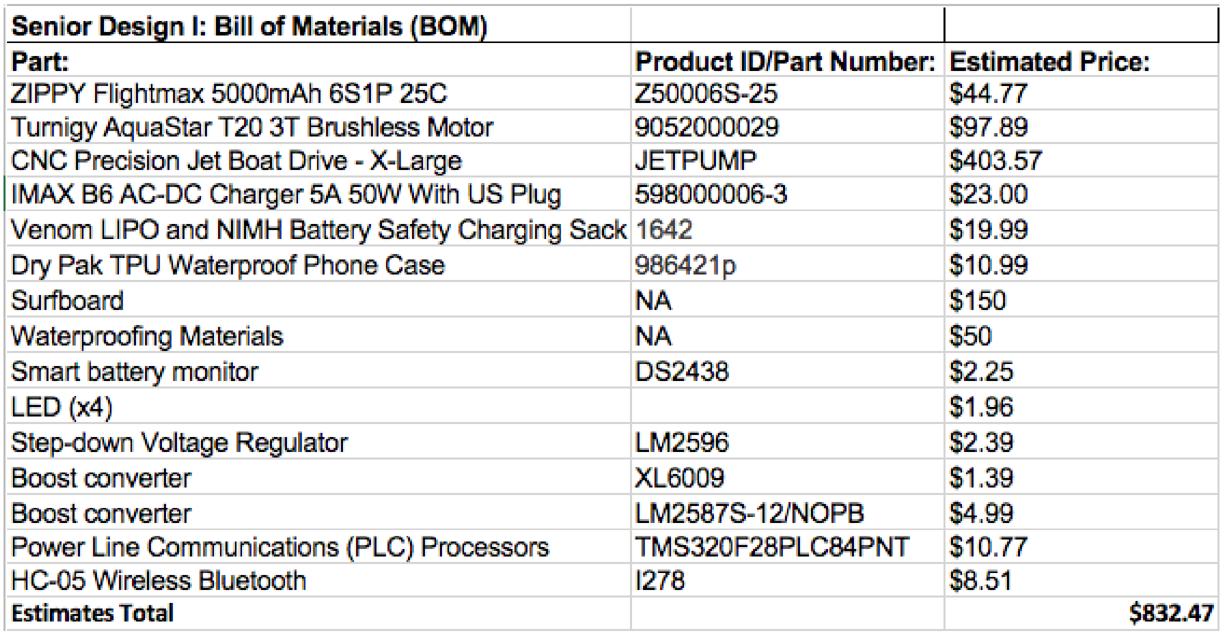
We have set milestones and deadlines within our group for the spring semester build phase to assure that we stay on schedule and produce a functional project at the end of the semester. The milestones can be broken into three simple categories that can then be broken into smaller, more detailed, subcategories. The three main categories we are going to be using throughout the semester are; parts acquisition, build, and test. Our build phase timeline has been developed and described in the Table 10.1 -2-.

Milestone Objective	Deadline
Parts and Supplies Acquisition • Battery, Motor, Jet Drive • Circuit Components and Bluetooth	Jan. 7, 2016 – Jan. 21, 2016 Jan. 14, 2016 Jan. 18, 2016
Bluetooth Communication	Jan. 25, 2016 – Jan. 31, 2016
Wireless Throttle Control	Feb. 1, 2016 - Feb. 5, 2016
System Integration	Feb. 6, 2016 - March 4, 2016
Waterproofing	March 15, 2016 – March 21, 2016
Build and Retest	March 22, 2016 – May 2, 2016

Table 10.1 -2- Senior Design 2 Milestone Timeline

10.2 Finances and Budget

Once all the parts we are using were decided an estimate of the total budget could be constructed. A few of the products drove the budget up more than the rest. Unfortunately, the products that did this are very hard to find cheaper so there was no way to avoid this unless the design were to be changed. This will especially help give a better idea of what items need to be taken care of most and what items can be experimented on with less caution. This also provides clarity to how much will most likely be spent out of pocket in comparison to what will be funded by our sponsors as described in section 5.1. The prices of each of the components can be found in Table 10.2 -1-.



Senior Design I: Bill of Materials (BOM)		
Part:	**Product ID/Part Number:**	**Estimated Price:**
ZIPPY Flightmax 5000mAh 6S1P 25C	Z50006S-25	$44.77
Turnigy AquaStar T20 3T Brushless Motor	9052000029	$97.89
CNC Precision Jet Boat Drive - X-Large	JETPUMP	$403.57
IMAX B6 AC-DC Charger 5A 50W With US Plug	598000006-3	$23.00
Venom LIPO and NIMH Battery Safety Charging Sack	1642	$19.99
Dry Pak TPU Waterproof Phone Case	986421p	$10.99
Surfboard	NA	$150
Waterproofing Materials	NA	$50
Smart battery monitor	DS2438	$2.25
LED (x4)		$1.96
Step-down Voltage Regulator	LM2596	$2.39
Boost converter	XL6009	$1.39
Boost converter	LM2587S-12/NOPB	$4.99
Power Line Communications (PLC) Processors	TMS320F28PLC84PNT	$10.77
HC-05 Wireless Bluetooth	I278	$8.51
Estimates Total		**$832.47**

