Pool-AID:
A Drowning Prevention System

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1. Executive Summary

According to the CDC, drowning is the third major cause of accidental deaths after medical overdoses and traffic accidents, and the top-ranking cause of children fatalities. In the United States alone, drowning-related incidents have led to an average of ten deaths per day. Drowning is an understated contributor in the leap of unintentional deaths worldwide, and the time has come to minimize the damage it is doing to families with children under six years old. The inability to swim, absence of adult supervision, and lack of pool-safety measures are some of the leading causes of drowning.

Drowning is an issue that needs to be taken as seriously as the other top leading issues have been taken in the past. For example, to avoid medical overdoses, child-proof packaging was designed to ensure the safety of kids under five. Similarly, car seats are required by law for children ages five and under to help prevent severe injuries after a car accident. Our project, Pool-AID, is intended to provide an effective solution to help prevent drowning incidents from happening.

Pool-AID will be a tool every family with children will want to have in their pool to ensure the safety of their loved ones. It will guarantee pool supervision without the risk of not paying attention or multitask as its only task is to detect drowning activity in the pool. Regardless of the previous safety measures taken to keep toddlers and children away from different bodies of water, kids have no notion of sensing danger. Whether it is to dip their hand or fill a little bucket with water, kids will always try to interact with any type of pool near them.

While swimming is a fun activity to do in the warm summer days, it is not as compelling of an experience in the wintertime so the pool area might be deserted with not much activity. Owning a pool requires some effort and weekly maintenance, regardless of the current season. The maintenance of the pool is not limited to regularly checking the water quality, plumbing system, or filtration, but also providing safety tools to avoid tragic incidents from occurring when no one is around. Different safety devices like fences and rope lines have been used in the past; however, their reliability and efficiency levels are limited. A fence will not prevent a child from accessing the pool once it has been overcome, just like a rope line cannot provide assistance to an infant with no physical strength. The only way to prevent children drowning incidents from happening is through the help of an adult. Our device will be used to seek the attention of any present or nearby adults when swimming or drowning activity has been detected.

Pool-AID is being designed to provide pool surveillance services for families with young kids, toddlers, and even pets. Our device will be engineered with the finest tools in the market with a focus on reliability prior to any other feature. Using Pool-AID will not require any external installations as the device is meant to float in the pool or body of water. Pool-AID will be a sonar-based device that detects any unexpected activity in the pool and triggers an alarm to inform adults in the house of the drowning activity. In addition to the alarm sounding, a notification will be sent to the mobile application on the homeowner's device. A camera module will begin recording the incident as soon as the activity has been detected by the sensor and will be sent to a database with timestamps. The device will be powered via solar panels and batteries, depending on the environments of the pool that it will be used in. This document will cover technical research done regarding the hardware components considered to build the design and software programs that will be used to manage the mobile application and data. It will also cover standards and constraints imposed by different factors.

2. Project Description

The following section will provide general information regarding the motivation behind Pool-AID, the ideal objectives and goals of the system, and technical background regarding the process design. This section will also provide the reader with an idea of the requirements desired by the customer and the engineering specifications established by the design team.

2.1 Motivation

According to the World Health Organization, a United Nations agency dedicated to the wellbeing of people around the world, there are approximately 236,000 drowning deaths worldwide on a yearly basis. This means that drowning is responsible for 7% of all accidental deaths. In the United States alone, an average of 4000 children less than four years old die each year due to a drowning accident. While most drowning incidents are not reported, the statistics from the reported cases are sufficient to prove the gravity of this issue. *Stop Drowning Now*, an organization committed to raising awareness on drowning, has stated that 87% of all drowning deaths occurred in backyard pools where children less than 5 years old were the victims. Based on this statistic alone, we can narrow down our issue to one source that accounts for most of the fatalities, which is a poorly surveilled backyard pool.

The motivation behind Pool-AID is to create a system that is easy to use, water resistant, and affordable for families to keep their loved ones, young or old, safe. With technologies developing in every aspect of the world today, it is our responsibility to make sure that technology is also used to help prevent such tragic events from happening. The leading causes of drowning, as reported by the CDC, can be traced back to lack of supervision and neurological disorders. The ultimate purpose of the project is to notify the homeowners, lifeguards, or babysitters if anyone has accidentally entered the pool and is struggling inside the body of water. With most drowning-related incidents happening in less than a minute, our system will be designed to recognize a child or person in distress in a reasonable timeframe.

The purpose of this anti-drowning tool is to allow parents, lifeguards, and babysitters to let their guards down a little without any life-threatening consequences. The use of a device whose only job is to detect drowning activity could be much more reliable than a parent juggling between multiple tasks at once. Pool-AID will ensure the safety of their loved one and provide much needed surveillance with little to no effort from the user.

2.2 Goals & Objectives

The goal of this design project is to minimize the number of accidental drowning deaths happening around the world and in the United States. Our drowning prevention system will include a wide range of features to help minimize drowning accidents in residential and private pools. The main objective of this device is to provide parents with a reliable surveillance system to alert them when suspicious pool activity has been detected.

- The system must be waterproof and be able to float in a standard-sized pool. To cover a significant range of the pool, the device should float along the center of the body of water.
- The system will be accurate and reliable. Reliability is crucial as its failure means the system could not address its primary motivation of preventing children from drowning.
- The device will be portable, easy to set-up, and priced below previously marketed devices. We want the cost of our device to encourage parents to purchase the safety tool.
- The device will have low power consumption with solar panels being the primary source of power.
- Our system will be able to trigger an alarm once the sonar and PIR sensors have given sufficient data showing a target is in distress.
- The alarm of the safety system should be heard within a range of 50 ft.
- The device will record the activity with the relative timestamps and send it over to the mobile application where it can be accessed by the user.
- The Pool-AID application must be user friendly and provide the user with the option to configure their saved data history.

2.3 Related Work

There are certain products available on the market that were designed to serve the same motivation as Pool-AID. A side-by-side comparison of the products will be conducted in sub-section 3.1 of this document. This issue has been approached by a 2019 Senior Design group with the name of Baby Buoy. They were able to deliver a successful product with very interesting design techniques. While our projects will be answering the same motivation, our design will use different sensor technology and logic to deliver a solution to this matter.

2.4 Requirement Specifications

Our design can be broken down into two main categories, the hardware and software modules. For an efficient system, we must design and build our device around ideal measures that line up with our project goals and objectives. These specifications must also adhere to the desires of the customer. The following table provides a summary of the quantitative measures of the project.

The hardware design of Pool-AID will involve multiple components and sensors to make the device as reliable as possible. The main part that will affect how all the different modules relay data and interact with one another will be the microcontroller. The controller will be attached to all the sensors, power sources, and software modules. The hardware specifications will be finalized once all the parts have been acquired and tested. Pool-AID will be portable and lightweight, so the dimensions will not exceed 12 inches and the weight will be less than 15 pounds. The device will be buoyant and designed to function in standard sized pools with 10 x 20 ft dimensions. The power consumption will be low and battery life will last for a minimum of 1 year, assuming the device is only activated when movement has been detected and not woken up by the user on an hourly basis.

Characteristic	Quantitative Description
Dimensions	L x W x H ≤ 12 x 12 x 12 in
Weight	≤ 15 lbs
Range	10 x 20 ft sized pools
Device Durability	Minimum of 1 year
Microcontroller	Operating Voltage: 5 V
Sonar Sensor	Range: 6.5 – 96 in Readings every 50 mS
Passive Infrared Sensor	10 ft radius detection
Buzzer Module	At least 90 dB Heard within 50 ft
Solar Panel	5 x 5 in circular panel
System Response Time	Less than 8 seconds.
Wi-Fi Module	2.4 GHz range
Cost	$300

Table 1 - Project Hardware Specifications

The software specifications of Pool-AID are based on the development of the mobile application. The application size will not exceed 35 MB and will be free of charge for users with a Pool-AID device. The loading speed of the different application pages will be less than 3 seconds, while the initial configuration of the app with the device will not take longer than 15 minutes. Depending on the user's preferences, the history of the activity detected by the device will be saved up to either 30 days or until the storage capacity has been reached.

Characteristic	Quantitative Description
Configuration Time	Less than 15 minutes
Application Size	≤ 35 MB
Loading Speed	≤ 3 seconds between different app pages
Data History	30 days or storage is full
Notification Latency	Less than 30 seconds after detection

Table 2 - Project Software Specifications

2.5 House of Quality

The house of quality is a diagram that allows us to map a customer's desires in relation to a product's actual engineering requirements. The diagram is divided into categories that describe the needs of the user and the essential characteristics required to realize a product that satisfies both parties. This diagram helps us visualize the different trade-offs that can be taken when needs cannot all be fulfilled. Based on their rankings and the characteristic correlations, we can prioritize certain tasks and maintain a balance to satisfy both sides. When the importance of a marketing desire overlaps with that of a design requirement, the characteristic holds a strong positive correlation.

Pool-AID 's marketing requirements highlight the importance of the reliability, feasibility, and durability of the system to the customer. It also shows that the cost of the device and effectiveness of the mobile application are factors that could affect how satisfied a customer is with the product. On the engineering side of the map, we notice that the product's durability, power consumption, and notification abilities and cost are deemed essential for Pool-AID to maintain its credibility as a surveillance system.

For our design, the marketing requirements of feasibility, long battery life, reliability, and durability are ranked the most important. Having a device that is easy to use with no complicated installation procedures is crucial for a safety device to earn its customer's satisfaction. How durable a device does not just mean a long battery life, but also the physical condition of the device.

Pool-AID will be water-proof and difficult to damage permanently. Most homeowners with pools do not want a robot-looking device taking up the majority of their pool space; hence, it is important that the size of the device is small. On the other side of the diagram, we prioritize the device's resistance to water, alarm and Wi-Fi ranges, and cost. The weight and dimensions strongly affect the size of the product, while an increase in the Wi-Fi and alarm ranges strongly affect the reliability demanded by the customer.

The project's ultimate motive is to prevent drowning accidents from happening, so the dimensions and power consumption of the tool are not directly affecting the purpose of the design. When having to make a decision that directly affects another key feature, we can determine how the change will affect any other requirements using the HOQ diagram.

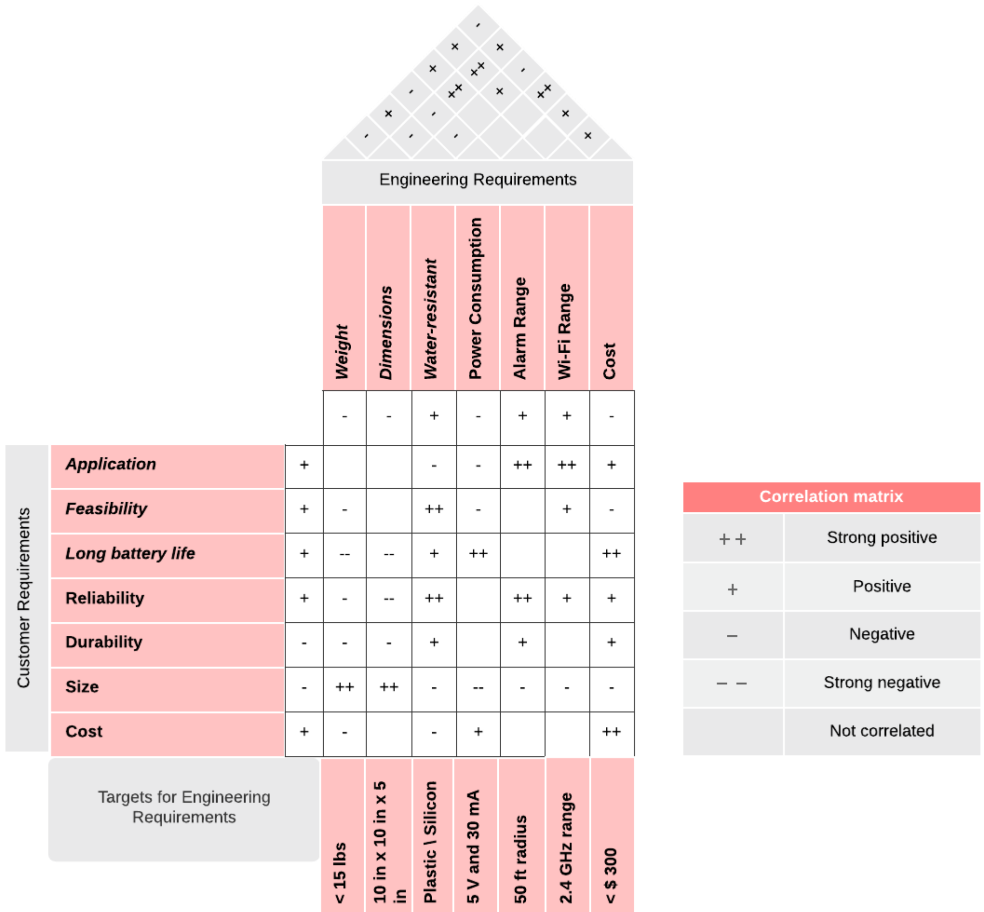

Figure 1 - House of Quality Diagram

2.6 Block Diagrams

This section will highlight the overall design plan for Pool-AID. We will cover the design plan for the hardware components, and how they all communicate, work with one another to produce a feasible and functional device to the customer. This section will also go over the software block diagram, which will highlight how data is transferred over from the main unit to the mobile application and the different functions of Pool-AID's mobile interface.

2.6.1 Hardware Diagrams

We will have two hardware units, a transmitting, and a receiving unit. The following section will breakdown each separate device and the anticipated modules it will contain.

2.6.1.1 Hardware Diagram of the Transmitter

The following block diagram shows the layout of Pool-AID 's hardware components from the transmitting end of the device. The goal is to position all the modules in an efficient manner to minimize the final board size and ease the testing process. The controller will be centered so that it is accessible and easy to connect to all the other modules. The solar panel, battery, and sensors will all be a part of this transmitting unit.

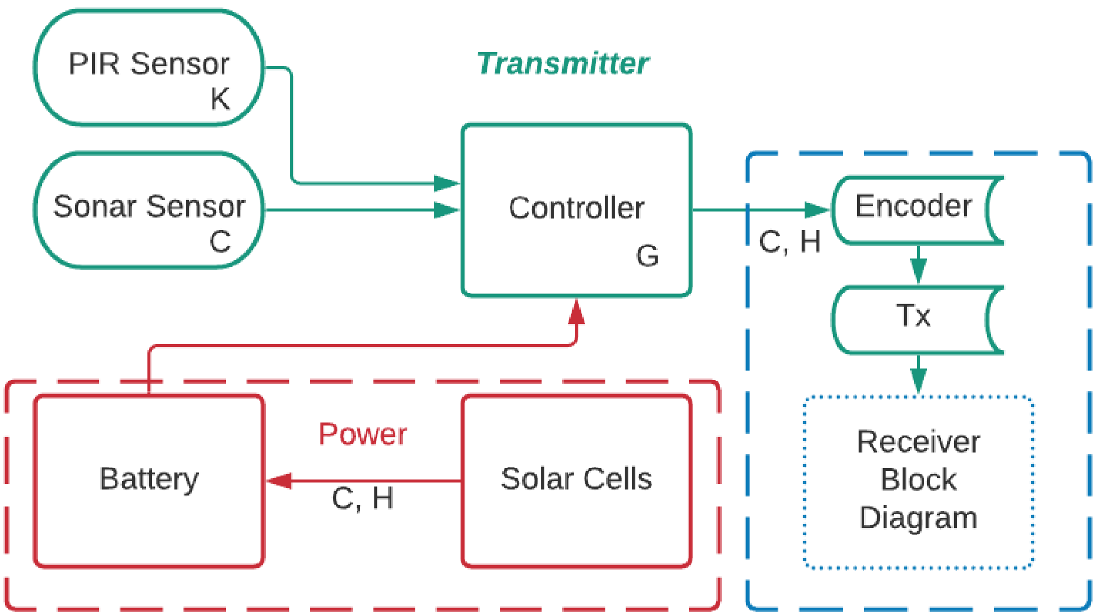

Diagram 1 – Hardware Block Diagram Transmitter

2.6.1.2 Hardware Diagram of the Receiver

The transmitter will collect all the data and detect the drowning activity. When that event is detected, the local receiver must be able to sound an alarm. Although the buzzer module is not going to be physically connected to Pool-AID's central system, it will be on a separate device that will allow us to decrease the response time it would usually take an adult to notice someone that has entered their pool unexpectedly. The closer it is to the house itself, the better the chances for someone to hear the buzzer sounding.

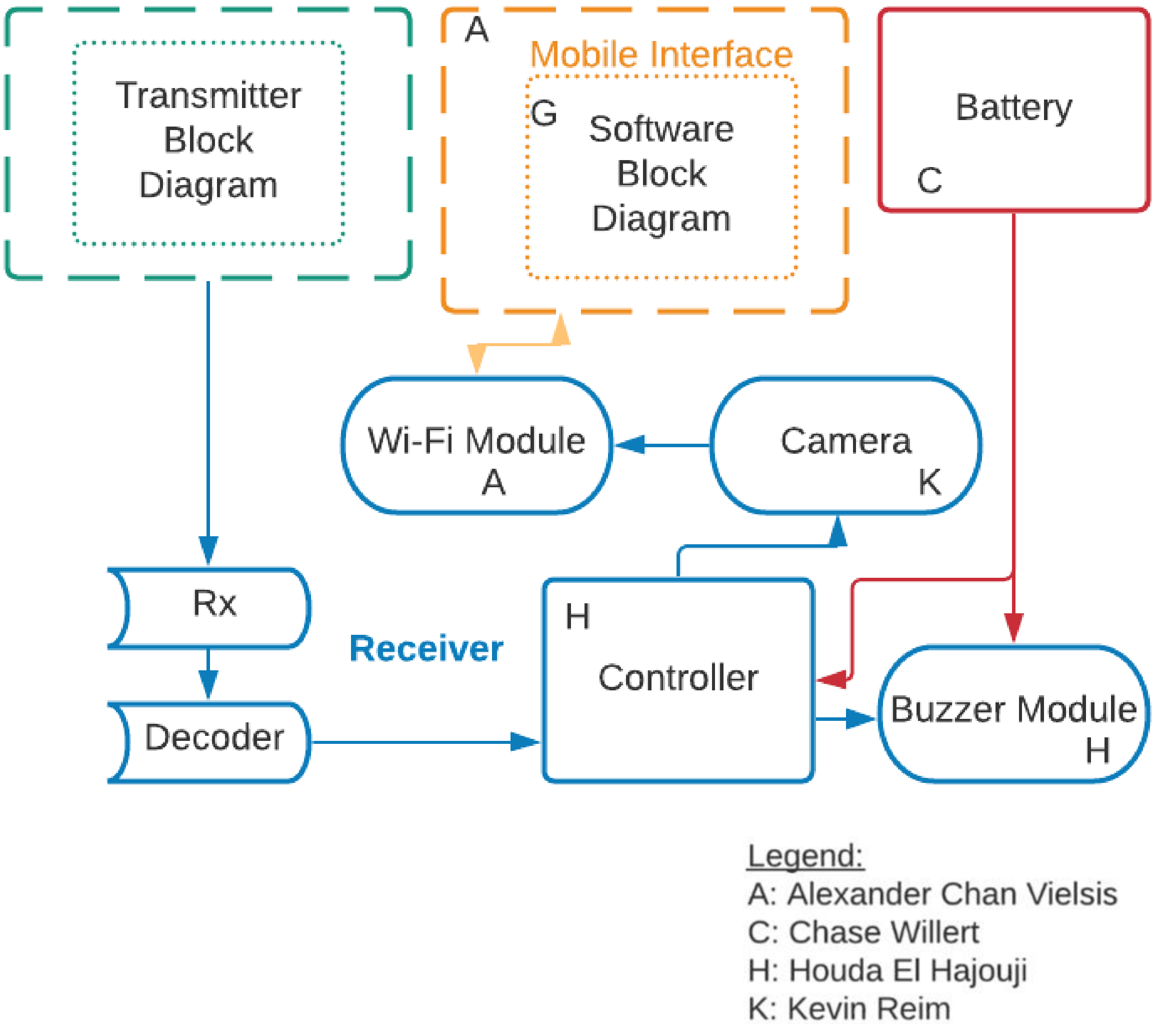

Diagram 2 – Hardware Block Diagram Receiver

2.6.2 Software Diagram

In the software diagram we will show how the software implementation of the design works and communicates with the hardware system. There are some cloud services we need to store the data collected by the controller. We are showing the connection between the WI-FI module and the cloud server we will use to send the data and later store it to the database. Using the mobile application, we will make a request to the database to extract the data and show it in the user interface. Additionally, the mobile application should be able to communicate with the actual system to monitor the status of this one. Further explanation about this diagram will be shown in the software design section

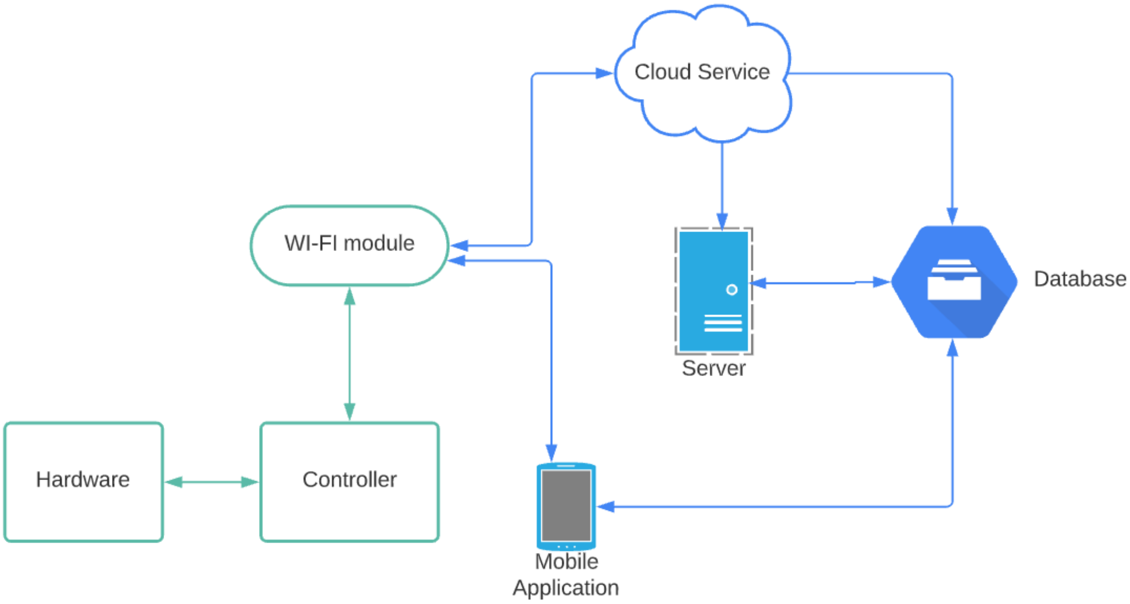

Diagram 3 – Software Design Diagram

2.7 Work Distribution

While the workload will be distributed evenly amongst all team members, each member is responsible for a number of components and tasks. The delegations of tasks are based on the member's area of expertise and preference, which will ensure that each module is functional and ready to use.