Table 10.2 -1- Projected Bill of Materials

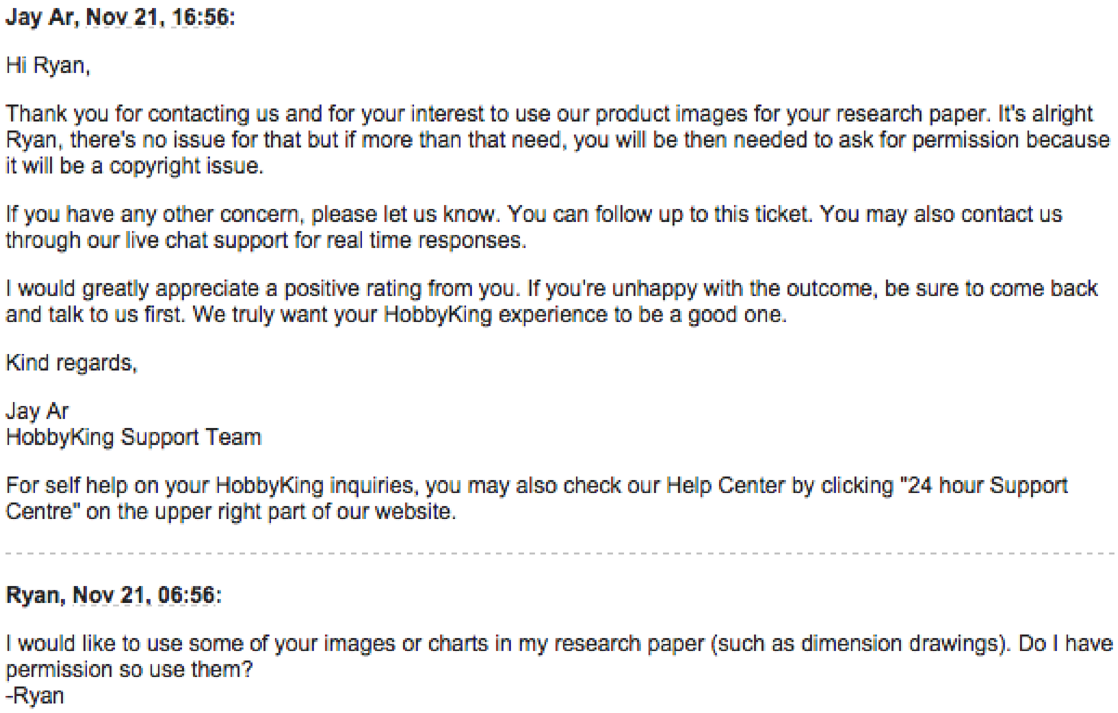
At the end of the project it turned out that the projected bill of materials was much higher than what was actually spent. This is because a few items were cut from the design as well as availability of some intended products were limited. The correct bill of materials for this project can be found in Table 10.2 -2-. This was just under the funding that was provided by Boeing and Leidos so we met our goal much better than expected.

Senior Design II Bill of Materials		
Part:	**Product part number:**	**Price:**
Surfboard	N/A	Free
Jet drive	N/A	$69.95
Battery	Z45006s-45	$68.68
Motor	9052000029	$69.89
Battery Charger	598000006-3	$23.00
Electronic speed controller	hef-HB60120L	$66.99
Battery monitor	DS2438	Free
Microcontroller	ATmega328p-AU	$13.72
Custom Housing Unit	N/A	$45.71
Bluetooth	HC-05	$5.25
LEDs	N/A	Free
Waterproofing Supplies	N/A	$7.56
PCB and components	N/A	$35.88
Total		**$406.63**

Table 10.2 -2- Final Bill of Materials

Appendix A: Copyright Permission

Hobbyking.com dimensions images permission approval:



Jay Ar, Nov 21, 16:56:

Hi Ryan,

Thank you for contacting us and for your interest to use our product images for your research paper. It's alright Ryan, there's no issue for that but if more than that need, you will be then needed to ask for permission because it will be a copyright issue.

If you have any other concern, please let us know. You can follow up to this ticket. You may also contact us through our live chat support for real time responses.

I would greatly appreciate a positive rating from you. If you're unhappy with the outcome, be sure to come back and talk to us first. We truly want your HobbyKing experience to be a good one.

Kind regards,

Jay Ar
HobbyKing Support Team

For self help on your HobbyKing inquiries, you may also check our Help Center by clicking "24 hour Support Centre" on the upper right part of our website.