From the block diagram shared in section 2.6, we can identify the team member and their designated module. Chase Willert, referred to as C on the block diagrams, is responsible for the elements that contribute to our system's energy consumption and power sources. His prioritized parts are the battery and solar panels modules. He will also have a role in developing certain features on the mobile application.

Kevin Reim, referred to as K, is in charge of the camera and the passive infrared sensor module on the hardware level of Pool-AID. As for the software part of the project, he will contribute with developing the user interface and system configuration of the mobile application.

Houda El Hajouji, referred to as H, is going to administer the hardware receiving end of the device, which includes the buzzer module. She is also overlooking the communication between modules on the device and making sure the same data is transferred over to the software end of Pool-AID.

Alexander Chan-Vielsis, referred to as A, will manage the embedded Wi-Fi module on the transmitting end of our main hardware unit. He is also taking the lead with providing remote control of the device through the software module and developing the mobile interface of the device. All team members will be interacting with the controller since it is crucial that the whole team understands how Pool-AID processes sensor data and uses that to communicate with the application and the buzzer module.

3. Research

3.1 Technology Comparison

With the number of drowning accidents rising over the years, many pool alarm systems were developed to help prevent such incidents from happening. Traditional prevention systems like fences and rope lines around a pool have very limited abilities to help prevent drowning from occurring. Once a kid passes through the fence door and falls in the water, there is not much else the fence can do to save them. To prevent their kids from getting close to the water, parents have started resorting to more digital devices built to provide more assistance when drowning has been detected.

3.1.1 Poolguard DAPT-2

The Poolguard DAPT-2 is a system designed to work alongside pool fences. It uses a magnet sensor to detect if a child has passed through the fence door and is near the unsupervised body of water. If an adult wants to go through the door, they have 7 seconds to push a switch on the device before the alarm goes off. If an adult does not push the switch, the alarm is triggered and can only be silenced once the door is closed, and the magnetic sensor is reset. The alarm is 85 dB and ranges through a 10-meter radius. This device requires external installation before use; however, it does come with the advantage of detecting children and not adults. If installed at a reasonable height, a child will not be able to reach the switch and the alarm will raise the awareness of the parents. The device is also relatively cheap, selling at $59.95 on Amazon.

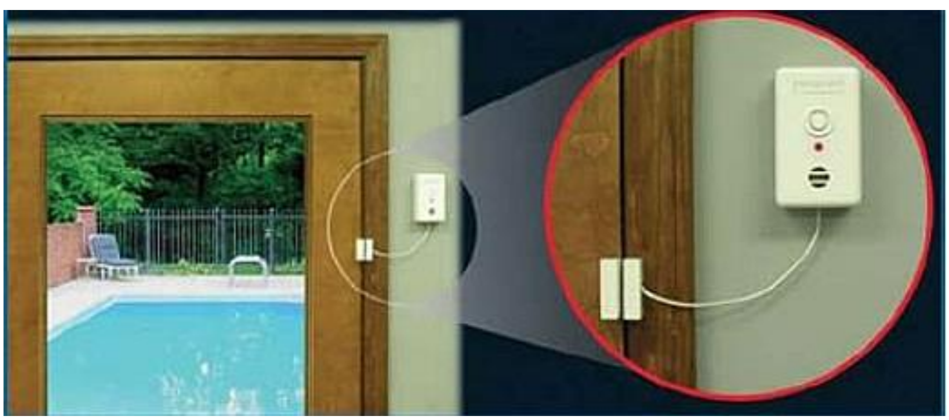

Figure 2 - Poolguard DAPT-2 **Permission pending (Appendix B1.1)**

3.1.2 PoolEye

The PoolEye device is an infrared based system that is installed on the side of a pool. It detects objects that weigh at least 15 pounds in or near the water. The device has several configuration options depending on the shape of the pool, meaning it is customizable; however, there is a pool size constraint. This tool is not waterproof and requires the user to drill certain holes alongside the perimeter of the pool. Another downside of this item is that it requires a certain water level to function properly as the submerged part of the device cannot exceed 2.5 inches. The user must check the water levels regularly to ensure that the device does not get damaged. It is currently retailed at $134.99 with an average review rate of 3 out of 5 stars.

Figure 3 – PoolEye **Permission pending (Appendix B1.2)**

3.1.3 Poolguard PGRM-2

The Poolguard PGRM-2 is a sonar-based device that is installed inside a pool, underwater. The sonar sensor allows the system to reject any activity caused by bad weather, making it reliable. It is designed to function under pools with 16 by 32 ft pools but can go all the way up to 20 x 40 ft sized pools. The alarm cannot be de-activated once installed and will be triggered when removed from the pool under the wrong settings. The device comes with a remote that has a maximum range of 200 ft. The device functions on a 9-volt battery and has low power consumption. This device is retailed at $199.49 on Amazon with an average rating of 4 out of 5 stars.

Figure 4 – Poolguard PGRM-2 **Permission pending (Appendix B1.3)**

3.1.4 Pool Patrol PA-30

Pool Patrol PA-30 is the current best seller in the pool safety category. It is a floating device that uses motion rings to calculate the displacement of waves in water. The greatest advantage this device provides is the option to adjust its sensitivity to objects. The alarm is triggered when a wave is detected by the sensing rings. This device is designed to work in 20 x 40 ft sized pools and is the easiest to install out of all the available options in the market. It weighs one pound and comes with a transmitter and receiver to notify the user when an alarm is sounded. This device is on the market for $199.99 on Amazon.

Figure 5 – Pool Patrol PA-30 **Permission pending (Appendix B1.4)**

3.2 Hardware Part Selection

3.2.1 Microcontroller Unit

For our Pool-AID device, we will have a microcontroller unit as the main manager of the entire system. Some tasks the MCU will perform are mainly communication between the chosen modules and sensors our system will implement, to obtain and make decisions over the data collected by these devices. Some requirements we need for choosing the most suitable microcontroller are being compatible with a WI-FI module, which will be used for communication with mobile or desktop devices, low power consumption when the MCU is in active mode, easy to program using a common high programming language such as C or C++, enough GPIO pins to interact with the sensors used. Since we have a limited budget, one essential requirement when selecting the microcontroller being low price.

Similar IoT projects have used different microcontrollers depending on the system necessities. There exist many tutorials on Arduino boards, such as Arduino UNO which uses ATMega328P or Arduino Mega Rev3 with the ATmega2560, programmable using C++ and has high compatibility with different modules including Wi-Fi and cameras. Our next considerations will be the MSP430FRx series which are Ultra Low-Power MCUs. These microcontrollers fabricated by Texas Instruments have been used by all the team members, so it would be a very good option for this project.

3.2.1.1 MSP430FRx Series

As mentioned previously, the MSP430FRx series from TI are described as Ultra Low-Power MCUs which are good for projects that don’t require a lot of energy to operate. FR stands for ferroelectric random-access memory (FRAM); this type of memory can perform fast write at low voltage and provides reliability over data to avoid tearing. The MPS430 family includes a considerable set of peripherals such as LCD controller, timers, direct memory access, Universal Serial Communication Interface, for UART interface, I2C, and SPI communication protocols, and ADC converters.

MSP430FR6989

The MSP430FR6989 is ultra-low-power mode MCU that is implemented in the launchpad with the same name. The board can be programmed through USB using C language and Code Composer Studio. This board was used in the Embedded Systems class, so the team members already have experience with the launchpad functionalities. The recommended operating voltage range of the microcontroller goes from 1.8V to 3.6V, and it has a total of 83 GPIO pins. The MCU counts with a non-volatile memory of 128kB and 2KB of RAM. Some peripherals it has are the Analog to digital converted of 12-bit SAR, UART interface, 2 Timers A and B of 16-bit each, I2C, SPI, LCD controller, and 3 DMA channels.

Since the group are already familiar with some of the board's features, it would be a tentative choice as the main brain of the Pool-AID device. Some disadvantages of this one might have been redundant peripherals such as the LCD display which might not be used. Not everyone from our group has used the DMA channels; however, using them would be very good for our project to minimize power consumption. The price of the Launchpad is around $26 dollars, and since we already have functional boards, we don't have an availability constraint.

MSP430G2553

The MSP430G2553 is an ultra-low power MCU developed by Texas Instruments that is part of the MSP430 family. The shape of the chip is similar to the ATmega328p, but slightly smaller than it, which is good because we want to keep the design as portable and small as possible. Its power consumption in active mode is around 0.506 mW and has an operating voltage of 3.3V. The MCU counts with a 16MHz CPU clock, 16KB of non-volatile memory and 0.5KB of RAM. It has a total of 24 GPIO pins which are enough pins that we can use for the design. Some peripherals it includes are 10-bit ADC SAR-type, Two 16-bit timers, a Direct memory access (DMA) channel, and Universal serial communication interfaces such as I2C, SPI, and UART. There are not many tutorials on how to program this microcontroller, so we would have to learn how the MCU should work with other modules such as sensors. In embedded systems, we learned how to use Code composer studio to program Texas Instruments microcontrollers and refer to information about the chip from the documentation such as the chip datasheet and Family User's guide. However, if we want to keep the code simple and easy to read than having the register's name and use logic operators, we can use an IDE that is similar to Arduino IDE called Energia that is compatible with Texas MCUs. The MSP430G2553 is compatible with this IDE, and we can study how to program this chip using the sketches provided.

MegaAVR Family 8-bit

The MegaAVR family are a series of microcontrollers developed by Atmel which count with an 8-bit processor that utilizes picoPower technology to minimize power consumption [1]. This series is suitable for projects that are battery-powered; offering different low power modes that can be selected depending on the applications needs. Arduino implements chips that belong to this family in many on their boards such us Arduino UNO and Arduino Mega, so there are many online resources we can use as a guide to implement them in our project.

ATmega2560

The ATmega2560 is an 8-bit microcontroller unit that can be found Arduino Mega 2560 Rev3 board with 256KB of flash, 4KB of EEPROM and 8KB SRAM. The MCU has a total of 86 GPIO pins and 32 general purpose registers. Some peripherals the ATmega2560 includes are 4 Universal Asynchronous Receiver/Transmitter (UART), 5 Serial peripheral interface, one I2C, 12 PWM channels, 16 ADC channels, and 2-bit timers and other 4 timers of 16-bit. The operating voltage starts at 1.8V, with a current of 500 uA, at a speed of 1MHz. Currently the chip only can be obtained if the Arduino Mega Board is acquired, but it is still a good option since what we are looking for is low power consumption. The price of the chip is around $14 dollars, so it is somewhat expensive compared to what the group expects to spend, but that doesn't disqualify it as a potential microcontroller choice for the Pool-AID project.

ATmega328P

The ATmega328P is one of the most used microcontrollers in different projects, and since it is used by Arduino boards it is very popular among the AVR RISC architecture-based microcontrollers. The Atmel chip is an 8-bit microcontroller of high performance. The microcontroller has 6 analog pins, and 15 digital pins for I/O and 32 general purpose registers. The operating voltage of the chip goes from 1.8 V to 5.5 V.

The power consumption of the ATmega328P in active mode is 1mA at 3 V with a speed of 4MHz, around 4.5 mW, and 1uA at 3 V in power-down mode which is similar to LPM in MSP430. The MCU has a 32KB of in-system self-programable flash, 1KB EEPROM, and 2KB of internal SRAM. Some other features the Atmel chip has are a serial programmable UART, 6 PWM channels, Master/Slave SPI serial interface, 2-wire serial communication for I2C, and an 8 10-bit Analog to digital converter channels. The operating temperature of the chip is between -40 C to 85 C.

One interesting feature the ATmega328P has is the six sleep modes which are a similar version of the low power modes found of the MSP430. We have the Idle which keeps the CPU off while other peripherals such as timers or serial communication keeps operating, ADC noise reduction to keep the asynchronous timer and the ADC running and stops CPU and I/O modules , power-save keeps the device sleeping while the asynchronous timer keeps running, power-down saves registers contents while other chip functions are disable until a hardware interrupt or reset occurs, and standby and extended standby which only keeps the crystal oscillator is running and sends the device to sleep. Depending on what peripherals or features we need for the projects, we could use any of the sleep modes to highly reduce power consumption on the Pool-AID device.

One of the most famous Arduino boards, the Arduino Uno R3, utilizes the ATmega328P. This board is highly available since it comes with any development kit along with other components. It uses C++ as its main programming language and the Arduino IDE to program the boards. The price of the ATmega328P is around $2.24, and the Arduino board is around in between $20.00 and $23.00. This is a good microcontroller with a lot of features and low-cost, and this could work properly as the main controller of our project.

3.2.1.3. MCU Selection

After researching the potential microcontroller for our Pool-AID device, we will now discuss the main differences between the boards mentioned for each MCU. Some key points to consider are power consumption, memory, price and availability, and feasibility. It is important to consider not only the difference, but also some similarities; if a board has some similar features to another, but due to some constraints it cannot be chosen, another option with the same capabilities should be considered.

Starting with power consumption, all the boards are considered low power. We will start by considering the power consumption in active mode, which is when the device is not sleeping or in low power mode. For the first board, the MSP430FR6989 draws a current of 103 uA/MHz when using the maximum clock speed of 16 MHz; the operating voltage of the MCU is 1.8V which gives us a power consumption of 2.96 mW in active mode.

For the Arduino Mega 2560 R3 which uses the ATmega2560 chip, the power consumption is mentioned on the data sheet with a current of 500uA, operating voltage of 1.8V at 1MHz which would give us 0.9mW; however, since we want to compare it with the previous board at 16MHz, the new operating voltage changed to 5.5V and a current of 6mA which gives is 33mW. Lastly the Arduino Uno R3 which works with the ATmega328P with a power consumption of 4.5mW. We notice that the Arduino Mega power consumption overpasses the one from the other two boards by around 7 times; however, this can be fixed using sleep modes. In terms of power consumption, the MSP430FR6989 is the best of all 3 options.

The next point to discuss is memory capacity for each board. In this area, we are not checking which board has the greatest memory size; we are looking for a board with enough capacity to upload the program we will build for the system. For the MSP430FR6989, it utilizes a non-volatile memory of 128KB FRAM. The Arduino Mega uses a flash memory of 256KB, while the Arduino Uno Rev3 has only 32KB of flash memory. The Arduino Mega seems to have the greatest amount of memory capacity, and the MSP430FR6989 seems to have a considerably good amount of space; nevertheless, our program would likely not use even half of the memory of the MSP430FR6989 FRAM. I think the ATmega328P offers a standard memory size, which would be enough for our code use for this project.

A board cannot be chosen if it is not accessible or has a convincing price. Luckily the microcontrollers are not always expensive, but to help the group stay on budget, we should consider the boards that are the most affordable. Starting with the MSP430FR6989 launchpad has a price of $26.60 dollars. All our team members have this board from Embedded Systems, so we do not have an availability constraint for this board. For the Arduino Mega 2560 R3, the price is comparable to the one from a Raspberry PI 3, with a cost of around $40. The chip itself costs around $13.34; however, the chip is sold out in most vendors, so the only medium to acquire the ATmega2560 microcontroller is by getting the development board. Lastly, the Arduino Uno R3 is sold for $22.00 to $23.00 dollars at Amazon or Arduino Official Store, and the chip is being sold by Ardafruit for

$5.95. All boards are available on different vendors, but the Arduino Uno board is the cheapest and easiest to find from all the listed options.

For our design, we are implementing different modules such as sensors, cameras and Wi-Fi. When choosing the board, we need to make sure when we can implement those new features for our system and have high compatibility with the board we choose. Arduino Boards are the most use in IoT projects, implementing sensors and other modules such as Wi-Fi work perfectly with those boards. The libraries needed for each module and sensor are compatible with Arduino IDE, and that makes their implementation easy to set up and configure. It is not certain that all libraries will work be supported by CCS if we work with the MSP430FR6989 board, but there is no reason the sensors would not work properly with it. One of the reasons why Raspberry Pi Boards were not considered was because to program them you need to know python and they have a lot of redundant peripherals and features. A programming language such as C or C++ would be easier for us to program the board.

The launchpads or development boards are going to be used for testing only, and the individual chip will be acquired to implement it on the PCB design. One small issue of the ATmega2560p and the MSP430FR6989 is that they are surface mounted; This means that if the chip gets damaged there is no way to replace them other than just making a new PCB, and soldering is somewhat difficult since they are very small components. However, if we look at the ATmega328P and the MSP430G2553, they are not directly soldered to the PCB. What is soldered is an IC socket that connects the MCU with the board and can be easily removed. We would increase sustainability and maintainability of the system if the chip can be replaced from the system in case this one is damaged. This would make these two previously mentioned the best options from all the microcontrollers listed.

Comparing the MSP430G2553 and ATmega328P, the TI chip might have more memory and more peripherals, but some of them are not needed for our project. The memory required for the Pool-AID system will depend on the size of our program. Even Though the MSP430G2553 has a greater memory, the ATmega328P has more than enough to run the program we will write for the system. Besides, comparing Code composer Studio with Arduino IDE, programming the Atmel chip would be simple.

The board that seems to fulfil the general requirements of the Pool-AID System is the Arduino Uno R3 Board with the ATmega328P chip. The board provides low power consumption, and it counts with different sleep modes we could use to reduce power consumption even further. The memory the board uses should be more than enough for all the code we want to implement for the project. There shouldn’t be any constraints to acquire the board since it is sold by many vendors at a reasonable price. Programming the Arduino Board with the IDE and implementing the extra features should be simple since all libraries for additional modules are compatible with the board.

Name	MSP430FR6989	ATmega328P	ATmega2560	MSP430G2553
Development Board	MSP430FR6989 Launchpad	Arduino Uno Rev3	Arduino Mega 2560 R3	MSP430G2ET
Operating Voltage	1.8V – 3.6V	1.8V – 5.5V	1.8V – 5.5V	3.3V
GPIO	83	23	86	24
Max CLK Frq	16MHz	8MHz	16MHz	16MHz
Memory	128KB FRAM (non-volatile)	32KB flash	256KB flash	128KB (Non-volatile)
Peripherals	UART, SPI. I2C, DMA, ADC 12-bit SAR, 2 Timers with 3 channels each	3 Timers (1 of 16-bit, 2 of 8-bit), UART, SPI, I2C, 6 PWM channels	6 timers, UART, SPI, I2C, PWM, 16 channel ADC 10-bit	2 timers, UART, I2C, SPI, DMA channel, 10-bit ADC SAR
LPMs	LPM0, LPM3, LPM4	Idle, ADC noise reduction, power save, power-down, standby, extended standby	Idle, ADC noise reduction, power save, power-down, standby, extended standby	LPM0, LPM2, LPM3, and LPM4
Operating Temperature	-40C to 85C	-40C to 125C	-40C to 85C	-55C to 150C
Price	$10.00 (Chip), $26.00 (Board)	$2.24 (Chip) $23.00 (Board)	$14.10 (chip) $40.30 (Board)	$ 3.45 (chip) $11.99 (Board)

Table 3 – MCU Comparison

3.2.2 Battery

The Pool-AID will be required to operate in a body of water for extended periods of time and thus will require a battery power supply system to ensure that the device can operate without the use of external cables. The battery that will be powering the device will need to be a secondary battery (rechargeable battery), as the Pool-AID is intended to operate for an indefinite period via the use of solar cells, where possible. In, the cases of an indoor pool, the main battery will not be required to change, as the solar cell component will be replaced by a system that will require the end user to remove the device, such as a charging port or a battery holder for common consumer grade primary batteries (single use/disposable).

Some of the important parameters that are of note as deciding factors for the battery are: size/weight, operating voltage, capacity, operating temperature, cost, and shelf life. The battery will have to be of a somewhat smaller profile, due to the limited available space within the device and its need to remain buoyant. The operating voltage of the circuit will be 5 V, so a battery of near this voltage will be necessary, though it is likely that form of voltage conversion and regulation will be required to maintain this 5 V operating voltage. The capacity of the battery will depend on the needs of the overall circuit, however a minimum battery life of around 18 hours per charge will be paramount due to the limited operating hours of the solar cells that will be used to provide power.

As the Pool-AID will need to be available for outdoor purposes, it is important that a battery which can withstand the temperature extremes of weather conditions at the time is used. This means that a battery with flexible operating temperatures will be preferred. Cost is desired to be as low as possible, though the battery is likely to be one of the more expensive components in many systems and given the other requirements of the battery for the Pool-AID, cost will likely be somewhat inevitable. Finally, shelf life is an important constraint to keep in mind, especially considering that batteries typically have reduced capacities as they age

3.2.2.1 Lead-Acid

Lead-acid batteries are the type of rechargeable battery that is typically used in motor vehicles. These batteries have the benefits of being some of the cheapest rechargeable batteries, with high durability and temperature ranges. One of the main drawbacks of lead-acid batteries, however, is their relatively large power-to-weight ratio, which makes them unideal for small, portable devices. Due to the large size and weight of these batteries, they are likely not the best fit for the needs of the Pool-AID.

3.2.2.2 Nickel-Cadmium

Nickel-Cadmium (NiCd) batteries have low operating voltages of around 1.2V and have a very high discharge rate. They are still of fairly low priced, however more expensive than lead-acid batteries. They also have the advantage of being durable to low temperature environments and offering a higher-than-average life cycle. One of the biggest drawbacks that these batteries face is something known as the memory effect which requires the battery to be fully discharged before being capable of storing new charge. This effect alone is enough to make these batteries a poor candidate for use in the Pool-AID due to the unpredictable nature of solar cells which will not give time to discharge before charging may occur.

3.2.2.3 Nickel-Metal Hydride

Nickel-Metal Hydride (NiMH) batteries share many of the advantages of NiCd batteries with higher capacity and no memory effect. They also have a higher energy density and are quite safe, due to their resistance to leakage and explosions. These batteries generally are usable as alkaline battery substitutes with a lower but still compatible cell voltage.

3.2.2.4 Lithium Iron Phosphate

Lithium iron phosphate (LiFePO4) batteries are a type of lithium-ion battery that can serve as a possible substitute to lead-acid batteries. Being a lithium-ion battery means that it will be more expensive than other options. While being safer than many other lithium-ion based batteries, they still require appropriate circuitry for protection and charging. They also will have a slightly higher power-to-weight ratio, though they are still very valid as fairly portable options with slightly lower energy densities.

3.2.2.5 Lithium Polymer

Lithium polymer (LiPo) batteries are another type of lithium-ion battery, though much more care needs to be taken in terms of safety compared to LiFePO4 batteries, due to their tendency to explode when charged or discharged improperly. They have exceedingly high energy densities and lower power-to-weight ratios, which makes them ideal for portable applications. They are also designed to work in varied temperatures, though this range shrinks when charging. These batteries are the most expensive of these options but have some of the best results for this application if utilized properly.

3.2.2.6 Battery Selection

Due to the above descriptions, lead-acid batteries and NiCd batteries are likely not suitable options for the Pool-AID due to size and memory effect, respectively. This leaves NiMH, LiFePO4, and LiPo batteries, with the most likely candidates being the lithium-ion batteries due to their range of capabilities.

	Lead-Acid	**Nickel-Cadmium**	**Nickel-Metal Hydride**	**Lithium Iron Phosphate**	**Lithium Polymer**
Energy Density	80-90 Wh/L	50-150 Wh/L	140-300 Wh/L	325 Wh/L	250-730 Wh/L
Operating °F	-40°F-120°F	70°F-90°F	68°F-113°F	-4°F-140°F	-4°F-140°F
Cost	7-18 Wh/USD	3 Wh/USD	3 Wh/USD	3-12 Wh/USD	3-12 Wh/USD
Safety	↑	↑	↑	—	↓
Memory Effect	X	✓	X	X	X

Table 4 - Battery Comparison

3.2.3 Sensors

Pool-AID is a sensor-driven device, meaning its efficiency relies heavily on the quality of the sensors used. To make the anti-drowning system functional with a minimal false rate, the sensors chosen must be able to detect the characteristics of a drowning victim. While there are no fixed characteristics of a child or pet drowning, there are certain actions that lead up to the drowning incident. Our design will try to use that to detect the motion leading up to that moment to trigger an alarm to prevent it from happening before it is too late. Its functionality will not be limited to detect drowning prior to it happening, but also while the target submerges in the water. The sensor components required to design Pool-AID are the ultrasonic sensor and the passive infrared sensor.

3.2.3.1 Sonar Sensor

An ultrasonic sensor will detect the kind of motion happening underwater. A sonar sensor measures the soundwaves produced by the activity. The system will be able to locate where the action is happening underwater and send the data to the controller. Depending on the range determined by the sensor, a decision will be made to categorize the child as safe or unsafe. Depending on the depth of the pool, a safety boundary will be configured prior to determining if a child is drowning or just swimming. The sonar sensors we are considering are all LV-MaxSonar-EZ sensors. They all have different advantages as well as drawbacks; however, all three contain characteristics we want for our design. All three sensors have low power consumption, can detect people in a reasonable range, and work with different power sources.

The **MB1000** has the widest beam and highest sensitivity to detect objects. High sensitivity is a feature that could be used to hurt the reliability of the drowning-detection system. The more sensible our system is to random things that fall in the pool, the more likely the user will find false alarms disrupting and will want to shut down the system. The **MB1010** is one of the more popular sensors as it compensates for the high sensitivity by disregarding lightweight objects. In a scenario where a ball or a toy is thrown into the pool, the sensor will ignore it as it does not create any motion after it is submerged. It provides less coverage than the MB1000, but still covers a significant area of 8 ft. The **MB1040** is the least responsive to lightweight commotion, but only covers a narrow width of approximately 4 ft compared to the 8 ft to 10 ft provided by the other modules. None of the sensors were designed to be waterproof; however, they can function underwater with the use of a shielded cable.

	LV-MaxSonar-EZ MB1000	LV-MaxSonar-EZ MB1010	LV-MaxSonar-EZ MB1040
Operating V	2.5 V – 5 V	2.5 V – 5 V	2.5 V – 5 V
Distance Detection	Min – 6.5 in Max – 120 in	Min – 6.5 in Max – 96 in	Min – 6.5 in Max – 48 in
Cost	$30.745 for 9	$27.445 for 9	$27.445 for 9

Table 5 - Sonar Sensors Comparison

3.2.3.2 Passive Infrared Sensor

The Passive infrared sensor (PIR) will be used to detect motion both outside and inside of the water. The PIR does this by detecting changes in infrared radiation. This sensor can be used to trigger an alert when someone is near the perimeter of the pool as well as inside the pool. Because of the generic function of the sensor, it cannot detect distance, nor can it differentiate the size of an object. Therefore, the main function of the PIR will serve to be an initial detection of living motion by the device. It can then alert the sonar sensor to detect distance and motion within the pool's boundaries. The sensor's being considered must meet several basic requirements. They must have low power consumption, accurate detection distance up to 3 meters, wide viewing radius, and be able to be powered with 5 volts DC or under. As the Pool-AID will float within the consumer's pool multiple sensors will most likely be needed for greater visibility range.

EKMB1306112K

This sensor from Panasonic Electric Works is a PIR that can operate at a voltage as low as 2.3 and drive an average current of 6 microamps. It comes with a maximum detection range of 12-17 meters depending upon the temperature difference of the object with its surroundings. Detection of 17 meters can be achieved with a temperature difference of 8 degrees Celsius or 4 degrees at 12 meters. The detection range is 62 degrees in both the vertical and horizontal axis, meaning roughly 6 sensors would be necessary to always capture the entire pool area. This is the one significant downside to this sensor. Its cost is listed as $15.56 per unit which factor out to be $93.36 for full 360-degree coverage.

EKMC1691113

The EKMC1691113, another sensor from Panasonic Electric Works, can operate on voltages from 3 to 6 Volts. It consumes an average current of 170 microamps. This device has a much lower detection range of 2.5 to 3.5 meters with the same temperature constraints as above, which is still within the requirement specifications of the Pool-AID design. The viewing radius, however, is greatly increased from the previous device. The viewing radius in both the horizontal and vertical planes is 97 degrees. Therefore, with roughly 3 sensors, almost the entirety of the pool could be covered at one time or with four sensors the full 360 degree will be covered with some overlap. The cost per unit of the sensor is $18.60, which would bring the total cost of coverage to either $55.80 for three or $74.40 for four.

EKMB1301111K

This sensor from Panasonic Electric Works has a standard operating voltage range of 2.3 to 4 Volts and an average current consumption of 6 microamps. It has a detection range of up to 5 meters and a detection radius of 82 degrees. This sensor provides a middle ground option between the first two sensors explored providing an improved detection range from the EKMC1691113 but with a smaller detection radius, while having a greater detection radius than the EKMB1306112K with a shorter detection range. Choosing this sensor would require roughly 4 in quantity to cover nearly a 360-degree radius. The cost per unit for this sensor is $25.65 which for full 360-degree coverage would cost $102.6 for four sensors.

Parallax 28032

This sensor from Parallax incorporated has a standard operating voltage from 3 to 6 Volts with an average current consumption of 150 microamps. The detection range for this device is up to 9.144 meters. The detection radius is 180 degrees. These two specifications are ideal for the Pool-AID design requiring only two sensors for a 360-degree viewing radius. In addition to these specifications, the 28032 has an additional enable pin not normally found on most PIR sensors. This pin, defaulted to high when left unconnected, can enable the sensors high sensitivity mode for nighttime functionality which could be a useful addition for nighttime detection of the Pool-AID device.

Sensor	EKMB1306112K	EKMC1691113	EKMB1301111K	Parallax 28032
Operating V	2.3- 4	3 – 6	2.3- 4	3 - 6
Current (uA)	6	170	6	150
Range (m)	12 – 17	2.5 – 3.5	5	9.144
Radius	62	97	82	180
Price	$15.56	$18.60	$25.65	$12.99

Table 6 – PIR Sensor Comparison

PIR Selection

From table 6 direct comparisons can now be made for the four PIR sensors up for consideration. For the operating voltage ranges, the typical ranges are similar. However, after the consideration of the voltage requirements of other components both EKMB sensors can be excluded since they cannot operate well under 5 volts, which may be a requirement of the system. Now current comparisons for the remaining two sensors show they are relatively similar at 170 and 150 microamps respectively. The distance range of detection for the EKMC is up to 3.5 meters, which is well within the Pool-AID requirements however it is significantly outclassed by the Parallax's 9-meter detection distance.

The excess viewing distance of the Parallax sensor therefore could be considered redundant in most cases other than larger pools than the Pool-AID is designed for. Finally in comparison for the viewing radius, the Parallax has a 180-degree radius while the EKMC has only a 97-degree radius. So, to cover the same range two EKMC sensors would be needed to cover the same range as the Parallax sensor. Factoring this into the cost that would mean to cover the same area as the Parallax the cost for the EKMC would be $37.20 as opposed to $12.99 for the Parallax. After making these comparisons the most effective choice of PIR sensor for the Pool-AID design will be the Parallax 28032. It has the lowest price, highest detection range, detection radius, and reasonable voltage and current specifications.

3.2.4 Solar Panel

The solar panel will be an essential element to the Pool-AID when used for outdoor pool purposes. It will allow the device to operate for an indefinite period by charging the battery power supply. The solar panel will need to be mounted on the top of the Pool-AID in order to take advantage of the sun during its peak hours. There are two primary types of solar panels that are under consideration, being monocrystalline or polycrystalline cells. The monocrystalline panels are able to utilize a higher efficiency for energy conversion at a higher price while the polycrystalline offer a slightly reduced efficiency at a lower price. Polycrystalline panels seem to have the best prospects for the Pool-AID, as the higher efficiency will likely be unnecessary for the extra price that is required. The exact specifications that are needed of the solar panel will depend on the other components and the battery used but it should be smaller than 10in by 10in and be able to deliver enough power to recharge the battery with in the general operating window of the cells.

3.2.4.1 Sunyima Tech

Sunyima tech offers various mini polycrystalline solar panel sets that vary in output parameters and price. These solar panels range from around 40x40mm to 80x80mm. Because of their small size, it is likely that many of these solar panels will be necessary to accommodate the needs of the Pool-AID. The solar panels offered have various output parameters which offers a plethora of customizability dependent on what the demands of the systems might be.

3.2.4.2 Sunnytech

Sunnytech offers a few larger panels in the range of approximately 6 square inches that offer 6V and 3.5W. Specifically there is the B033 and B034 models which are very similar with the main difference being the B034 is slightly larger and comes with some pre-installed additional components such as a blocking diode and a USB cable. The B033 seems to be the more customizable option of the two, as it does not include the pre-installed diode and cable, which leaves room for the team to determine what is necessary for the Pool-AID 's purposes.

3.2.4.3 AMX3d

AMX3d is a vendor that offers a few solar panel options, though the only one that is suitable for the Pool-AID seems to be the PET solar panel which is 130x150mm with a 5V 2.5W output. This option is similar to what is offered by Sunnytech with a lower operating power delivery and a lower price. Depending on the needs of the system, this option may be preferrable due to its cheaper price point.

	Sunyima Tech	Sunnytech	AMX3d
Voltage	5-6 V	6 V	5-6 V
Current	50-220 mAh	580 mAh	500 mAh
Power	0.2-2 W	3.5 W	2.5 W
Size	40-80 mm^2	165x135 mm	150x150 mm
Price	$9-12	$13-17	$13

Table 7 - Solar Panel Comparison

3.2.5 Camera Module

The camera module for the Pool-AID will be used to capture images of people submerged in the pool. This added feature to the device will allow it to connect with the software module and user app to give real time snapshots of motion present in the pool. This module needs to be capable of viewing the entire pool either by servo motor or 360-degree lens. It must meet a minimum required viewing distance. It needs low power consumption, preferably with a low power mode for periods of inactivity and transmission as it is projected to be inactive most of the time. It must have an operating voltage between 3.3 to 5 Volts. It needs to be able to interface with the microcontroller for interrupts from sensors to trigger screen captures to forward to the mobile application. It also may need to be interfaced with the Wi-Fi module. It must have a size consistent with the specifications of our project's 12 x 12 x 12 in dimensions and weight.

Intel 82635DSPWGPRQ

This camera module requires a supply voltage of 5 Volts with a current consumption of 700 mA. It has active stereo depth resolution of 1280 x 720 and RGB resolution of up to 1920 x 1080. Furthermore, it has 90 fps, with up to 90-degree angle view with up to 10-meter range. It can be interfaced via I2C, SPI, MIPI and USB. This is a very underwater friendly camera and could be directly interfaced with the floating transmitter module for underwater snapshots. It comes with a price per unit of $69.00. Its dimensions are 74.7 x 10 x 4.7 mm.

ArduCAM-M-2MP

The Arducam is a camera module that requires 5 Volts and 70 mA consumption. It is capable of I2C and SPI configuration. It has a 68-degree field of view. Therefore, to interface with the transmitting module this would have to attach to a servo motor or up to 6 modules would not to be statically attached to the system. It features a low power mode for idle use, which is essential as the camera module will be idle the majority of the time. It has a weight of 20 grams and dimension of 34 x 24 millimeters. It's cost per unit is $25.99 which would amount to $155.94 for six.

Adafruit TTL serial JPEG camera with VC0706

This camera requires 5 volts with a 75-mA current draw. It has a 60-degree field of view rated for distances up to 15 meters. It has UART connectivity capabilities with a baud rate up to 115200. As an added feature this camera module comes equipped with a motion detector sensor capable of alerting movement in the frame. This added feature could assist the sensors with motion detection if placed on the transmitter module. The dimensions of the camera are 32 x 32 mm. The cost per unit of the module is $39.95. Similar to the Arducam up to 6 modules would be required for full visibility costing a total of $239.70.

Arducam OV7670

This camera module requires 3.3 Volts and drives less than 20 microamps of current when idle. It has a viewing radius of 25 degrees which is the smallest of the four options. Additionally, depending upon the MCU chosen for the project an additional interface may be required to connect the camera module to the microcontroller. It has an incredibly small size of 3.8 x 4.2 mm. The camera has a cost per unit of $5.52. With only a 25-degree viewing radius to monitor the entire field of view at once up to 15 modules would be needed bringing the cost to $82.80.

Camera Selection

From table 8 direct comparisons can be made to select the most effective camera module for the Pool-AID design. The first consideration is the operating voltage requirements. All four camera's fall within the 3.3-5 Volt acceptable operating range. In terms of current consumption, the Intel camera has the highest consumption of up to 700 mA, this coupled with the fact that it is the most expensive camera module means it can be excluded from the selection process. For the remaining three the Arducam-2MP and Adafruit have nearly identical viewing radius' while the OV7670 has a radius of 25. In the case of the OV7670, as mentioned previously, this would require up to 15 separate camera modules which would significantly constrain the PCB board space and would require too many pins connections for the chip to handle. Finally, between the remaining two modules they have similar dimensions, so the only difference comes down to price. This leaves the ArduCAM-M-2MP as the clear choice for the Pool-AID design as it is $13.96 cheaper than the Adafruit module.

	Intel82635DSPWG PRQ	**ArduCAM-M-2MP**	**Adafruit VC0706**	**Arducam OV7670**
Operating V	5 Volts	5 Volts	5 Volts	3.3 Volts
Current	700 mA	70 mA	75 mA	20 uA
Radius	90	68	60	25
Dimensions	74.7 x 10 x 4.7 mm	34 x 24 mm	32 x 32mm	3.8 x 4.2 mm
Price	$69.00	$25.99	$39.95	$5.52

Table 8 - Camera Module Comparison

3.2.6 Buzzer Module

A buzzer module will be an essential part of our device. It will be responsible for sounding whenever a child is sensed to be in danger. This module will be built separately from the device floating on the pool, as we want the alarm to be closer to the home than the pool. The reasoning behind this is if a parent is around the pool area, the need of an alarm becomes redundant if they can hear a child drowning. The device is built to notify adults that are not around the pool area when a child is. The alarm will be installed closer to the house, but not too far from the pool to provide some relief to the child that help is coming. Our project is seeking an indicator buzzer, so an audio output is produced when needed.

Grove Active Piezo Buzzer

The active piezo buzzer operates under a high voltage and low current typically less than 20 mA. They provide the user with a higher sound pressure level, which is ideal for our design plan. The audio output of a piezo buzzer can range anywhere from 85 dB to 120 dB [4]. This kind of buzzer sounds as soon as a DC voltage is applied and shuts down with no voltage supply. This part will be compatible with most microcontrollers due to its low current consumption.

CEM-1205-IC Magnetic Buzzer

Unlike the piezo buzzer, the magnetic buzzer operates under a low voltage and high current that is around 30 mA. It also operates under a DC voltage supply. Its SPL is less than that of a piezo buzzer with a maximum of 92 dB, so this puts this particular component at a disadvantage compared to the grove buzzer. Our device prioritizes safety over anything else and being able to reach a wider range with the alarm satisfies that condition.

	Grove Active Piezo Buzzer	**CEM-1205-IC Buzzer**
Sound Pressure Level	Max 120 dB	Max 92 dB
Power Consumption	5 V Min 20 mA	5 V Max 30 mA
Rated Frequency	2400 Hz – 3000 Hz	2400 Hz
Indicator or Transducer	Indicator	Indicator

Table 9 - Buzzer Modules Comparison

3.2.7 Wi-Fi Module

Wi-Fi is a wireless technology that allows many devices such as computers, mobile phones, printers, and other smart devices to be connected without physical connectivity for wireless communication. The network band of a Wi-Fi network can go start 2.4GHz up or 5GHz. The 2.4GHz frequency allows connection to be established at longer distances, but with limited speed, while 5GHz is faster, but only at short range.

Our system will be communicating with mobile devices using an application. We would be able to send data from the sensors and the image captures of the camera module using Wi-Fi to a data cloud database. This doesn't mean we are going to buy a router for the system; however, we can use a Wi-Fi module that is able to establish Wi-Fi connectivity between other devices at low cost. This module can be found already built in MCU such as ESP8266.

3.2.7.1 Wi-Fi vs. Bluetooth

Just as there are Wi-Fi modules, there are also Bluetooth modules to establish wireless connection with other devices. Some reasons why we choose Wi-Fi over Bluetooth are related to security, range, connectivity, and transfer rate. The range of Bluetooth connection is very short compared to Wi-Fi; While Wi-Fi connectivity range can achieve from 150 feet to 300 feet, Bluetooth would achieve up to 30 feet.

Not many devices can be connected to the same Bluetooth network at the same time, usually it is one to one, while with Wi-Fi we can connect many devices to the same network. We want many mobile devices to be able to receive the alert trigger by the Pool-AID system, so they all need to be connected through the same network. Bluetooth transfer rate is slow compared to Wi-Fi; we are comparing 2.1Mbps with 600 Mbps.

3.2.7.2 MCUs with Wi-Fi Modules

ESP8266

The ESP8266 is a low-cost and compact Wi-Fi MCU designed by ESPRESSIF, it is an ultra-low power microchip with a 32-bit CPU and 512KB of flash. Its current consumption goes up to 215mA in active mode with a power down leakage current of less than 10uA. The MCU counts with SPI and UART for serial communication. It has a maximum clock frequency of 52MHz used to drive to transmitter and receiver. The ESP8266 has a radio frequency of 2.4GHz for the receiver and transmitter, this would help us for long range connectivity. Some development boards that use the ESP8266 are the NodeMCU and the WeMos D1. This chip can be found from $1.93 to $4, so it is very accessible. It is compatible with the Arduino IDE, and there are many tutorials on how to use it with Arduino Uno, and how to configure the boards previously mentioned in the IDE. Some features the ESP8266 have are 802.11 b/g/n protocol, TCP/IP protocol stack, Peer to Peer Wi-Fi, and +19.5dBm output power in 802.11b mode.

ESP32-WROOM-32D

The ESP32-WROOM-32D is a Wi-Fi module with an embedded dual-core chip, ESP32-D0WD-V3, with a 32-bit microprocessor developed by ESPRESSIF which also has Bluetooth features integrated. The chip counts 448KB of room and 520KB of SRAM for data and instructions. The operating temperature of the chip is from -40 degree Celsius to 85-degree Celsius. The CPU clock of the module is adjustable from 80MHz to 240MHz.

The Wi-Fi wireless standards are IEEE 802.11b/g/n, and its Wi-Fi radio frequency is also 2.4GHz. The ESP32 chip has some peripherals such as serial communication (UART, SPI, I2C), ethernet, Hall sensors, capacitive touch sensors and SD card interface. The price of the chip varies between $3.60 to $4.00, and the development kit board costs $10.00 in Mouser; the price is still accessible. This module has been used in many applications, including Image and speech recognition, home automation, Smart building, and IoT projects.

ESP32-CAM

The ESP32-CAM is a development board with built-in camera and WI-FI capabilities using the ESP32-S chip. As its name says, it comes with a camera module OV2640. It has a 32-bit CPU, , and a clock frequency of 160MHz, . It operates under the WI-FI standards 802.11b/g/n/e/i, with a frequency band of around 2.4 GHz to 2.5 GHz. It has a built-in flashlight with a brightness that can be adjusted. The operating voltage of the ESP32-CAM is 5V. It supports serial communication protocols and interfaces such as UART, SPI, and I2C. Some advantages we can get by using the ESP32-CAM in our design is not having to transfer data from the main microcontroller and send it to the Wi-Fi module to later send the data to a server.

The chip has enough space to store HD pictures, and the memory can be expandable using a SD card. In addition, we can have the images stored in the chip and send it to a cloud server directly. The price of the ESP32 CAM is around $13.00; however, the price increases to $19.00 dollars since an additional FTDI USB module is needed to program it. Even with the additional FTDI USB module, the price is still lower than having to buy the camera module with the ESP32S Wi-Fi-module separately.

W600 Wi-Fi Module

The W600 is a low power Wi-Fi module which is based on the ARM-Cortex M3 chip with a 32-bit processor with FreeRTOS kernel and is manufactured by seed studio. The module comes with an integrated flash memory of 1MB. It uses IEEE 802.11 standards with 2.4GHz of radio frequency. The W600 support serial communication such as UART, I2C, and Master/Slave SPI with their respective controllers. W600 is suitable for IoT applications; it can be used for smart home applications, medical and industrial control, wireless video, and many others.