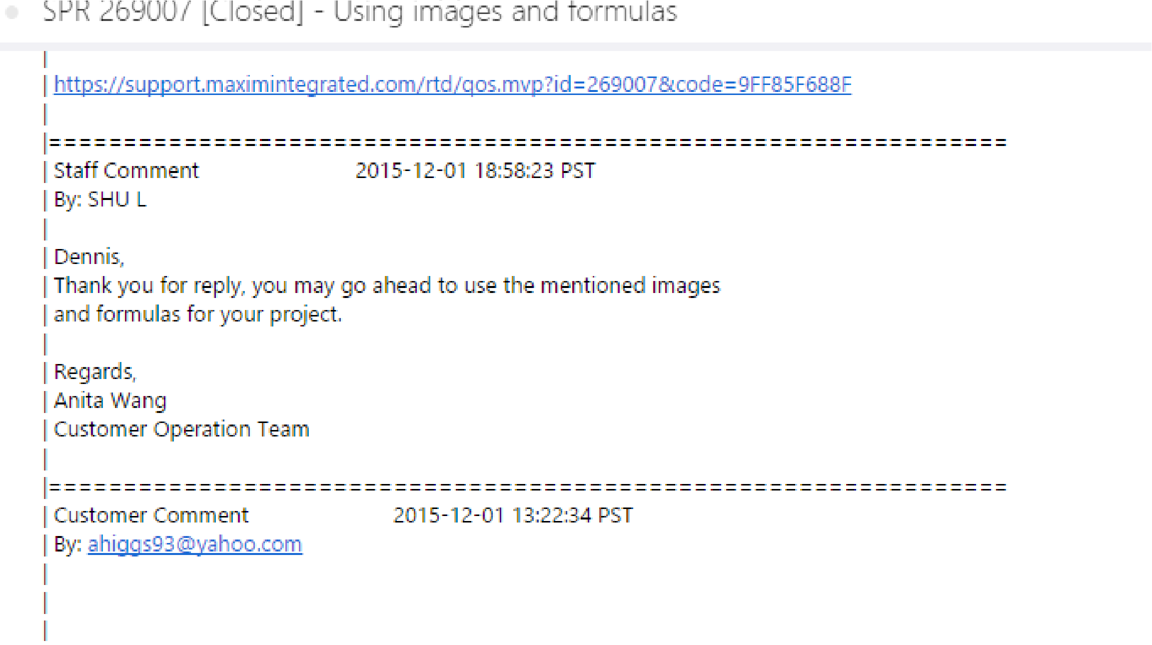
Ryan, Nov 21, 06:56:

I would like to use some of your images or charts in my research paper (such as dimension drawings). Do I have permission so use them?
-Ryan

Applicable to the following:

Figure 3.2.2 -1- Motor Specifications - Turnigy AquaStar T20 3T 730KV/1280KV – Refer to Appendix A
Figure 3.2.2 -2- Motor Specifications – Dimensions – Refer to Appendix A
Figure 3.2.3 -1- LiPo Batter Dimensions– Refer to Appendix A
Figure 3.2.3 -2- LiPo Batter Specifications– Refer to Appendix A
Table 6.1.3 -1- Turnigy AquaStar Motor Specification –Refer to Appendix A

Maxim Integrated permission approval:



SPR 269007 [Closed] - Using images and formulas

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| https://support.maximintegrated.com/rtd/qos.mvp?id=269007&code=9FF85F688F
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|=================================================================
| Staff Comment                    2015-12-01 18:58:23 PST
| By: SHU L
|
| Dennis,
| Thank you for reply, you may go ahead to use the mentioned images
| and formulas for your project.
|
| Regards,
| Anita Wang
| Customer Operation Team
|
|=================================================================
| Customer Comment                  2015-12-01 13:22:34 PST
| By: ahiggs93@yahoo.com
|
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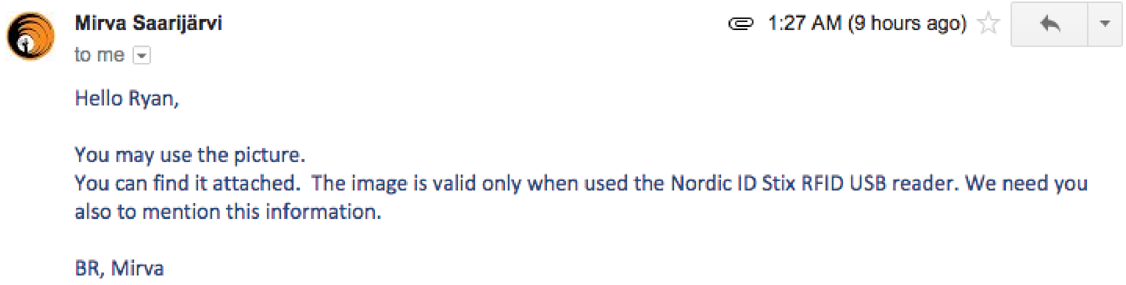
DS2438 battery monitor datasheet and pictures permission

RFID Power Consumption Chart Permission for section 6.3.3:



Mirva Saarijärvi

to me

1:27 AM (9 hours ago)

Hello Ryan,

You may use the picture.
You can find it attached. The image is valid only when used the Nordic ID Stix RFID USB reader. We need you also to mention this information.

BR, Mirva

Appendix B: Official Citations

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