The supply voltage of the module is 3.3V and its maximum current consumption is 230mA. The operating temperatures from the W600 go from -40 degrees Celsius to 80 degrees Celsius. The only boards currently being sold that with the W600 built on board are the Wio lite W600, Grove W600, and Wio W600, which is a bigger version of the Wio lite W600 with 6 grove ports for communication protocols. The development boards prices are around $10.25 to $12.00, and the W600 module itself is available for $3.79. Seed Studio provides the Arduino SDK with some demos included for testing the module; This would help us understand functionalities of W600, since there are not many tutorials available online on how to use it.

3.2.7.3 Wi-Fi Module Selection

If we take a closer look at all the Wi-Fi modules mentioned previously, there are many similarities between them. They all have Wi-Fi features, with the difference that the ESP32-WROOM-32 also has Bluetooth. All three Wi-Fi modules have a radio frequency of 2.4GHz which would accomplish the Pool-AID system requirements of being able to communicate with mobile devices from long distances.

Some features are redundant for the system requirements, since our project will only use Wi-Fi for wireless communication; we don’t need to use the Bluetooth features from the ESP32-WROOM-32e. In terms of size, they are all compact, and the smallest is the ESP8266. The camera module is essential for the design, and the ESP32-CAM can provide us the camera at a cheaper cost than the separate camera module. However, this component cannot be soldered in a PCB, so if we want to design our own PCB, we would prefer the camera module separately.

This does not mean the ESP32 chip cannot be acquired separately and work with a separate camera module, so it might be considered in case of redesign. Our design has some requirements related to size and weight, so the ESP8266 module would make the device more portable. The W600 is a newer module compared to ESPRESSIF modules; meaning they have more support for their implementation with other boards, and there are more resources available. If the selection of the Wi-Fi module is considered its price, the W600 is the cheapest, but for the board with the built-in module the NodeMCU with the ESP8266 is a good choice. For the selection, the ESP8266 would be considered since it is available in different vendors, provides long range communication, more than enough memory, and easy to program because of the high number of available tutorials and resources about this module working with other microcontrollers and mobile device communication.

	ESP8266	ESP32-WROOM-32D	W600 module	ESP32-CAM
Boards	NodeMCU, WeMos D1	ESP32-DevKitC	Wio Lite, Grove, Wio	ESP32-CAM
Operating voltage	2.5V – 3.6V	3.0V – 3.6V	3.3V	3.0V – 3.6V
GPIO	17	34	16	10 GPIO
Radio frequency	2.4GHz	2.4GHz – 2.5GHZ	2.4GHz	2.4GHz – 2.5GHZ
Memory	512KB flash	520KB SRAM	1MB Flash	520KB RAM, (up to 4GB for microSD)
CLK Frequency	26MHz to 52MHz	80MHz to 240MHz	80MHz	160MHz
Temperature	-40C to 125C	-40C to 85C	-40C to 85C	-20C to 85C
Price Module - Board	$6.95 $8.20	$4.20 $10.00	$3.79 $10.60	$3.25 $12.99

Table 10 – Wi-Fi Module Selection

3.2.8 Servo Motor

A servo motor's main function is to assist with the angular or linear position of a device. For the purpose of Pool-AID, due to its needs for a 360-degree viewing radius for several components, a servo motor can be used to continuously rotate the device to allow for a larger viewing window. As most of the sensor modules will not have a 360-degree viewing radius on their own the servo motor will be crucial in allowing those sensors the ability to view the entirety of the pool. Therefore, the rotation speed must be fast enough to allow for the greatest reactivity of the Pool-AID. Low power consumption will also be important for the longevity of the device as this component will never be idle.

Continuous Rotation Servo - FeeTech FS5103R

This servo motor from Adafruit operates at a voltage anywhere from 4.8 to 6 Volts. It is capable of rotating fully forward and backwards at a speed of .18 seconds per 60 degrees, or around 1 second per full revolution. With dimensions of 1.5" x 2.1" x 0.8" and a weight of 40 grams it is an ideal compact size for use with the Pool-AID. Its price is set at $11.95.

Metal Gear Digital Servo Part No. LS-0009AF

This servo motor from OSEPP Electronics LTD operates at a voltage anywhere from 4.5-6 Volts. It can execute a full rotation at a speed of .1 seconds per 60 degrees at 6 Volts and .12 seconds per 60 degrees at 4.5 Volts. The dimensions of the motor are 22.3 mm x 11.8 mm x 26.3 mm. The weight is 10 grams. Even at low supply voltage this motor will provide a significantly higher rotation rate which is desirable as fast response time is essential to the Pool-AID 's success. The price for this motor is $23.99.

DFROBOT SER0050

This servo motor operates between 4.8 – 6 V. This servo has a 180 degree back and forth rotation. The dimensions of this motor are 42.40mm x 16.60mm with a weight of 9 grams. The major advantage of this motor is its pricing. At only $6.00 for one it would help reduce constraints on the budget.

FEETECH Standard Servo FS5103B-FB with Position Feedback

This is a specially modified servo motor that operates at both 3.3 and 5 V DC. The speed of revolution is around .16 seconds per 60 degrees at 5 Volts. While this is not the fastest device, this servo can provide position feedback which could be used to help identify location of objects noticed by the other sensors in the Pool-AID. This product is priced at $11.95 similar to the FeeTech FS5103R.

Parts	**FeeTech FS5103R**	**Metal Gear Digital Servo**	**DFROBOT SER0050**	**FEETECH FS5103B-FB**
Operating V	4.8 – 6	4.5 – 6	4.8 - 6	3.3 - 5
Rotation sec/60°	0.18	0.1	N/A	0.16
Price	$11.95	$23.99	$6.00	$11.95

Table 11 – Servo Motor Comparison

3.2.9 Voltage Regulator

Because the voltage of the battery and the voltage of the solar panels will not be able to exactly match the required 5V for the rest of the Pool-AID system, a voltage regulator will be required. Depending on the exact setup of the Pool-AID 's power system, a different regulator may be needed. One possible way to connect the power for the system is to have the solar panel only used to charge the battery, with the battery being the only source of power for the overall system. In this case, it is likely that a DC-to-DC boost converter will be necessary to increase the battery's voltage to the required 5V.

This method has the advantage of being cheaper and simpler but results in possible wasted power, in the case where the battery is fully charged but the solar panel is currently outputting. The other method is to have the solar panel provide power to both the battery and the overall system. In this case it is likely that a DC-to-DC buck-boost converter will be necessary to step-up the voltage of the battery and the solar panel and step-down the voltage of the solar panel when maximum output parameters are met. This method is less wasteful but will have an increased cost and complexity.

For both of these methods two choices are possible for the implementation of the regulator: purchasing an integrated circuit chip and designing a circuit custom to the Pool-AID or purchasing a prebuilt circuit that implements the chip.

Comidox Boost Converter Board

The Comidox boost converter board is a very compact boost converter that can take input voltages in the range of 0.9-5V and convert it to the needed 5V output with a maximum current output of 480mA. The board has a typical conversion efficiency of 85% and has a very compact footprint of 11mm x 10.5mm x 7.5mm. This module is very cheap and small but may not be suitable for the Pool-AID system depending on the required current draw, as this converter cannot handle very high current loads.

ANMBEST Mini Boost Module

The AMNBEST mini boost module is a slightly larger converter that can handle a higher current draw of up to 1A. This board is designed for use with a single-cell lithium-ion battery and can output the desired 5V output. The footprint of the board is slightly larger at 22mm x 11mm x 3.6mm but remains at a relatively low cost.

Texas Instruments Boost Converter ICs

Texas instruments offers a variety of IC chips that can be used for designing a boost converter circuit. This method is slightly more complicated but should be slightly cheaper and more flexible to the needs of the system. IC chips can be found by entering the system specifications into the TI website and selecting the chip which best matches the criteria. Some chips which seem like viable options for the Pool-AID system are the TI TPS61256A, the TI TPS61092, and the TI TPS61256C.

SparkFun Buck-Boost Converter COM-15208

The SparkFun COM-15208 is a buck-boost converter that is based around the TI TPS63070 IC chip and accepts a range of input voltages between 3-16V with output voltages able to be between 2.5V and 9V. The maximum output current depends on the input and output voltage used, but with the expected values for the Pool-AID, a maximum current of approximately 1A can be expected with an efficiency of up to 95%. The circuit also include an extra protection measure of overtemperature protection.

Texas Instruments Buck-Boost Converter ICs

Texas instruments also offers a variety of IC chips that can be used for designing a buck-boost converter circuit. This method is more complicated but again it should be slightly cheaper and more flexible to the needs of the system. IC chips can be found by entering the system specifications into the TI website and selecting the chip which best matches the criteria. Some chips which seem like viable options for the Pool-AID system are the TI TPS63061, the TI TPS63070, and the TI TPS63010.

Pololu 5V Step-Up/Step-Down Voltage Regulator S7V7F5

The Pololu S7V7F5 is a buck-boost converter that is based around the TI TPS63061 IC chip and accepts a range of input voltages between 2.7-11.8V with the desired output voltage of 5V and a maximum output current of 1A for step-down and 500mA for step-up. It has a very small footprint of 9mm x 12mm x 3mm and its typical efficiency is over 90%. There is no reverse voltage protection include in the circuit so the use of a diode may be necessary. It is the regulator that best fits our needs.

3.2.10 Battery Charger

A battery charger will be necessary to charge the battery that will be power the system, either by solar panel or by some other charging method, depending on if the pool is indoor or outdoor. The exact battery charger that will be needed cannot be known until a battery is selected, however, there are some options to investigate, especially if the battery will be lithium-ion based.

Two main methods for obtaining the battery charger are available: purchasing an integrated circuit chip and designing a circuit custom to the Pool-AID or purchasing a prebuilt circuit that implements the chip. The benefits of the first method are that the circuit can be customized easily and made custom tailored to the needs of the system, while also having the possibility of being cheaper. On the other hand, the premade circuits have a wide selection of options and can be designed with proper safety integrated into the circuit (which is especially important if a lithium polymer or other lithium-ion based battery chemistry is selected).

These circuits can get fairly expensive, but with careful selection, a circuit can be purchased that has all of the specified needs for a decent price. This also alleviates some of the work that will need to go into soldering and designing the PCB necessary for the integrated circuit.

CN3065

The CN3065 is a common IC chip offered by Consonance Electronic used for charging lithium-ion batteries. It is designed to operate well with solar based implementations and offers some basic safety mechanisms such as undervoltage lockout and battery temperature sensing. It also is included in many prebuilt circuits, such as the Beizuu ZuuIModule_1189 and the Elecrow Mini Solar/Lipo Charger.

TP4056

The TP4056 is another common IC chip which is offer by Top Power for lithium-ion battery charging. It is not specifically designed to operate for solar based implementations but allows for a range of 4-8V for input voltage which should work well with solar input. Overall, it shares many similar traits to the CN3065 with different input and output ratings and the addition of a current monitor. It is also offered in many prebuilt circuits, such as the MglglcM TP4056 Charging Board and the Icstation TP4056 Charging Board which includes many necessary safety measures such as overcharge, over-discharge, and over-current protection.

CN3791

The CN3791 is another IC chip offered by Consonance Electronic and is heavily focused on solar powered systems. Specifically, it includes photovoltaic cell maximum power point tracking (MPPT) which allows for the charger to utilize the maximum possible power that the solar panel can provide given the current illumination level. It also has some more advanced protection built into the chip such as overvoltage protection. This additional functionality comes at a higher cost and the chip is suited for solar power systems much larger than what is intended for the Pool-AID. MPPT is also more important in larger scale systems as the difference is not as major for small scale applications.

Texas Instruments Battery Charger ICs

Texas Instruments also offers a wide variety of possible battery charger IC chips. Its website has an in-depth system for narrowing down and choosing a viable chip for the circuit and can offer a lot of flexibility with chip selection based on various necessary ratings. They also offer chips specifically designed for solar power systems such as the TI BQ24210, TI BQ25504, and the TI BQ25505.

3.2.11 Tx Rx Wireless Modules

The Pool-AID device's buzzer module is the one component that will not be housed in the floating device containing all other components. It shall remain separate outside of the pool in order to have no unintended distortion or reduction in sound when triggered. As the majority of residential pools are located outside, having the buzzer module being hearable indoors is a critical element of the Pool-AID 's design. Therefore, locating the buzzer module near the entrance to the home as opposed to inside the floating device will help to mitigate the risk of not being alerted to its activation. This, however, creates a new complexity to the design of the Pool-AID as the core device must now be able to transmit over some distance to the buzzer module. For this new challenge a wireless transmission module will be used for communication from the core device to the buzzer module.

There are several kinds of wireless transmission modules that can use various communication methods such as Bluetooth, Wi-Fi, and RF. For the purposes of the buzzer communication only antennae-based RF transmission modules will be considered. These types of transmitters receive serial data from an input and transmit it to a receiver operating at the same frequency using the same process. The two most common methods of transfer are either Frequency shift keying in which the frequency of transmission is altered in order to transmit data, or Amplitude shift keying in which the amplitude of the waveform is changed to correspond with data transmission.

3.2.11.1 TX Options

RC-CC1101-SP

This transmitter is an RF FSK based transmitter. It has an operating voltage of 3.3 V a power output of 10dBm and an operating frequency of 868 MHz Its frequency modulation ranges from 25 – 35 kHz. This transmitter goes for $16.00 on Digikey. It has a through hole design for PCB attachment and is 11 by 20 millimeters in dimension.

TXM-315-LR

This series of RF transmitter is Amplitude Shift Keying (ASK). It has an operating voltage of 3.3 Volts and a typical output power of 0 dBm. The operating frequency is 315 MHz This product retails for $9.66 on Digikey. The main drawback to this transmitter is that it requires purchase of an antennae for proper functionality. Options are given in the datasheet for suggested antennas.

RC-TX1-434

This series of RF transmitter is also ASK. It has an optimal operating voltage of 5 V. Typical output power is 10 dBm and an operating frequency of 433.92 MHz. This transmitter retails for $14.00 on Digikey but requires a minimum of 10 units purchased at once. The dimensions of this transmitter are 10 by 18 millimeters.

MICRF114T-I/OT

This transmitter is an On off Keying output which is a simple form of Amplitude shift keying where if data is being transmitted it represents a binary one where as no signal is a binary zero. It has an operating voltage range of 1.8 to 3.6 Volts. Additionally, it has a wide functional frequency range between 285 to 445 MHz. This frequency range is set by the clock that is connected to it. This is a surface mounted part with dimensions of 2.2 by 2.7 millimeters. This part retails for $0.85 on Digikey making it the cheapest option of the considered transmitters.

3.2.11.2 RX Options

RC-RFSK3-434

This RF receiver uses FSK for receiving data. It has an operating voltage range of 4.5-5.5 Volts. The operating frequency is 433.92 MHz. The dimensions of this receiver are 46 mm by 16 millimeters. This product retails on Digikey for $18.00 and requires a minimum purchase of 10 units.

RCASK2-315

This RF receiver uses ASK for receiving data. It has an operating voltage range of 4.5-5.5 Volts. The operating frequency is 315 MHz. the dimensions of this receiver are 38 by 14.5 millimeters. This product retails on Digikey for $18.00 but requires a purchase of 10-unit increments meaning purchase of this receiver would require a $180.00 budget commitment.

AM-RRQ3-433P

This RF receiver uses ASK for receiving data. It has an operating voltage range of 3.3 to 8 Volts. The operating frequency is 433.92 MHz. The dimensions of the receiver are 38.1 by 14.5 millimeters. This product has a unit price of $13.42 on Mouser electronics or $10.50 on Digikey. It comes with an idle mode which is ideal for power consumption as the device will remain idle the majority of the time.

AM-RX12-433

This RF receiver uses ASK demodulation for receiving data. It has an operating voltage range of 3 – 5 Volt. The operating frequency is 433.92 MHz. The dimensions of the receiver are 43 by 6 millimeters. This product retails for $6.55 per unit on Mouser. Like the AM-RRQ3-433P this receiver also has an idle mode that conserves power.

Selection

In order to make the decision on the transmitter and receiver several factors must be considered. The most important thing to consider is the fact that the transmitter and receiver must operate at the same frequency. The second factor to consider is that both modules must use the same modulation technique to transmit or receive data. This means that only certain combinations of the two modules can be considered.

First, is the RC-CC1101-SP. This transmitter operates at a frequency of 868MHz which is faster than every receiver that was researched. This means we can exclude this one from consideration as it is incompatible with all receivers. The TXM transmitter with a frequency of 315 MHz is compatible with the RCASK receiver. This is one potential option however because the RCASK has to be purchased in groups of 10 units this would be a costly combination. Therefore, we can eliminate from contention any transmitter or receiver that only retails in bulk.

This leaves both AM receivers and both the TXM and MICR transmitters as options. The TXM transmitter is not compatible with either of the AM receivers as they operate at different frequencies. This leaves the MICR transmitter as the best viable option for the transmitter module. Additionally, as it is capable of operating on a range of frequencies from 285-445 it can transmit successfully to the AM receivers. It is also by far the cheapest of all transmitters at a retail of $0.85. Both AM receivers have similar functionalities, including the low power modes. The dimensions are also nearly identical the main difference between them is the retail price. The AM-RRQ3-433P retails for as low as $10.50 while the AM-RX12-433 retails for $6.55. Therefore, the module combination selected for use is the MICRF114T-I/OT transmitter with the AM-RX12-433 receiver.

Transmitter	RC-CC1101-SP	TXM-315-LR	RC-TX1-434	MICRF114T-I/OT
Modulation Type	FSK	ASK	ASK	ASK
Operating (V)	3.3	3.3	5	1.8 – 3.6
Frequency (MHz)	868	315	433.92	285 - 445
Dimensions (mm)	11 x 20	-	10 x 18	2.2 x 2.7
Price	180 for 10	9.66	180 for 10	0.85

Table 12 – Transmitter’s comparison

Receiver	RC-RFSK3-434	RCASK2-315	AM-RRQ3-433P	AM-RX12-433
Modulation Type	FSK	ASK	ASK	ASK
Operating (V)	4.5 – 5.5	4.5 – 5.5	3.3 - 8	3.3 - 5
Frequency (MHz)	433.92	315	433.92	433.92
Dimensions (mm)	46 x 16	38 x 14.5	38.1 x 14.5	43 x 6
Price	180 for 10	180 for 10	10.50	6.55

Table 13 – Receiver’s comparison

3.3 Software Selection

3.3.1 Database

A database will be required to store the video files that have been sent by the Pool-AID once the camera module activates. The database will need to be able to store possibly large quantities of unstructured data being fed by the camera’s video feed. For this reason, NoSQL databases are of higher consideration due to their ability to excel in the storage and management of unstructured data. The database will be required to store the video files that have been sent with associated timestamps for when the video was captured. This will allow the end user to get a decent understanding of the chronology of events and what happened during said event through the use of a mobile interface that connects to the database.

3.3.1.1 Cloud Firestore

Firestore is a database offered by Google’s Firebase that is designed around flexibility and scalability. Firestore uses documents and collections to store data, where documents can be complex nested objects or subcollections and collections are groupings of documents. The database is also considered highly scalable in order to ensure that as a database workload increases the database will be able to handle it. Firestore also utilizes local data caching to allow for robust offline support with actions performed offline synchronizing with the cloud once a connection is made. All data is synchronized real time allowing any device connected to the database to see changes as soon as they happen. Because it is a Google owned database, Firestore can only be used with the Google Cloud Platform.

3.3.1.2 Realtime Database

Realtime Database is an older database offered by Google’s Firebase that was designed around real time synchronization and cloud-based storage. This Firebase database is very similar to Cloud Firestore but does have some unique characteristics. One of these characteristics is that the Firebase Realtime Database stores data as JSON files rather than documents and collections. Due to Firestore being a newer database, it outclasses Realtime Database in many areas such as sorting and filtering, scalability, and availability. Overall, Firestore is likely the better option in most situations, though both databases can be used concurrently for the same application. Because it is a Google owned database, Realtime Database can only be used with the Google Cloud Platform.

3.3.1.3 MongoDB

MongoDB is a document-oriented database with the use of JSON-like documents that allow for wide support and useability. Due to the structure of the documents used by MongoDB, JSON formatted files are readily supported for use with MongoDB. MongoDB has a master-slave replication which means that one database is related to other databases which allows for updates to ripple throughout slave databases through the master database. MongoDB is designed around allowing for high flexibility while supporting the ability to perform transactional and warehouse-style workloads. MongoDB is designed to allow for high performance at scale with many robust and advanced querying options. It also is more flexible when is comes to what cloud platform is used as it does not lock the developer into using only one specific cloud platform.

3.3.1.4 Couchbase

Couchbase is a key-value and document-based database that is memory first, where data is stored in a memory cache allowing for faster performance. Couchbase also utilizes a JSON schema, allowing for easy implementation with JSON file formats and allows for SQL-like queries, as well as fully NoSQL querying. As opposed to MongoDB, Couchbase is a masterless database which means that all nodes can operate independently. Couchbase also allows for flexibility with cloud platforms as it also does not lock the developer into using only one specific cloud platform.

3.2.2 Mobile Development

In the previous section we talked about how the data collected by the Pool-AID System will be stored in the database of our choice; Information such as pictures and time of capture should be displayed on a mobile application for the customer to have a better representation of the data. A mobile application will be developed to communicate with the system. The application should be responsive and have a friendly user interface. There are different technologies we could use to develop the application; Frameworks, Libraries, and SDKs will be listed below. Our application should work on any Android and IOS device, which are the main operating systems for mobile devices currently used. The tools we are including in this section don’t require high programming skills, so no data structures or algorithms are needed for the app.

3.3.2.1 Flutter

Flutter is an open-source UI toolkit developed by Google released in 2017 for developers to build mobile and web development using a single codebase. It provides support to applications to run in Android and IOS devices, and it can also be imported to work as web applications. Developers do not need to worry about having to port their application from

IOS to Android or redoing their work for both operating systems; that is why Flutter is used to develop the same application using a single codebase.

Flutter provides some react-style frameworks for the design, and it also includes high quality material design and Cupertino widgets which are customizable; developers can create their own widgets for their needs. Android and IOS devices come in many sizes, so applications should be adapted to any screen size. In other frameworks such as React, to achieve responsiveness, there needs to be more code added to the stylesheets that can be repetitive. On the other hand, Flutter helps by drawing the widgets for the application within the given space by the screen; it is not necessary to create additional stylesheets for making an application responsive. Flutter uses Dart as the main language to structure their frameworks and widgets.

Dart is a programming language created by Google, and its syntax is comparable with JavaScript, so developers who have used JavaScript frameworks in the past could adapt to this new language. The frameworks and widgets are used to design the front-end of the application; however, applications built using flutter can use some libraries compatible with dart to communicate with a cloud service, like Google Cloud, and acquire the data store in a database such as Firestore. Using the frameworks and widgets provided we can display the data acquired in our applications. This looks promising for our Pool-AID system if we get to choose Firestore or Real time database as our main database to send the pictures captured by the device, since we can design the back end with those services and using flutter, we can fetch the data using some libraries. Flutter provides many options to develop applications that can work in different Operating Systems; This toolkit could be the main environment we could use to develop the Pool-AID application.

3.3.2.2 React Native

React Native is an open-source framework developed by Facebook for mobile development for Android and IOS devices. As its older brother, React.js for web applications, it implements the same concepts of hooks, reducers, and components for UI design. React native is single codebase; this means that the same code for the application will be used to compile it for Android and IOS. Some widgets might look different between devices, but they are used using the same code. React allows you to create customized widgets using styled components written using a syntax similar to SASS. This framework uses JavaScript as its main programming language, and it helps create native applications to satisfy user experience. React Native uses some blocks that are injected to the application which are called components. Initially, developers had to write large lines of HTML or XML and CSS to design the UI of their applications, and this became a repetitive task. React Native provides built-in components such as View, a version of div tags in HTML, and Text which can be used as blocks to build the front-end of the application. Most applications have different functionalities; By pressing a button we can move to other features in the application. React native uses React Navigation to link components to other components to make navigation easier in the app.

The mobile application for our Pool-AID system will come with features such as device configuration, data display, and camera access, so we can use React Navigation to link the components for each feature with the main component of application for easier navigation between these. React native is compatible with back-end frameworks for JavaScript such as Node and Express to get data from a database like MongoDB. This would serve good on our project since we want to fetch data from a NoSQL database, since images and sensor data are unstructured. React native has support for working and testing applications using firebase; if we use Cloud Firestore as the database to store our device data, we can easily fetch the data to display it on the application by installing the right packages and implementing the right libraries.

3.3.2.3 Xamarin

Xamarin .NET is an open-source framework handled by Microsoft to develop modern and high performance IOS and Android applications. Xamarin uses .NET platform to provide some tools and libraries for app development. Xamarin uses a single codebase written in C#, a programming language very similar to Java, for all the applications; it can also use XAML to build the user-interface. It uses shared C# logic to be develop applications for any operating system using Xamarin.forms for cross-platform UI. Xamarin.forms comes with built-in widgets such as layouts, pages, and controls that are customizable for the front-end of the mobile application.

Xamarin uses model-view-ModelView (MVVM) patterns to create extensions for the application with low effort. MVVM separates the UI from the application logic for better unit testing and additional features without repeating code. For the demo of the Pool-AID system, our mobile app will be able to only receive the captures of the camera and display them; but more features will be added for the final version such as camera monitoring or data storage. Xamarin MVVM pattern can be used to add these new features for the Pool-AID application without having to make many changes to the original source code. Xamarin has been used to build applications for businesses such as UPS, BBVA, and Azure app.

3.3.2.4 Selection

Flutter, React Native, and Xamarin are different technologies, one is a toolkit and the other two are open-source frameworks, but they all provide different sets of tools and libraries for building native applications with high performance. React native and Xamarin have been used in applications for big enterprises such as Facebook, Instagram, Microsoft, UPS, Azure and many others, while Flutter was designed for developers. Both Flutter and React use similar languages which are Dart and JavaScript; JavaScript is the most common and easy to use between the two because of its syntax. If we compare Xamarin programming language, C#, the syntax is very similar to Java, which is a language all the members are familiar with. Some issues with React Native are not being able to develop Android and IOS applications if we are working on a windows machine. This is something similar that happens with XCode and Swift for Mac; IOS applications cannot be developed in windows computers with React Native, but Android and IOS applications can be developed in an macOS device.

When updates on the Operating System, either Android or IOS, occur there is a chance some features added are not yet supported by React Native; while Flutter has an interop and plugin system to have access to the newest mobile OS capabilities, and this could give more support to our application. Xamarin will receive less support after November 2021, but it will be extended and replaced by .NET MAUI which implement all the extensions from Xamarin and add more tools.

If Xamarin is chosen as the main tool to develop our mobile application, a possible change to MAUI has to be taken to continue with its development. The Pool-AID is not going to be a huge application like Xbox or Netflix; we want the application to be able to display the data from the camera module to a database in real time and fetch that data to display it on a phone. Another thing would be the camera view, for checking monitoring the activity near the pool. This means that we need our mobile app to be user friendly for users to access all the app options, and we could use React Navigation for that. In terms of who builds better applications, there is no way to tell if an application is better if designed with Flutter or React Native. These three technologies would help with building native applications that guarantee fast response.

3.3.3 Cloud Platforms

For Pool-AID 's data storage and management, a cloud platform must be selected to suit the mobile applications needs. The device will be sending snapshots during periods of activity that will require storage for user defined periods of time for later access. The important aspects for the cloud platforms to have an affordable storage price, secure data storage, multiple storage options for different data types that have various required storage longevities.

3.3.3.1 Google Cloud

The google cloud storage system provides a variety of useful features helpful in the maintenance of a mobile application. First and foremost, it provides multiple options, or classes, of storage. This includes standard, which is meant for frequently accessed data, nearline which is meant for data that can be stored up to 30 days, cold line which is data that can be stored up to 90 days and archived which can be stored up to a year. Each of these storage classes has a different cost with the standard storage being the highest cost. This also features Object Lifecycle management. This feature allows for the user to define data deletion and also data transition between storage classes. Retention policies can be set by the user for specific data as well as holds to prevent expired data from being discarded. The cost of standard storage is $.02 per GB per month.

3.3.3.2 AWS

Amazon web services has a vast array of options for cloud storage services. One of the most popular is the Amazon simple storage service, or Amazon S3. This service includes several features. First, like Google cloud it has several classes of storage designed for different kinds of data. The general-purpose storage is meant for low latency high throughput data. This is designed for frequently accessed data. There is the Infrequent access class which provides the same speed of access as the standard but is streamlined for data that is accessed less frequently but must be obtained quickly upon request. There is also an archived class meant for long time storage of data. For the standard storage the cost is $0.023 per GB for the first 50 TB per month. The data storage in this system also has heightened security due to all data will be copied and stored across several systems.

PCB Design Software selection

For the design and implementation of the PCB for the Pool-AID there are several choices in terms of software to aid in the design stage. There are several characteristics necessary for the selection of PCB software. The ideal software will have decent library features, easy readability, and be capable of producing the necessary schematic a manufacturer will require once the design of the PCB is completed. Useability is also important in the selection. A successfully designed PCB is a crucial element of this project and the longer the learning curve for using the software the greater strain on time the PCB design becomes. Additionally, the ability to design our own component footprint may be necessary if no library exist for any components. There are three PCB design software's to be considered for the Pool-AID. The first is EAGLE. The second is fusion 360 and the third is EasyEDA.

EAGLE

The EAGLE PCB design software comes from Autodesk. With this software entire schematics can be uploaded from built in libraries or downloaded into the program and then used. Alternatively, schematics can be generated from scratch as will be necessary for this project. Each part used will be loaded into a library if it doesn't already exist and the schematic can be designed in EAGLE and directly loaded as a PCB design. This software allows for easy combination of separately generated schematics into one design interface. From the schematic stage the user can quickly generate a potential PBC with the footprints stored in the library. The user can then place the footprints on the board layout manually and choose between manually routing or auto routing. The added tools such as auto routing to assist with trace routing can be very helpful when choosing a proper layout. Most importantly, this software will be free to use if chosen for the design of the Pool-AID.

Fusion 360

This software is also from Autodesk. It is a cloud-based PCB, CAD, CAM, and CAE software. This software has one distinct advantage over its EAGLE counterpart and that is the fact that it can implement simulation as well. This would allow for simulated testing of the device in schematic stage which could help to avoid errors in the design or layout going undetected before fabrication. Ultimately, this software is expensive, and has more features than is strictly necessary for the full design and implementation of the Pool-AID.

EasyEDA

This is a PCB design software that allows for schematic capture and PCB design. It has its own internal part database of over 1 million components and is continuously updated. It allows for creation of custom libraries used for design, links directly to PCB creation with an auto routing, 3D viewing portal, and dimensional checks. This software can be used as a base version completely free. The functionality of this software is similar to EAGLE however it does have the advantage of a more human readable interface.

Selection

Each software compared in this section was deemed capable of serving our groups needs in order to design a PCB to have manufactured. The first parameter to compare is the price of each software. Both, the EAGLE and EasyEDA softwares, have free versions available for use. The fusion 360 however must be purchased and was therefore deemed the least favorable software solely based off of the pricing requirements.

This project has a strict cost constraint, and the added cost of PCB design software was not accounted for in that process and therefore fusion 360 must be excluded from consideration. Therefore, the choice comes down to EAGLE and EasyEDA. The EasyEDA has one advantage over EAGLE and that is its readability. The viewable interface creates a more human readable schematic which is useful for our design of the transmitter which will be fairly complex and involve many components. Both having similar functions and being free to use make this a choice that comes down to useability. Since there is a learning curve with any new software, as a group, each of us has experience with designing a PCB using the Autodesk EAGLE software. Therefore, the software being chosen to design the PCB for the Pool-AID will be the EAGLE software. It has the necessary functions of schematic capture, PCB design, and library design necessary to complete this project.

4. Design Constraints and Standard

Pool-AID, like many other projects, is designed to be compliant with ANSI standards and a variety of constraints. Our goal is to provide our users with a device that meets the market requirements and abides by the specifications addressed in existing standards.

4.1 Constraints

Our team will be working against multiple constraints to realize Pool-AID. The following section will cover all the different constraints that have a direct impact on the design. This section includes economic, health, safety, environmental, manufacturability, sustainability, political, ethical, and social constraints. Analyzing these constraints prior to designing and building our product is one of the most important initial steps. Building a functional project off some considered constraints is far more efficient than designing a device and having to alter, change, and limit its operations at the end.

4.1.1 Economic

One of the bigger constraints we are working under is the economic, financial constraint. Having an affordable device was one of the market requirements we wanted to satisfy so that it could be purchased by an average-income household. As discussed in sub-section 3.1, there are multiple technologies on the market that address the same motivation as ours; however, only two of the presented technologies provide the user with the safety mechanism intended for the system to deliver at a relatively affordable price of $200.

The second economic constraint we will be working under, is the budget to fund the project. This design will be funded by all four group members equally. While the device as a whole unit will not exceed $300, we are and will be experimenting with different parts to provide the most efficient system without compromising the overall cost of Pool-AID. As we research the necessary parts for our device, we are exploring all the different components available in the market and comparing their costs to their efficiency level that they would provide us with. It is implied that the more expensive a part is, the better it will make our transmitting system as a whole; however, we only need the transmitting end's performance to be at a certain level. Sometimes having a device handle many different tasks, compromises the initial motivation, which is why we are taking this economic constraint to our advantage and designing a system that will address its purpose.

4.1.2 Health & Safety

Health and safety are constraints that go hand-in-hand with the motivation behind Pool-AID. Pool-AID is a device that will minimize drowning, a safety issue that has the potential to be fatal or impose lifelong health conditions. As our tool is meant to operate in a body of water, the device must be insulated and waterproof with no room for error. Pool-AID will be designed in a careful manner to help prevent any harm or injuries to the user. Its simplicity and user-friendly concept will not put the user in any danger, as long as the device is used and maintained appropriately.

Another health and safety mechanism our design will be sure to implement is regulating the buzzer module's sound level. Our goal is for the alarm to sound at 95 dB continuously. According to the National Institute for Occupational Safety and Health, NIOSH, the recommended limit for continuous exposure is 85 dB to not permanently damage a person's hearing [9]. While that is the case, the alarm will be configured to sound only for a certain period until someone manually or remotely disarms it.

4.1.3 Environmental

The environment in which Pool-AID will operate under is a constraint that affects our design plan heavily. Pool-AID is a device meant to operate in backyard pools where a pool's maintenance is out of the designer's control. On the other hand, we prefer that such a variable does not affect our device's performance. Another important factor to consider is a pool's water flow. When positioning the device in the pool, we do not want the device to drift away alongside a wall in a way where it would reduce its visibility scope.

As seen in section 3, Pool-AID will be solar powered. The ideal environment for our drowning prevention system is a location where the temperature ranges between 59° F to 95° F. The average Florida temperatures ranges from a low of 56.8° F to a high of 82.1° F [10]. This environmental constraint will not limit our design plan as the location meets the solar requirements desired to provide maximum efficiency.

4.1.4 Manufacturability

This type of constraints will emphasize some limitations the group might have during the Pool-AID system development. The components required for the Pool-AID project will need to be evaluated and selected on time. All essential parts for the design need to have high availability on the market and not be the only choice for the implementation. The project is meant to be functional in pools, so we need the project to be waterproof. Some of the components such as the Sonar Sensor are functional underwater; however, they need shielded cables to have this function.

It is difficult to find components that are water resistant, and if there are the cost would be greater for getting those parts; These types of components might not be available in the market, or their availability is limited. We also want to consider the weight and dimensions for the device. The project should be kept as small as possible, so the components should be small for building a compact and transportable design. In terms of availability, many of the components have already been ordered, but further testing should be made in order to decide whether the parts selected help us meet the requirements specification. Once testing is finished, we need to make sure that components to be replaced are available from the manufacturer or third parties and if shipping is short, so the design development is not affected. Some of the constraints we might encounter is make the system fault tolerant.

The false alarm rate should be minimal, and accuracy should be preserved when identifying a person drowning. There is no measurement, that we have considered, to identify when a person is drowning; further study of the issue must be completed to continue with the development of the system without having to change major things to the design.

4.1.5 Sustainability

When it comes to sustainability there are several factors that need to be considered. First, is the overall lifecycle of the product. The desired life cycle for this product is a minimum of one year. In order to achieve this level of longevity the product must be able to withstand several environmental factors that will pose as sustainability constraints. As this is a floating device, it would encounter both water and potentially intense heat depending on where it is deployed. Therefore, in order to be sustainable, the housing for the product needs to be fully waterproof with little risk of degradation to its housing over the course of its intended life cycle.

Furthermore, it needs to be resistant to any heat or wind damage that could affect either the housing or sensors inside. Additionally, as the device houses several individual components each part must be capable of lasting a full year while still accurately performing its functions. If even one sensor were to malfunction within the first year the entire system might not be able to perform its functions as adequately as intended to the customer.

The final sustainability constraint to consider is the business longevity of this product. There are roughly 10.4 million residential pools in the United States alone, and about 4 million babies born each year in the U.S. As this product will be targeted towards an audience filling these criteria, there is no foreseeable sustainability constraint long term with regards to a decaying customer population. The biggest constraint to sustainability in this regard for the Pool-AID will be based on how well it competes with similar products currently on the market as well as any similar products produced in the future.

4.1.6 Political

It is important as a group that we do not conflict with other’s political beliefs and that our product is not perceived in a way that has a particular political edge or motivation. However, after careful consideration of the various potential conflicts that could arise from the nature of the Pool-AID it has been determined that there are no foreseeable political constraints involved in the research and development of this product.

4.1.7 Ethical

The purpose of the Pool-AID is to help prevent loss of life due to drowning. To this effect special attention will be paid towards using the best tools to create this product. This product will float in the pool so will be in close contact with the individuals using it so nontoxic materials will be researched and used in order to provide the most ethically sound product to consumers as possible. No functions of this product will be cut due to financial constraints if said function is considered critical to the effectiveness of the Pool-AID. Furthermore, extensive research has been done on other products on the market to ensure that no patent infringement or intellectual theft will be conducted during this process.

4.1.8 Testing

As this product is a floating device meant to be employed in a pool ideal testing will need to be done in that environment to ensure proper function of the Pool-AID. As this is a critically important parameter for testing, a family with a pool at their residence has agreed to grant us access to their facilities for the purposes of testing the Pool-AID. This pool has a max depth of 6 feet, length 30 feet and width 15 feet. These parameters are considered typical among residential pools and will be a good indication of Pool-AID functionality under test. However, this does not fully encompass the incredible variety that exists among pool size, shape and depth as well as weather and environmental factors of potential different geographical locations of pools. Allowances will have to be made when testing to account for these differences.

4.1.9 Social

Societal values, ethical and moral, play an important part in the realization of the Pool-AID as these are the core values that determine what is viewed as appropriate for the sensitivity, means, and validity of the mechanisms at play for this device. It is important to meet the criteria imposed by society as a device that does not adhere to these expectations is likely to be regarded as faulty, dangerous, and/or unserviceable. Without a proper understanding of the constraints that are imposed by societal values, a design that is accepted and understood by the general public would be very difficult to create. Therefore, it is of great importance that these societal constraints are understood before the overall design is to be created, in order to achieve a result that is of greater importance and value to the average person in our modern society.

The first of these social ideas that must be addressed is the sensitivity of the device. The usability of the device would be greatly diminished if it was so sensitive that even slight disturbances in the water would trigger the alarm, however it would also be deemed a danger if the device was not sensitive enough to pick up all instances of a drowning person. Palpably, it would be better to have false positives than to miss drowning incidents, but if these false positives are too abundant then the user may deem the device pointless. For these reasons the device needs to have a sensitivity in a reasonable range that adheres to what modern society would expect of a device that is intended to help detect events of potential drowning. Calibration of this expected sensitivity range can be done through abundant testing on what seems to be of acceptable tolerance when dealing with a situation as sensitive as this. Another important aspect of societal perception to consider is the means by which the system exists. Ideally, the device should not be of significant notice until it is needed, otherwise the device may get in the way of regular pool activities or be invasive to the way that people want to use the pool. For this reason, it is important not to overstep the bounds of what is needed to create a succinct and useful device, as a device that is too large or invasive may be perceived in a negative light due to its overall form factor. With careful consideration for the design, a form factor that allows for regular activities should be achievable while also still have the functionality to appropriately detect the necessary criteria.

The final important aspect that needs to be considered societally covered in this document is the perceived validity of the device. Users must be confident in the ability of the device so that they can trust it with someone's life. Of course, the device should not be used as an absolute stand-in for proper pool supervision, but the user should at least have confidence that the device can properly alert them to any possible issues that may arise when someone is near the pool. If the user cannot be confident in the device's ability, then they are likely not to use it as a possible option for increasing pool safety measures. For these reasons it is very important to create a system that is reliable and, importantly, verifiable. There should be clear, measurable goals for the device that can be used to allow for an increased confidence in the user that the Pool-AID is capable of performing the actions that it claims to do. With all of these societal constraints in mind, it should be possible to create a device that fully adheres to the expectations that are anticipated for a device that is centered around creating an increased safety measure.

4.2 Standards

In this section, we will discuss some important standards that are related to our Pool-AID system. The standards listed below are provided by organizations such as IEEE Standards Association, for the Wireless fidelity standards, and National Electrical Manufacturers Association (NEMA), for the Occupancy motion sensors standards. Standards are essential for every project to guarantee the safety and reliability of a product. Some other standards such as Programming languages standards need to be defined for the software aspects of our design for syntax and portability. Our design will also count with communication standards so the system would be able to communicate with other devices and transfer data using communication protocols.

4.2.1 IEEE 802.11 Standards

Our design will be able to communicate with a secure sever on the cloud to transfer over the microcontroller the data collected such as the images collected by the camera module and readings from the sensors. The Node MCU which works with the ESP8266 will allows us to communicate with the server using wireless communication. The Institute of Electrical and Electronics Engineers Standard association (IEEE SA) counts with wireless fidelity (WI-FI) standards known as the IEEE 802.11 for wireless local area networks (WLAN/LAN). There are different types of 802.11x standards which are listed in table 12 below, which depending on the wireless device there is a different standard. We will mention some of the different types of IEEE 802.11.

802.11a

This WI-FI standard was released in 1999 and it is also known as WI-FI 2. It operates with a frequency band of 5GHz for less interference and maximum data rate of 54 Mbps. The high frequency band allows more channels, and it is faster than other standards that operates at 2.4GHz. However, there is a tradeoff on speed over range on this standard. Additionally, since the operation band is the highest, it also increases the price of products, and that's why is recommended more for business applications.

802.11b

This standard was being developed at about the same time as the 802.11a. In contrast to the previous standard, it operates at a frequency band of 2.4GHz, and its maximum rates is 11Mbps which is much slower than the previously mentioned one. A long range of about 150 feet can be achieve on devices that support 802.11b. Another advantage of the 2.4GHz band is cost; products that support this standard are much cheaper than those using WI-FI 2. An example is the ESP8266 module which supports this type of standard and other 2. Interference might be an issue when there are devices operating at the same frequency of 2.4GHz such as Bluetooth Devices, Microwaves, baby monitors, so it is recommended not having such devices near the system being in used.

802.11n

The standard is also known as Wireless-N or WI-FI 4, and it was developed in 2009. It differs from the previously mentioned standards since it can operate at two radio frequencies of 2.4GHz and 5 GHz and has a data rate up to 600 Mbps. This was the first time 802.11 standards used Multiple input Multiple Output technology (MIMO) for fast data transmission over multiple antennas from one device at a time. The range for wireless transmission reaches approximately up to 230 feet indoors. The ESP8266 WI-FI module also supports this 802.11 standard.

802.11g

Its development was earlier than the 802.11n standards; it was released in 2003. It improved some characteristics from the 802.11b standard; operating at the same frequency band of 2.4 GHz, but a major increase on data rate up to 54 Mbps (similar to 802.11a). A previous constraint about the 802.11b was that it didn't have backwards compatibility with the 802.11a; however, the 802.11g standards does count with backward compatibility the 802.11b. This advantage over previous standards became a requirement to allow access points and computers with an older standard to connect with 802.11g access points. There is a cost in data rate due to the backward compatibility since transmission will be reduced to the 802.11b 11 Mbps rate. This standard is also supported on the ESP8266 WI-FI which will be used for the system.

802.11ac

The standard was developed in 2013, and it has a name abbreviation of WI-FI 5 or Gigabit WI-FI. Its development was meant to improve speed of WLAN and link speed with smart devices. The operating band is 5 GHz to reduce interference. Products such as common routers met this standard, and they are presented with dual band; reason why devices operating under 802.11ac standards are capable of transmit data with a 2.4 GHz band. However, the data transmission rate will differ depending on the frequency band in used.

A 2.4 GHz band will achieve a maximum rate of 450 Mbps, and 1300 Mbps if the 5 GHz band is used. This standard was the first from the family to allow data transmission to multiple wireless devices concurrently for bandwidth speed improvement and low latency using a technology called Downlink Multi-User MIMO. Since Wireless-N technology was implemented, 802.11ac is compatible with previous standards mentioned above.

802.11ax

It is the most recent WI-FI standard developed in 2019. This improves and adds new features compared to the 802.11ac standards, for faster speed, connectivity with multiple devices, low latency, and improvement of bandwidth. It also improves used of band when congestion occurs at places with a lot of people using WI-FI. It can operate at two frequency bands, 2.4 GHz, and 5 GHz, as 802.11n and a maximum data rate of 10 Gbps. The standard has an extension that will make devices under this standard operate at a 6 GHz band.

	802.11a	**802.11b**	**802.11n**	**802.11g**	**802.11ac**	**802.11ax**
Frequency Band	5GHz	2.4GHz	2.4GHz - 5GHz	2.4GHz	5GHz	2.4GHz - 5GHz
Data rate	54 Mbps	11 Mbps	600 Mbps	54 Mbps	6.8 Gbps	10 Gbps
Backward Compatibility	NA	NA	802.11a/b/g	802.11b	802.11a/n	802.11a/b/g/n/ac
Bandwidth	20 MHz	20 MHz	20/40 MHz	20 MHz	20/40/80/160 MHz	20/40/80/160 MHz
Modulation	OFDM	DSSS/CCK	OFMD	OFMD	OFMD	OFMD/OFMDA

Table 14 - IEEE 802.11 Standard

4.2.2 Programming Languages Standards

For any application or software product that requires a specific programming language follows a set of standards to maintain portability and standards syntax, so after every edition of the standards there is no conflict between updates or maintainability of source code. Our project will require use of high programming languages such as C or C++ for programming the microcontroller, and JavaScript frameworks for designing the mobile application. The programming languages mentioned follow some standards specified by important standards organizations such as ECMA, ANSI, and ISO. The standards included in this section are ECMA-262, and ANSI C Standard known as ISO/IEC 9899.

4.2.2.1 ECMA-262 (ECMAScript)

ECMAScript is the core of script languages such as JavaScript and TypeScript. The organization known as Netscape, which created JavaScript, presented the language created by Brendan Eich to ECMA international, and JavaScript was standardized as ECMA-262. There are many editions of this standards, between the most recognized editions of the standard we find ECMAScript 3, 5, 6, and 7. It is also important to know that after the 6th edition, there no major changes compared to ES6.

ECMAScript 3

This was the third edition of ECMA-262, and it was developed in 1999. It is compatible with current web browsers, but no longer used by developers. What this edition brought to ECMAScript brought was control statements, try/catch exception handling, regular expressions, better string handling, error definition, formatting for numeric output. It was published in 2002 as ISO/IEC 16262. This is an old edition of the standard, so it'll be uncommon to see a developer using it currently. However, it is still compatible with future editions.

ECMAScript 5

This was actually the next edition of ECMA-262 since the 4th edition was reserved and not released to the public. It was released in December of 2009, and it brought some new features compared to the 3rd edition. These features were support of JSON object encoding, object inspections, program control for property attributes, array manipulation functions, and a strict mode for program security and error checking. There was an extension denoted as Edition 5.1, but this one only included minor correction from the fifth edition.

ECMAScript 6

This edition was the big major change of the ECMA-262 standard. It was released in June 2015, but its development started during the publication of the 5th edition. It included features such as modules and class implementation, arrow functions, template strings, object features such as restructuring, the notation for variables added const and let, promises, new APIs, and array iterators such as forEach, map, and filter. This is the most used in frameworks such as React and Node, and after this edition the rest were just extensions of the same one.

Currently there are new editions of the ECMA-262 standards, until edition 12th, but none of them present novel features compared to ES6 or ES7. For building the application for the Pool-AID system, the JavaScript Framework will follow the standards of the 7th edition. Even though there are no big changes from ES6 to ES7, the 7th edition offers async/await functions that are really useful for fetching data when using APIs such as AJAX or AXIOS.

4.2.2.2 ISO/IEC 9899 (Programming languages C standard)

The ISO/IEC 9889 are Programming languages standards that "specifies the representation" of C language in programs. Some of the specifications of this standard are syntax and constraints of the C language, representation of C, input, and output representation in C of data being processed, but it doesn't specify mechanism for data processing in C programs, restrictions and limits imposed by a C program. The standard is composed on seven clauses. The first 4 clauses specify preliminary elements;

characteristics of environments for execution and translation are specified in clause 5. Clause 6 talks about syntax, constraints, and semantics of the language; this one includes some concepts data types, scopes and linkages of identifiers, conversions using Boolean and arithmetic operands, expressions, and declarations. The last clause brings library facilities; all definitions of the .h files we include in our C programs are explained in this clause. The C program we will use for the Pool-AID system will reflect the specifications of the standard; the syntax of the program will follow the rules specified in clause 6.

4.2.3 Software Testing Standards (ISO/IEC/IEEE 29119)

ISO/IEC/IEEE 29119 standards is a 5-part set of standards for software testing which is an essential element within the software development lifecycle. This set of standards are "internationally agreed" for any software testing performed by an organization. Each part of the standard is defined as ISO/IEC/IEEE 29119-x (x can be 1,2,3,4,5). It was released in 2013, but it wasn't until 2015 and 2016 where parts 4 and part 5 were released. Since part 3 relates on building templates and documentation on part 2, and part 5 is related to keyword-driven testing for test automation and reliability test, we will focus on the other 3 parts of the standard which have more details regarding software testing.

Part 1

The first part of the set of standards is related to some concepts and definitions of software testing. Understanding the concepts of software testing is important since it will allow us to evaluate the design during the development and gather information regarding the performance of the product. Testing should be performed constantly to see what changes on the software should be made in order to make the system work properly and identify malfunctions on time.

For our project, there will be constant testing regarding the software designed to work on the microcontroller to see if the device is operating correctly and depending on the results from the first testing decisions will be made and prepare the software with the corresponding changes for a new test. In addition, something similar can be applied for our mobile application. For web and mobile applications there is a term called unit testing, which refers to evaluating the codebase for identifying edge cause that can trigger unpredictable failures and result in a bad user experience. Before deploying any application, some unit testing must be made during the development to each individual component on the program, in different systems, and evaluate the behavior of it.

Part 2

This part of the standards is related to test process. ISO/IEC/IEEE 29119-2 refers to what procedures are considered for software testing. There are 3 levels of software testing defined in this standard; the is software testing at the organizational level, test management level, and dynamic test levels. The organizational level of software testing refers to testing policies and strategies defined by the organization; in this case the organization would be the group. The second level of software testing is test management; this one talk more about what are testing plan, correctness, related to monitoring and control process, and completion. Test plans is defined in the management level as the processes that will be implemented during testing such as system, acceptance, and performance. After the testing plan comes the monitoring and control processes; these ones usually change the original test plan after some results that were not prevented were shown during monitoring, and some correctness must be applied. Some activities the group must consider for implementing the test plan are obtain measures and evaluate them for correctness, implements all necessary processes stated on the test plan, and report results to modify the test plan when necessary.

The last stage of testing process is completion; this is also known as a verification test when all previous activities were performed, and system and performance testing was conducted to reflect satisfactory results. The third and last level of the test process is the dynamic test. It is related to testing at a specific test, and one example could be the previously mentioned unit testing. There are four types of testing at this level which are test design and implementation, test set-up environment and maintenance, test execution and incident reporting. This level is reached once the results are reported and completion test was already performed.

Part 4

The fourth part of the standard is known as test techniques. This part works with part 2 since it specifies all testing techniques applied in ISO/IEC/IEEE 29119-2. This part of the standards is important for those group members involved in the software implantation and management. Testing techniques are classified as specification-based techniques, structure-based techniques, and experience-based.

Test basis such as user needs, and requirements specifications are essential information to design test cases for specification-based testing. Similar to the previous one, structured-based testing develops test cases based on code and software model structure. For the last classification of testing will depend on testers skills. In Experience-based testing, testers utilize techniques such as error guessing to identify potential errors in software. This last one will be important when we get to the test the mobile application before its deployment, since prior knowledge will be used to identify possible bugs or malfunctions on the app.

4.2.4 NEMA Occupancy Motion Sensor Standards

The National Electrical Manufacturers association has developed a standard that incorporates the family of all occupancy motion sensors. Two sensor our product will use, the passive infrared and ultrasonic sensors fall into this category. One of the most important aspects this standard covers is the required field of view of sensors.

The requisite dimension to be considered as following this standard are to include mounting height, maximum horizontal coverage area, dimensions of coverage area, and surface material. Following this, are requirements for the testing environment. This is strictly regulated however, for our product to work additional testing must be done. This standard requires indoor testing which can be accomplished but to ensure full functionality of the Pool-AID outdoor testing must also be completed.

4.2.5 IPC PCB Standard 2221

The Institute of Printed Circuits provides many general as well as specific standards related to printed circuit board design. Within these standards is the 2221 which is a general standard for the design of Printed Circuit Boards. This standard outlines many design requirements such as general requirements, electrical properties, material properties. The standards outlined in this document are concerned with defining parameters that affect the lifecycle, performance, cost, and safety of the PCB design.

For example, the general requirements section shows a tradeoff diagram listing parameters such as via diameter, line width, line spacing, via wall spacing and several more factors which can either improve or degrade the performance functionality of the PCB. Using a manufacturer that follows these standards can help to ensure a superior PCB is crafted for the Pool-AID. In general, these standards should be followed as they outline requirements that will ultimately lead to a higher performance safer and longer lasting PCB design implementation for the Pool-AID.

4.2.6 IPC-J-STD-001G Soldering Standards

Some electronic components that we ordered and the PCB we will develop requires or will require soldering. Components such as the sonar sensor, boost converter, and battery charger have some mounting holes to solder pins or wires. The techniques we will use for soldering are represented in the IPC-J-STD-001G Soldering Standards. The purpose of this standard is to prescribe material, process, and acceptability requirements. This standard is similar to IPC-A-610 standards since both represent processes for soldering. Following this standard, we can ensure quality and reliability of the product.

There are several requirements [46] that are included within the standards. Prevent any contamination of materials, tools, and surfaces by keeping the soldering as clean as possible, keep cooling and heating rates as the manufacture specifies, wires should be in good shape, any defect or bad soldering has to be reworked or adjusted. Some of these requirements were already applied for soldering some components such as the sonar sensor. We make sure the area where the pins were soldered to be clean to avoid any contamination to the component. We used a descent temperature for the soldering iron that won't damage the sensor. As this was the first time the group was exposed to soldering components, the soldering was not clean or fully covered the pad, but we made some adjustments to the soldering to cover the full pad. The requirements specified in the standards would be used in the future when we get to design our PCB when we get to solder the components into the board.

4.2.6 IPC-7351 Footprint Design Standards

It will be important for our PCB footprint design to count with the right mounting space for adding components to it. Along with the soldering standards mentioned above, we will take into consideration the IPC-7351 standards which will provide information about what the size of the mounting surface should be to be able to mount the needed components that allows us to test, inspect, and rework of soldering [44].

Some requirements to consider meeting the standards requirement are using standard package specifications with specifications that are good for manufacturing, follow the dimension and tolerance guidelines specified by the document unless these ones don't match with the manufacturers, provide testing points, and have enough space for any rework. There are more design requirements specified on the IPC standard's document that we could follow based on how and what footprint we want the PCB to have.

5. Design

In section 3 of this document, parts and existing technologies were researched thoroughly to design Pool-AID as efficiently as possible. In this section, we will discuss the overall design plan, the parts that we have chosen for our design, and the parts acquired and tested.

5.1 Hardware Design

Pool-AID is a device that uses multiple sensors to determine and detect a person in distress. The goal of our design is to be able to relay that information given a set of thresholds for each sensor. The goal is to minimize the alarm's fault rate for nonliving items that fall in the body of water, so the use of multiple sensors is necessary for the system to come to a certain conclusion from multiple sensor inputs.

The passive-infrared and sonar sensor will both be connected to the controller and will continuously send any acquired data from the activity in their detection radius. Based on the received data from these sensors, the controller will have some decisions to make. If the acquired data matches with the configured thresholds, the controller will trigger the receiving module's alarm using a Tx Rx wireless module.

The controller will also have direct access to the camera module, which will not be sending any crucial data to the controller. It will only be sending the video or pictures taken. To be more concise, the controller will not be making any decision from the data sent by the camera module. The camera will only be used so that the user has access to the kind of activity that happened in their pool, and in the case of an accident, some raw footage of what led to the event. That footage will be sent over the Wi-Fi module to the mobile application where it will be saved and accessible.

On the receiving end of the hardware, the buzzer module will be connected to the controller. It will have a battery power supply to allow the user to use it inside their home without the use of solar panels like the transmitting unit. The receiver module will operate under minimal power consumption as it only has one task. The Rx module will be acquiring the data from the Tx module attached on the main hardware unit, decoding it, and setting the alarm accordingly.

The Wi-Fi module on the main unit will be used to connect the main transmitter controller unit to the software interface of Pool-AID. It will be the module that enables the device to communicate with the mobile application and has access to the camera module. That is, the user will be able to access data packages sent over by the camera through the app.

5.1.1 Overall Design plan

Pool-AID will be a two-part device that consists of a transmitter and receiver. The transmitter will be the central part of the device and will have all the sensors and other modules embedded within it. The receiver part of the device will only consist of the buzzer module and a power supply. The two parts will be connected wirelessly, to allow the alarm to be closer to the user but still close enough to the pool so that the person in distress knows that the adults have been alerted. The software portion of Pool-AID accounts for the making the device a user-friendly and smart device that one can interact with. The mobile interface of the device will provide the user with access to data and device settings to address the feasibility requirement desired by the client. The plan is to insulate and waterproof Pool-AID without compromising its weight and allowing it to float. The exterior will be a sphere-like shape with solar cells attached to the upper half *(subject to change)* of the device as shown on **Figure 6.** Note that the following figure is just an initial design idea, the team will provide more details when a final design draft has been prototyped.

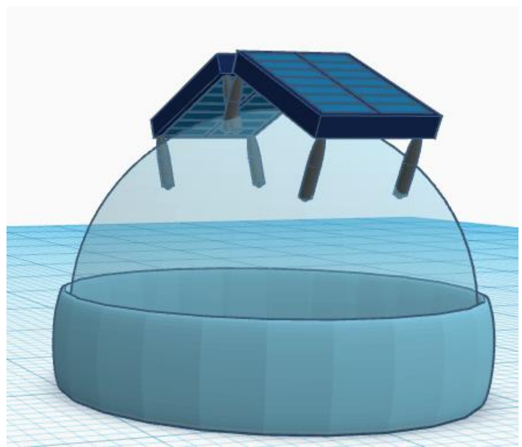

Figure 6 – Pool-AID Exterior Design

The system's internal architecture is still being planned out and designed as we want to be able to maximize the radius that the camera and sonar sensor will be able to record and detect at any given instance. We want to minimize the blind spots of the device without the need of purchasing additional sensors or parts to cover the given area.

One way we plan on approaching the physical layout of our device in terms of the sensor positions is shown in figure 7 below. With 360º of surface to secure, we need two back-to-back PIR sensors with as little distance between their backs as possible to limit the blindside margin. With these two motion sensors we can guarantee that the ground-level surface of the pool is guarded.

To minimize the fault-rate, we need a second step to confirm that a child is indeed in danger underwater. The best way to implement this check has to be underwater. Since there must be motion on the ground-level before there is any motion underwater, we can use this thought to our advantage and activate the sonar sensors only when prompted by the motion sensor. The use of multiple sonar sensors is necessary as they only have a 60º detection radius. The design below only uses four as they are relatively expensive for $30 a part. If we do use four, we would provide coverage to 66% of the pool underwater. From a statistical point of view, if we allow a blindside angle of 40º between the 4 sensors, we would not be compromising the system's reliability since any child submerged in water would move and enter the detection scope of at least one of the sonar sensors.

The ring surrounding the circumference of the sphere will be the weight necessary to maintain a perfectly balanced semi-sphere on the pool surface. It will also make sure the sonar sensors are detecting objects strictly underwater and not on the surface water level.

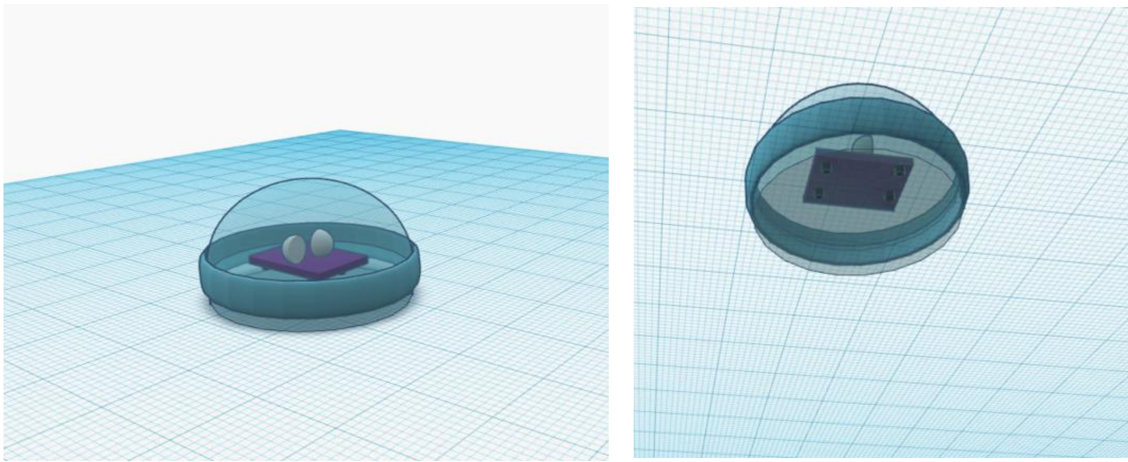

Figure 7 – Design Plan

Usage & Placement

Pool-AID is a device that will provide parents with easily accessible pools a security system that alerts them any time their child is near the pool and triggers an alarm once activity has been sensed underwater in the same time frame. Pool-AID will come with two units: the receiver and the transmitter. The transmitter will be the sphere-like looking figure, while the receiver will look like a classic alarm in a rectangular container (shown in the figure below as **(R)** and **(T)**).

The transmitter should be set in a standard-sized pool, or the area closest to the nearest exit point of the house. Note that the transmitter is waterproof and is able to float. To keep it in place and have easy access to it when necessary, we will have a transparent string attached to the thick ring around the unit. The positioning of the receiver is the more important of the two placements. We want the receiver to be closer to the home but not too far from the pool. The reason for that is we want the adult inside the home to hear the alarm when it sounds. The closer we have it to the indoor space, the more likely they are to respond to the activity. Allowing the receiver to be between both locations will allow our receiver to also capture the activity on camera. In essence, the user would want to position the receiver so that the camera captures the entirety of the pool in its frame.

The figure below highlights the thought process of the device. Assuming Pool-AID has been installed as recommended, it should work in the following manner.

A. A toddler [] finds the perfect time to go touch the water while his mom is busy cooking and dad is helping the other kids with their homework.

B. The toddler gets closer to the pool, in the range of the motion sensor.

C. The motion sensor communicates that information over to two items:

a. Sends a message to the sonar sensor on the same unit (**T**).

i. If the sonar sensor does not detect any object underwater within 60 seconds upon receiving data from the PIR sensor, the system goes back to idle.

ii. If the sonar sensor detects the object, it immediately sends a signal to the receiver which:

1. Sounds the buzzer.
2. Activates the camera and starts recording the activity.

b. Sends a message to the receiver (**R**).

i. The receiver activates the camera and starts recording the activity for 30 seconds.

ii. If the receiver receives a data from the sonar sensor, it follows step C→ a→i described above.

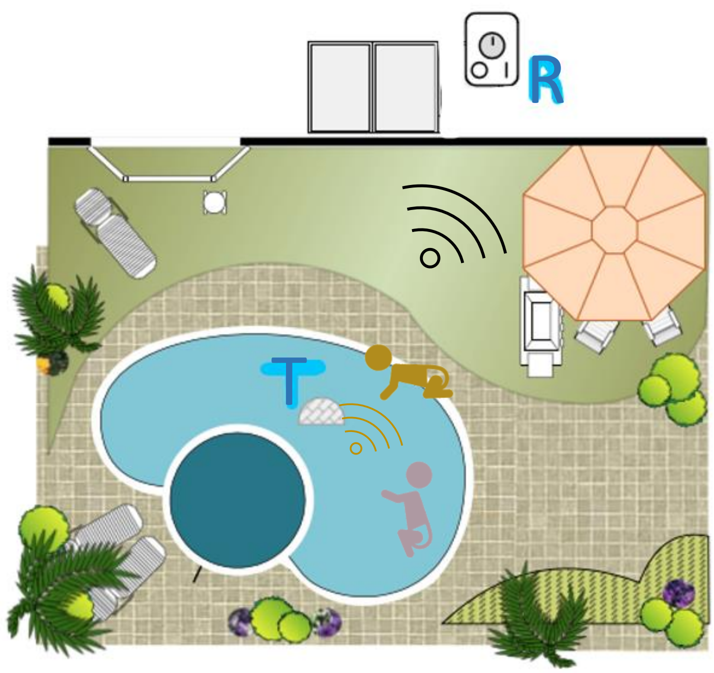

Figure 8 – Placement of Pool-AID

With a system that depends on the agreement of two sensors that function differently and independently from one another, we are decreasing the false-alarm rate. The Pool-AID functionalities will not be limited to work only under these settings. The scenario above presents the most generic situation in which drowning accidents have resembled in the past and puts our device in that setting to visualize how helpful it can be in preventing such tragedies from happening.

As mentioned above, Pool-AID will have multiple different scenarios implemented within the system's memory. In the case where the PIR sensor and sonar sensors keep miscommunicating in a certain time window, we will compromise the system's integrity and just override the receiver to sound the alarm regardless of the two sensors struggling to confirm the activity. While the probability of this happening is minimal, there can always be exceptions.

It is better for us to train our system to react a certain way if such thing happens rather than just ignore the activity and go back to being idle. We prefer that the tool is able to communicate something unusual is happening around the pool and, at that point, have a human do the check manually after being alerted. Prioritizing the safety of others is more important than keeping our device disarmed when it could possibly be preventing the incident from happening.

5.1.2 Acquired parts

As the end of the first half of Senior Design is nearing, our team has started acquiring and testing parts. Testing will be covered in detail in a later section of the document, more precisely, in section 6. The following table shows the parts acquired up to this point.

Part Label	Part Identification
1	Sunyima Solar Cells
2	Arduino Uno R3 (ATmega328P chip)
3	LP653042 3.7 V Battery
4	Piezoelectric Buzzer
5	LV-MaxSonar-EZ MB1010
6	Wi-Fi Module ESP8266

Table 15 - Parts Acquired

5.2 Software Design

The user will count with a friendly user interface to communicate with the Pool-AID Device using his/her phone. Software will not only be constructed for the mobile application, but also for the system itself. The system should be programmed in order to collect data from the modules and sensors implemented and perform some tasks related to the data such as processing and transmission. The outline of how the software for the system will be designed is listed as communication, database design, Web service, and mobile application development. The research about which are potential technologies we can use for the software design were made on section 3.3, so know we will discuss about the proposed selection and how it will be implemented. For further understanding visual representation of how the software will work with the system, a small block diagram was constructed in section 2.6.2 to relate all the components from the software design. The description about the software design will include the software implementation working from the user-end, and what features will the mobile application have to obtain and monitor the systems and environments status. Additionally, the implementation of software for the system such as communication will be discussed.

5.2.1 Communication

The unstructured data such as sensor's readings and images will be first processed by the main microcontroller from the system and then sent to a secure server on the cloud to not have storage limitations. Using WI-FI, the microcontroller will be able to communicate with the cloud server, and send data using a WI-FI module, such as the ESP8266. WI-FI is reliable when sending data to devices connected through the same networks and being able to transmit data from long range. This is beneficial when the user wants to monitor the device when he/she is not near the area. Additionally, some communication protocols will be used to send data obtained directly from the sensors and modules to the microcontroller; directly means that the microcontroller connection with the different modules will be wired. These protocols can be UART, I2C, and SPI. For more efficiency of the system, we will try to keep synchronous communication.

5.2.2 Database

For the database design, the team have decided to go with a NoSQL database. The decision was taken since the data obtained from the system, such as sensor readings and image objects, are presented in non-structured fashion. In this section we will discuss what data will be stored in the cloud database that will be displayed in the mobile application. As mentioned in subsection 3.3.1 related to the user interface design, the application will count with an authentication factor to keep the data stored on the system private and secured. One section of the database will be dedicated to storing those users with access to the application that registers using their mail and an assigned password. The security rules for authentication will be set first to test mode for the alpha version of the app for the team to test if users can be authenticated correctly and access data properly; however, on the beta version of the applications will be changed to locked mode, so only registered users can access private data.

After the authentication of the registered users, we will design the database that will hold the data captured by the system. Cloud firestore uses collections instead of tables since data is unstructured, so a collection is created for the alarm triggers. The first field that will be added to our collection is the time the alarm was triggered. In firestore, there is an option to create a timestamp object which takes the date and the exact time the data was inserted to the collection in the database. If the alarm is triggered on a Monday at noon, the capture time field will now include the current date, such as December 15, 2021, and the hour the data was added, 12:00:00 PM. The second field of the database will now include the image captured that was sent to firebase from the camera module. The original design mentions that the images captured by the camera module will be sent to a cloud server that will store the picture to a bucket storage. This bucket storage containing the picture has a link in a string format. This means that the image field in our collection will be of type string, and the string will correspond to the link of the bucket storage that contains the picture. A third field will be included to store the ID of the owner of the Pool-AID system. When a user was created using authentication, an ID for that user is generated; this ID is used to know to whom this data regards to. This helps in keeping the data secured since only the users that purchased the device will be able to login and access the data. The last field to include in our collection is the device ID. There might be many users that will be connected to the same device, so the data will be sent to a group of people who own the device instead of a single person. This field will be important since not all Pool-AID systems will have the same ID, so in order to increase security and reliability of the system a group of people will be associated with the device ID, so the database documents which are the users who connected to this device. The database will only serve as the main resource for storing the data that will be sent to the mobile application. As many other cloud services some policies might be changed to keep the data stored as long as the user decides to have it.

5.2.3 User Interface of the App

5.2.3.1 Design plan

We want the Pool-AID application to enhance the way our user interacts with the device. The goal of the application is to provide access to the activity captured by the camera and time-stamped logs. The stretch-goal of developing this app is to integrate a series of settings to remotely disarm the alarm, authenticate users, and accessing the live-feed of the camera. The application will be built simply for the user's convenience and will not affect the performance of the system in any way in case of failure. The figure below highlights the navigation between the different pages of the mobile app. The home page will show the most recent activity detected by the sensors. It will also show the status of the connection established with the device and have options for the user to save the data on their device.

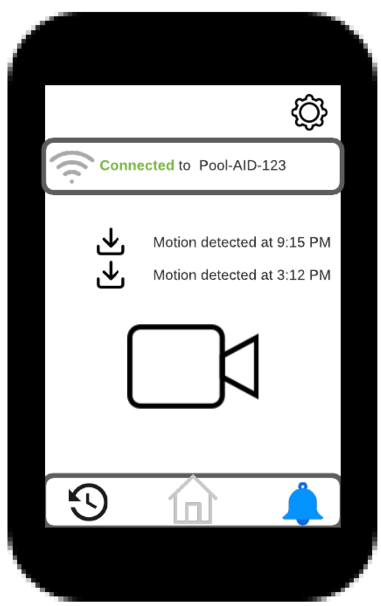

Figure 9 – Home Page of App

5.2.3.2 Design Implementation

In this section we will discuss about the design implementation, and some features our Pool-AID mobile application would have. The user interface of the mobile application will be developed with React Native. Some of the group members have experience and understands React, so we decided to go with what we already know than learning how to use flutter from scratch.

For simplicity of the project each component will be built separate from the main app file, so we can just mount each component and pass the needed props easily than having a single file where everything is built there. We are going to follow a structure similar to Reacts component lifecycle methods, to update the child components when some changes are made by some event occurring in the parent component. It was mentioned previously that the mobile application will need to have some communication with the database, so the data can be acquired from the database and be displayed on the mobile application. If our selection from the database is Firestore, there will be some component from the application that acts as a bucket storage to store the pictures taken by the camera module from the system.

Every time a notification pops up, the application should open directly to the storage component from the application and display the picture sent. The user can decide whether to delete or just keep the data in both the application and the database. If MongoDB is used as the database, data can be deleted or added in both places depending on the events that occur on the user-end. MERN stack offers some functions that can be applied to delete the data from both sides the database and user interface using Express for API request.

Another features the mobile application will count with is the system control option. This feature allows the user to communicate with the system itself, to either monitor the camera or turn off the device when there is a false alarm of the system. For the design of the application, pure CSS can be used or even styled components for the application to look professional and responsive to any type of screen. The main screen of the applications will include some widgets that will be beneficial for the user to navigate through the apps features and make it user friendly.

App development stages

Alpha version:

Before giving access to the mobile application to a selected group of people, the group will develop an alpha version which will be used for testing purposes described in the section reserved for software testing. This version will only contain the necessary widgets and use terminologies only the group members will understand. No authentication will be needed for the first alpha version since we want all members to have access. For each update of the application, we will set some goals and requirements for development and testing.

- The application should have a small loading time less than 3 seconds
- All features should appear on the screen regardless of the screen size of the device

- Check if connectivity with the Pool-AID system was successful
- Store data manually to the database and check if the data requested shows on the app (this can be done even when the device development is at early stage)
- Data should be maintained after exiting the application

If some bugs are found during the first version of the alpha, we will document the errors and make an update to the alpha version with the bugs fixed. There might be many versions of the alpha before passing to the beta version of the app. The purpose of the alpha versions is for the team to test and fix all possible bugs before the app is tested by a user interested in the device.

Beta version

After the last revision of the alpha version of the mobile application, the user interface will be redesigned and tested by users interested in acquiring the Pool-AID system. Compared to the alpha version, the beta will now contain the authentication factor mentioned in subsection 5.2.2 for security testing. The purpose of launching the beta version to a designated number of users is to get feedback about the following inquiries.

- How was your experience using the applications?
- Did you have any issues trying to create an account and login?
- Is navigation through the application smooth?
- Is there any feature you would like to see in a future update?
- Did the application provide a good experience to the users with a friendly UI?

The beta will be close to how the final version of the application will look like and function. It will be developed once the last version of the alpha is completed, and it won't have as many updates as the alpha version since this beta will serve more about adjusting the application based on feedback provided by the users that were given the alpha version. For testing the beta, the Pool-AID device needs to be at a late stage of its development since we will need to capture actual data from the system and display it in the application. This last part would have been considered previously on the latest alpha version, but now we will also be able to test it with a re-design user interface.

5.2.4 Receiver-End Software Design

The microcontroller we will use to manage all hardware components from the Pool-AID system needs to be programmed using the IDE we selected to perform all tasks that were explained in the hardware design section. The code will require a specific function for each task the system will perform. The device will only be active when movement within the pool is detected, so we can have a section for the PIR sensor called movementDetected() that will only read the sensor input pin, so when it is high it should make other verifications. Since the system will count with 2-step verification to confirm when a child is in danger within the pool; a function should be defined that checks whether the alarm should be triggered or not. Using a function called twoStepVerified() we can check if both the PIR sensor and Sonar sensor are getting some relevant data to trigger the alarm when necessary. The movementDetected() function will program a timer to keep the device active and waiting for the sonar sensor to detect something. Another important section in the software implemented on the board is the communication to the WI-FI module, which will also have its own program. Using the previous two functions, the microcontroller will write the data over serial communication to tell the WI-FI module that it has captured data. Once the data is sent from the microcontroller to the WI-FI module. The microcontroller will also control the camera module and store the image. What we just discussed is the software design that will be implemented for the ATmega328P. The last part of the receiver includes the WI-FI module software design that we will use to send the picture to the database we want. Most IOT cloud services require an API for establishing connection to them. Arduino IDE can use external libraries for services such as AWS or Firebase. If we are using firebase as the cloud service, the external library for firebase must be added. In addition, we will use the Arduino JSON library, so the format of the data collected as a JSON. For every application using Firebase we need to include a HOST and an AUTH key to know to which server we are connecting to. The ESP8266 requires a hotspot to be connected, so once the hotspot is set up with the right frequency band, the SSID and PASSWORD are set. Once the signal that will tell the ESP8266 to send the image to the cloud is received, the program will make a sentToFirebase(), to send the JSON objects with the values explained in subsection 5.2.2. If the image was sent correctly, our serial communication terminal should display “data sent”; otherwise, a failed function will be called instead, meaning that the data was not sent correctly. The receiver software design is not as complicated as the transmitter, but still requires more external libraries to send data over WI-FI to the cloud.

6. Testing and Prototype

Testing and prototyping is an important practice to ensure the quality of the system and that all members of the team have a good understanding of the subsystems and components at hand. Before prototyping can begin proper, suitable testing must be performed for each component that is intended to be used in the overall system. Once testing has been performed to assure quality and understanding, prototyping can begin by designing and integrating all of the components and subsystems to create a product that expectantly shall represent the general functionality of the intended final product. These processes will take a lot of time and effort and attention should be given aptly to them to ensure accuracy and functionality are of a high standard and quality that can be considered appropriate for the given scenario.

6.1 Overall Integration

Integration is the process by which all of the components and subsystems may come together and start to create a general prototype that can perform the base operating principles that are to be present in the final design. Integration requires having a proper understanding of how all data lines and power-based systems will come together to allow the overall system to perform the more complex tasks that it will be allocated with.

These data lines and power-based systems can be understood by utilizing the block diagrams discussed in section 2.6 and applying the concepts learned from the testing phase of development. In the case of the Pool-AID the data that will be necessary to transfer is the RS232 formatted serial output of the ultrasonic sensor, the analog output of the passive infrared sensor, and digital data steams necessary for the camera and Wi-Fi modules. In terms of the power-based systems that will be necessary for the integration of the overall system, there is the variable voltage power input of the solar panels, the constant voltage of the battery, and the constant voltage that is outputted from the voltage regulators. Once integration is fully realized, the prototype should be in working order to allow for a general representation of the overall functionality of the final product.

6.2 Printed Circuit Board (PCB) Software

One of the core elements required to create a fully integrated and realized prototype and final project is the main printed circuit board (PCB) that will host the majority of the overall functionality of the completed system. There are multiple steps necessary in realizing the full design of the PCB including using a PCB CAD software such as Autodesk Eagle to first create a schematic followed by creating the PCB file. Once the PCB design process is complete it can be printed, and the appropriate connections and components can be soldered on to create the final, fully integrated PCB which should be able to utilize the overall functionality of the project. This PCB can then be tested and integrated into creating a working prototype that should be able to perform all of the important functions that are expected of the final design. It is important to note that at least two PCBs will be required for this project as there is intended to be a transmitter device that is located on the water and a receiver device that is to be located somewhere away from the pool to allow for someone who is at a distance to hear the alarming of the device informing them of the possibility of a drowning incident.

6.2.1 Eagle

The PCB CAD software Autodesk Eagle will be utilized to design the overall PCB for the project. The first step in this process is to understand all of the components, their parameters, and the various additional passive or active components that they need to operate in the intended manner. Once this process has been completed, the part symbols can be arranged and connected to create the schematic file that will give an overview of all of the connections and components necessary to implement the intended design. Once the process of designing and arranging the schematic has been completed, the software can create a PCB file that utilizes the proper footprints of the various connections and traces that will need to be drawn to connect all of the footprints as described in the schematic drawing.

It is then important to create the appropriate grounding and mounting holes in the PCB file to allow for safe hardware operation. Eagle can also be used to create the bill of materials (BOM) for the PCB that will make ordering the appropriate components rather straightforward. At this point the final steps can be completed which requires ordering the PCB, ordering the components, and soldering all of the components and connections for the finished PCB. This process should be given special attention as it is of great importance to the final design, and it would be tedious to have to correct issues frequently and order new PCBs to get proper functionality.

PCB Architecture

The PCB design for the Pool-AID is the most significant part of this project. This design must integrate several components for both the transmitter and receiver. The PCB itself provides a compact reliable housing for several electrical components and connections that is a superior format to a breadboard environment. A PCB is made up of a laminated structure that incorporates conductive and insulating layers that support the placement of electrical components. Often multiple layers are used when constructing a PCB and vias, small holes, are placed to allow interconnection between layers.

Part Placement Selection

There are two main formats for attaching electrical components to a PCB. The first method is that of through-hole mounted components. This method of placing parts on a board layout involves placing the leads of a component through holes in the board and soldering them on the other side of the pad either by hand or automated process. The second method is by surface mount architecture. This method involves attaching a component directly to the surface of the board. This method was developed in the 1960's and has largely replaced the method of through-hole technology. This method has gained popularity because of the application towards manufacturability. This method allows for better automation of PCB production which in turn lowers cost and increases the quality of the boards produced in this manner. This process allowed for electrical components to be constructed much smaller when compared to through-hole parts, this allowing for more densely compacted boards. The downside to this process for this project is the challenge in self application. While this may be a better method for automation applying surface mounted components by hand can often be more complicated. As surface mounted parts are smaller than their through hole counterparts and have either small pin leads or no leads at all, this makes attaching surface mounted components by hand harder than with through-hole. Therefore, through-hole components have exclusively been chosen for the design of this board in order for ease of self-application techniques. While choosing this method means not as many parts can be placed on the board as with surface mount, this has been considered and should not affect the design of either the receiver or transmitter circuit boards.

General Practices

It is important to the design to follow some basic guidelines when constructing the layout for the PCB design. First is in component placement. Priority should be paid to placing the largest most significant parts first on the board, especially those with the most connections. Second will be avoidance of net crossing when routing the devices. It is also important to keep high power components separate from each other. This is necessary due to unwanted thermal interference or potential damage that high heat producing components could cause to the effectiveness of the circuit. Additionally, proper placement and separation of parts is necessary to avoid electrical interference on the board. With components placed attention must be placed on the power ground and signal traces. As this will be a 2-layer board one layer will be the ground plane and the other will contain the signal and power traces.

6.2.2 Layout

To establish the PCB layout, considerations had to be made in terms of essential connections and locations. There are two separate PCB layouts to be designed for the Pool-AID device, that of the receiver module and the transmitting module. In terms of the receiver module there is only a couple considerations to make. That is the location of the Atmega328p chip, the buzzer module, and the camera module. The layout of the receiver PCB therefore is quite simple. The most important aspect is the location of the camera module as it needs to have proper connections to the Atmega328p chip and be located near the edge of the board pointing towards the pool. This is user determined however so which edge of the board the camera module is placed is arbitrary. The pin connections for the receiver are explored in detail in the schematic section 6.3.2.

For the transmitting module PCB layout, the main considerations with regards to location comes in the form of sensor placement on the board. There are two types of sensors that need to be placed and 6 sensors total. The parallax 28032 sensor has a 180-degree viewing radius and is a through hole device and therefore needs to be placed on opposite sides of the board facing opposite directions. The 28032 sensors have a 4-pin package for connection. One is for ground, one for input 3.3 V, one for nighttime enable, and one for the output.

The output pins will be connected to input pins on the ATmega328p. The Vcc will be connected to the voltage regulator output and the enable pin will be left unconnected. The sonar sensor chosen to be used was the MB1010 LV-MaxSonar-EZ1. This sensor will be located adjacent to the two PIR sensors on the left and right side. The EZ1 sensor has 7 pins total. Pin 7 is ground and will be similarly connected. Pin 6 is Vcc and can be connected to either the 5-volt regulator or the 3.3 V regulator. For this PCB design a connection was made for the 3.3 Volt power source. Then using pin 3 for the sensor connected to an analog input pin of the ATmega328p the sensor is connected and will transmit data in the form of an analog signal to the processor.

Next, the ATmega328p must be assigned. In addition to the aforementioned connections, it will also need connections to ground and Vcc. This chip can operate on both 3.3 V and 5 V input and for the purposes of fewer connections to the 3.3 Volt regulator it will be connected to the 5 V regulator. The processor needs to be centrally located on the PCB in order for ease of connection to the sensors and modules that need to interface with it.

Two voltage regulators are necessary on the board to produce the proper powering voltages to the selected components. The 3.3 Volt regulator needs to be centrally located beneath the processor as it has almost as many connections as the processor itself. It will have output connections to the four MB1010 sonar sensors. Both of the voltage regulators also need connections to the battery. However, instead of linking directly to the battery both regulators will connect to the battery charger output. The battery charger has three connections. It will connect to the regulators as mentioned and will connect directly to the battery which for the layout will be the battery holder. The third connection to make is for the solar panel access. Two pin headers will be added so the solar panel, which is not directly placed on the board can connect to the PCB battery charging module. Next is the Wi-Fi transmission module used to transmit to the receiver module. This will be connected to the processor chip and 3.3 Volt regulator. The final component needed on the PCB is a battery holder to encase the lithium iron phosphate batteries that will be used to power the device. The battery charging module will be connected separately.

6.3 Schematics

This next section will go over the different schematics our team designed. Throughout this section, we have partitioned the larger and main schematic diagrams into smaller parts to be able to elaborate on each specific part. We will start off by explaining the receiving end, then move on to the main unit's schematic.

There will be at least two schematics necessary for this project, one for the transmitter and one for the receiver. Schematic design for the receiver will be a relatively simpler design that is similar to the transmitter schematic. For the transmitter schematic it will be required to utilize various libraries in order to obtain component symbols that will be needed to fully realize the overall design.

To appropriately create all of the connections and passive or active components it will be necessary to view the datasheets of the individual modules or ICs that are to be implemented on the PCB. These datasheets can sometimes also include typical application circuits that will be of great use when designing the schematics for the Pool-AID. It will also be useful to study schematics for prebuilt boards, such as the DC-to-DC converters and the battery charger, to get an idea of how the circuits should be implemented to be successful and efficient. The schematics for the receiver will be different depending on if the servo motor is used or not. The first section of the schematics will show how the WI-FI module would be connected to the ATmega328P for transferring data, and the servo motor control schematics. Next, we will discuss the two approaches that have been proposed by the group members about the receiver end design. There are some sections that are specific to the voltage regulators schematics that will be used for the transmitter and the receiver. Lastly, we have the schematic of the main system or transmitter, which will later become the PCB that will be used for the Pool-AID device.

Unfortunately, there might be no footprint available for any specific component that we could use for the schematics, so we can use any other component that has a similar shape or that has similar pin connections to construct the schematic, and later on the PCB design know what components goes where. There are some important points to consider when designing any schematic which uses a microcontroller or any chip. We need to make sure that the pins are the right ones. For example, if we need to connect the camera module to digital pin 7, considering the Arduino UNO board as an example for testing the camera, this doesn't mean we are connecting it to pin 7 from the ATmega chip. This is a common mistake when designing the schematic that has these chips; however, we can always reference the chip datasheet, so we have the correct mapping for the pins.

6.3.1 Wi-Fi Module Schematics

In this section we will discuss how will the WI-FI module schematic will look like to communicate with other hardware module such as communication schematic with the Microcontroller ATMega328P, which is the main MCU from the design, and also the connection with the servo motor to control it externally. The ESP8266 is not a common component that can be found in an Eagle library similar to other chips. However, we can get the .lib file that has the footprint compatible with eagle. By looking at different sites to get the footprint, the only footprint available is for the chip. In the original design, we want the module only to connect it later with the ATmega328P chip. There are three pieces for the schematic that make use of the ESP8266. All sections are important since the final design of the Pool-AID system is not yet decided. The first section that implements the ESP8266 is the servo motor which as part of the transmitter. The second section is used for serial communication with the ATmega328P

This first schematic in figure 10 is very simple since it only contains two pieces the servo motor and the ESP8266 module. The servo motor we are using has 3 wires connected to 3 pins which are the V+ for input voltage, ground, and the digital signal. The digital signal can be connected to any digital pin from the ESP8266, but in this case we will just use the GPIO5. The ground and VDD pin from the module will be connected to GND and V+ from the servo motor respectively.

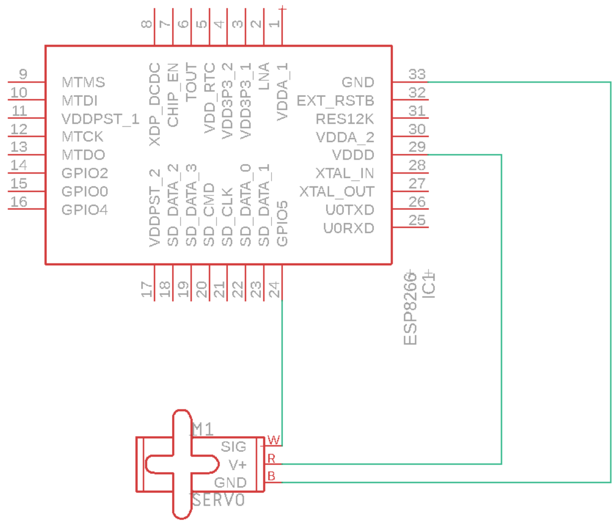

Figure 10 - ESP8266 with Servo Motor Schematic

The Second Schematic will represent how the ATMega328P chip will be connected to the ESP8266 for communication. The way these two chips will communicate with each other is using serial communication protocols and interfaces that were learned in embedded systems such as UART, I2C and SPI. All the data will be collected first by the ATmega328P chip, but if we want it to be sent later to a cloud server or database, the data should also be available to the ESP8266 WI-FI module.

For this schematic, An Ultrasonic sensor will be connected to the MCU, since there are no available footprints for the sonar sensor we are using, and the ESP8266 will be connected to the corresponding pins for communication as shown in figure 11. In the schematic the sensor will be connected to any digital pin from the MCU, and the VDD and GND pins from the sensor will also be connected to the pins with the same name from the chip. This will be replaced by the sonar sensor which will have two pins, one analog and one digital, which only one will be used. The ESP8266 will be connected to the ATMega328P using the Digital pins 0 and 1, which are the transmitter and receiver pins. The two pins mentioned will be connected to the receiver and the transmitter pins from the ESP8266.

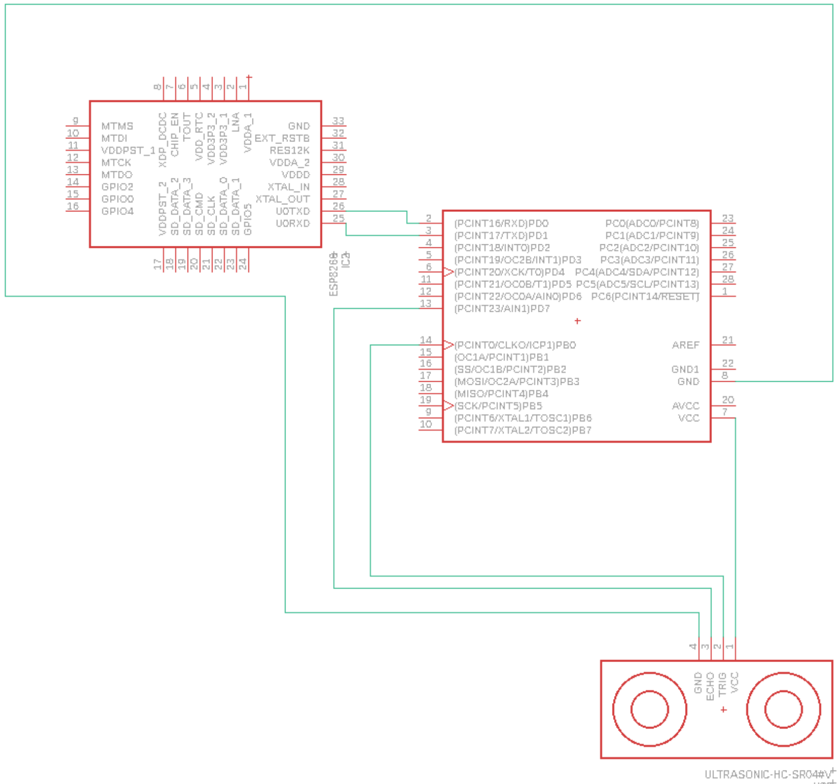

Figure 11 - ESP8266 Communication with MCU

6.3.2 Receiver Schematics

Schematics components

The Pool-AID design will count with two main components which are the transmitter which will do the monitoring on the surrounding area of the pool, and a receiver that will have the alarm triggered based on data sent by the transmitter. In this section, we will discuss the receiver's schematics, and then what and how components will be connected. There are two designs proposed for this part from which only one of them will be chosen for the PCB design. The components that are needed for the schematic are the following:

- A microcontroller unit such as the ATmega328p to be the brain on the receiver end
- A WI-FI module such as the esp8266 to communicate with the WI-FI module from the PCB designed for the transmitter (RF module could be a second option)
- A camera module that will communicate with the MCU chosen to take the picture once the transmitter makes the receiver trigger the alarm (Only in the WI-FI design)
- Buzzer module
- Voltage regulators of 3.3V and 5V
- AA battery holder to power the receiver

Receiver with antenna Schematics

The receiving-end schematics is made up of two major modules. The first module is the wireless receiver that is listening to the transmitter via an antenna. The second module is the alarm system, also referred to as the buzzer module. Both modules will be linked to the ATmega328P controller; however, the alarm will be triggered based on the kind of message received from the transmitter. While the buzzer module is dependent on the received signal, it is not directly linked to it in the circuit. The figure 12 below gives a close look at the receiver part of the schematics.

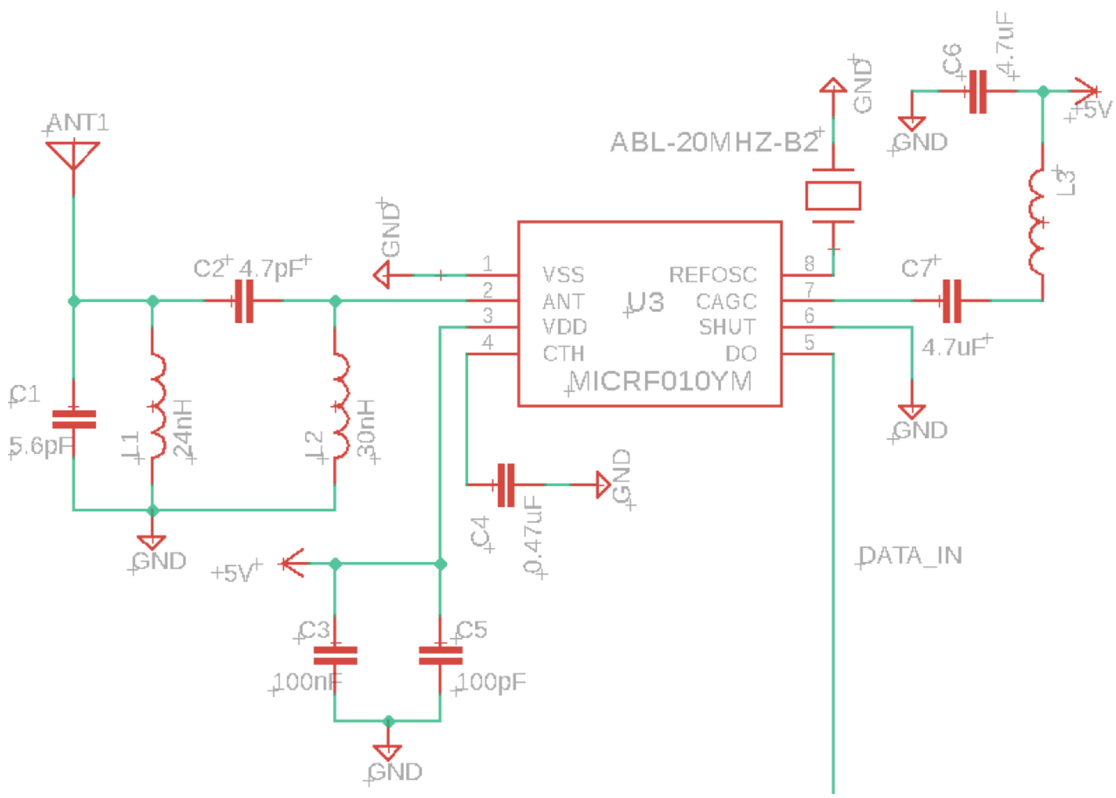

Figure 12 – Wireless Receiver Schematic

A closer look at the wiring of the second module is shown below in figure 13. The buzzer is interfaced directly to pin 17 on the chip with a 5 Ω resistor on the negative terminal to regulate the sound level to 100 dB. The data transferred is wired directly to pin 18. This way, the buzzer is only triggered through the controller that will interpret the data before setting off the alarm. This is done so that the buzzer does not sound any time the receiver is interpreting a signal. The buzzer will have a cancel switch that immediately shuts it off when the user toggles the switch once. An LED is interfaced to provide a visual trigger in case the parent has some loud noises happening in the background that are not allowing them to hear the alarm. The corresponding schematic diagram below is inspired by existing buzzer schematics and is subject to change for the final product [40][41].

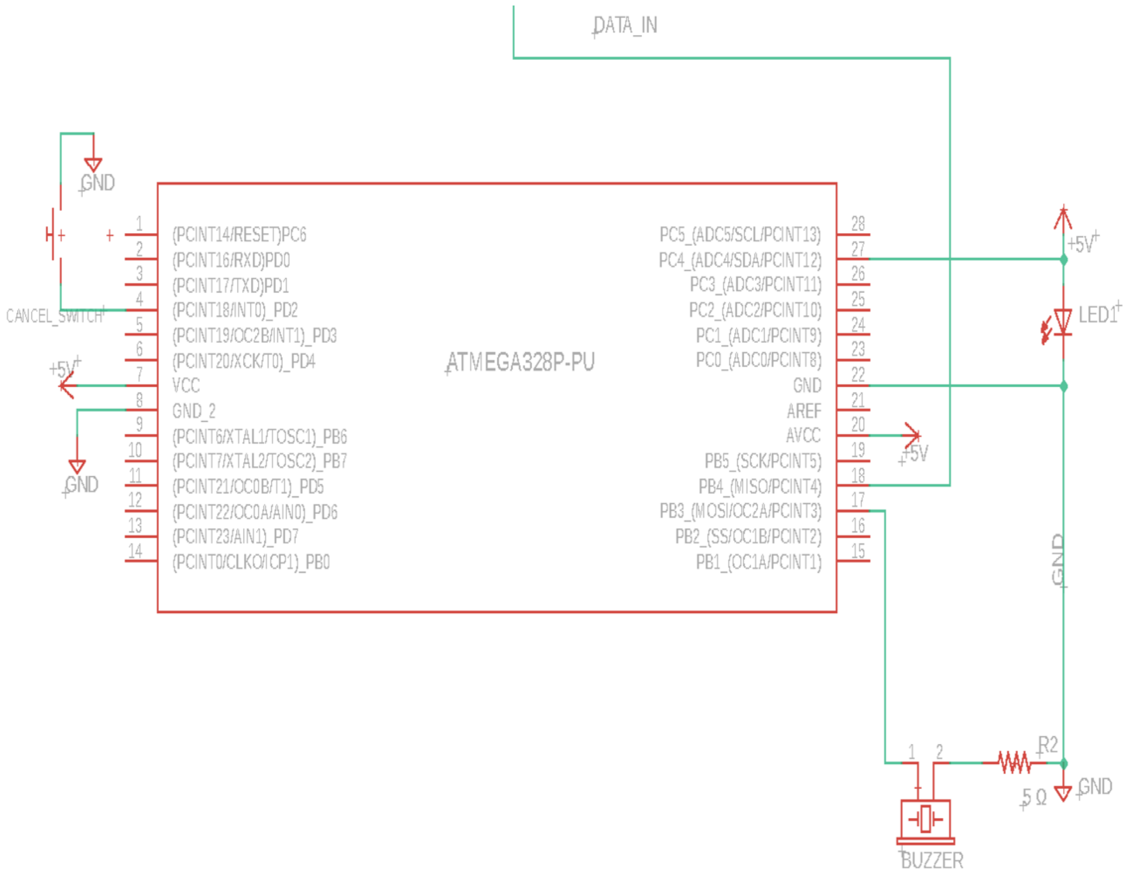

Figure 13 - Receiver’s Buzzer Module Schematic

The overall system of the receiver will be battery powered; hence, the battery source on the upper right-hand side of the figure below. Some parts of the circuit are yet to be designed depending on the frequency we deem to be reasonable for the transmitter. Other parts like the decoder and relay are also still being analyzed. The need for a design that matches the specifications indicated in the second chapter of the report is essential to building a system that functions with a minimal fault rate.

While we could have made the system a little less complex by using another Wi-Fi module on the receiver, we are still trying to keep the cost relatively low. Since the transmitting side is already using a 2.4 GHz Wi-Fi module, it would be easier to relay the data from one module to another. This, however, depends on a factor that can be unreliable, which is an internet connection. To eliminate that risk and dependency, we chose to make our design plan slightly more intricate to increase the reliability of Pool-AID as tradeoff.

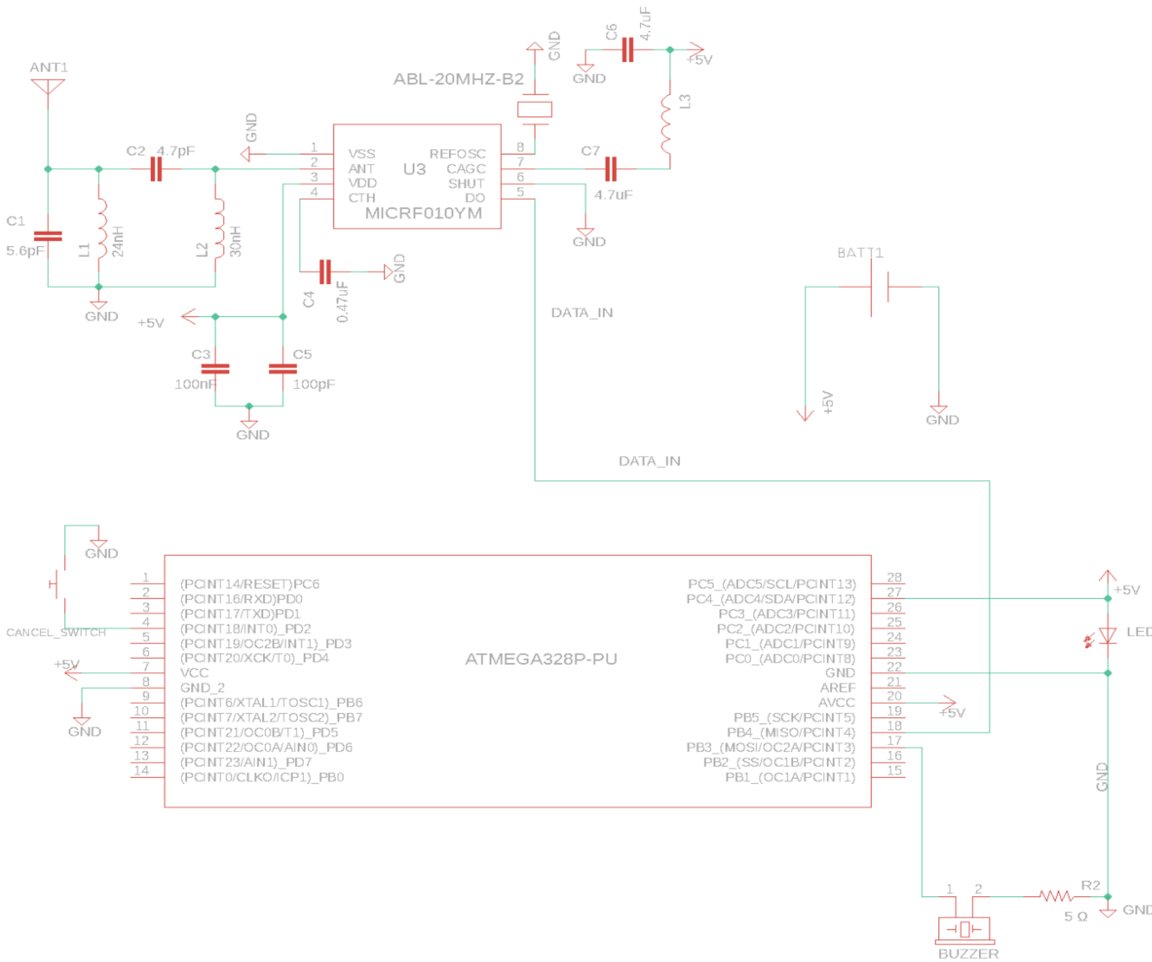

Figure 14 - Receiver's Schematic Overall

Receiver schematics with WI-FI module

As you can see in figure #, the schematic does not include the voltage regulator or the battery holder; However, the supply voltages of 5 volts that goes to the VCC, AREF and AVCC pins from the microcontroller and the camera module will be connected to the output of the corresponding voltage regulator from figure # as well as the 3.3V volts for the VCC pin in the ESP8266. For the connections of the ATmega328P, we were trying to simulate some of the components from the Arduino UNO board since we are using it to program the chip. The ATmega328P has pins 9 and 10 that are connected to the 16 MHz crystal oscillator Similar to the Arduino UNO we require two 22pF connected to ground and the same pins that are connected to the crystal. We want to add a manual reset functionality in case the device needs to reset manually. The reset button is located near the cancel switch in the schematic, and it is connected to the reset pin in the ATmega328P, and to keep it high, a 10 Kohm resistor was added to add the push down and pull state when pushing the button. We couldn't find a footprint for the camera module, but since it has 8 pins, a pin header of 8 pins was used and labeled with the same names as the ArduCAM. The pins for SPI such as SDA, SCL, SCK, MOSI, and MISO will be connected to the ATmega chip with the pins of the same name. However, the chip select pin from the

ArduCAM can be connected to any digital pin that is available such as digital pin 7 at pin 13. We need to supply 5V to the camera module which will come from the voltage regulator. The buzzer connections are the same as the previous schematics. Lastly, the antenna was replaced now for the Wi-Fi module which will use a similar logic to figure 16. The only difference is that the receiver pin from the ESP8266 is connected to two resistors of 1 KOhm.

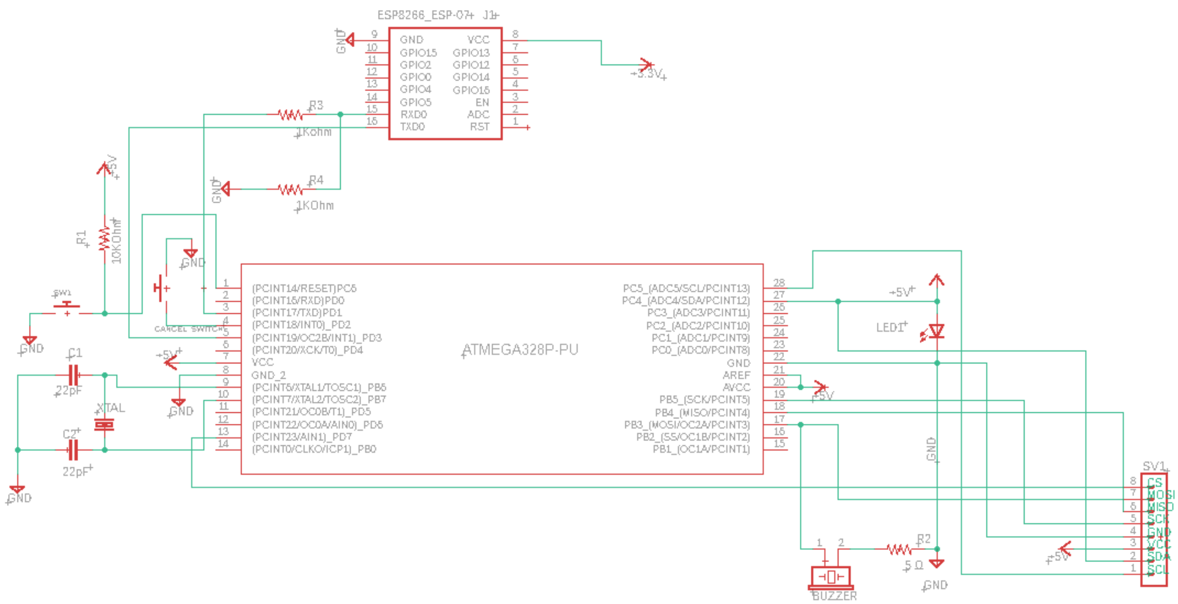

Figure 15 – Receiver's Schematic with WI-FI

Voltage Regulator Schematics

For preliminary testing, a pre-built 5-volt boost converter was utilized to ensure certain characteristics could be met and that proper understanding of how the boost converter would be utilized and implemented into the overall power design of the system was gathered. However, for the final implementation of the circuit, voltage regulators should be specifically designed to ensure that all of the needs and conditions of the circuit are met. Because there is both 3.3-volt and 5-volt logic utilized on both the transmitter and the receiver and different overall current draw characteristics will be present for both, four unique voltage regulators will need to be designed and implemented into the final design (two for each PCB).

To aid in the design of the schematics for these voltage regulators, the Texas Instruments tool, WEBENCH Power Designer, can be utilized to generate schematics that meet all of the criteria necessary to implement proper and adequate voltage regulation circuits for the overall power design. The software has many possible input values for the design of the regulator that should be looked at individually to ensure appropriate design of the characteristics necessary for the circuit's power supply.

First, the design of the receiver voltage regulators will be examined here to see what values will be selected in WEBENCH to ensure proper operation. First, the input values must be filled out. For the receiver, two alkaline AA batteries will be used in series which means that the supply type will be DC. To determine the maximum and minimum voltage for the input, the maximum and minimum voltages for the AA batteries must be determined and the doubled, to account for the batteries being wired in series. According to the Energizer Eveready 1215 datasheet, a typical alkaline AA battery has an operating voltage of 1.5 to 0.8 volts, which means the maximum and minimum input voltages for the receiver voltage regulators should be 3.2 and 1.6 volts, respectively with ±0.1 volts. This means the range that shall be imputed into WEBENCH is 3.3 volts for the maximum voltage and 1.5 volts for the minimum voltage. As mentioned before, the output voltages shall be 3.3 and 5 volts respectively for each regulator. The maximum output current can be calculated by summing the maximum current draw of component on the receiver, according to their respective datasheets. For the ArduCAM-M-2MP, the maximum current draw was found to be 70 milliamps. For the Grove Active Piezo Buzzer, the maximum current draw was found to be 20 milliamps. Finally, for the ESP8266, the maximum current draw was found to be 170 milliamps. This means the overall maximum output current for the receiver should be 260 milliamps and with a 15% tolerance to ensure safety of the voltage regulators, 300 milliamps can be used for the maximum output current in WEBENCH. The final two elements of concern for this application are the design consideration and the maximum ambient temperature. The design was determined to be balanced to ensure a mix of efficiency and cost and a maximum ambient temperature of 40°C was chosen (as this is typically the hottest a Florida day can get in the summer). The schematic for the 3.3-volt and 5-volt regulator for the receiver can be seen in figure 16.

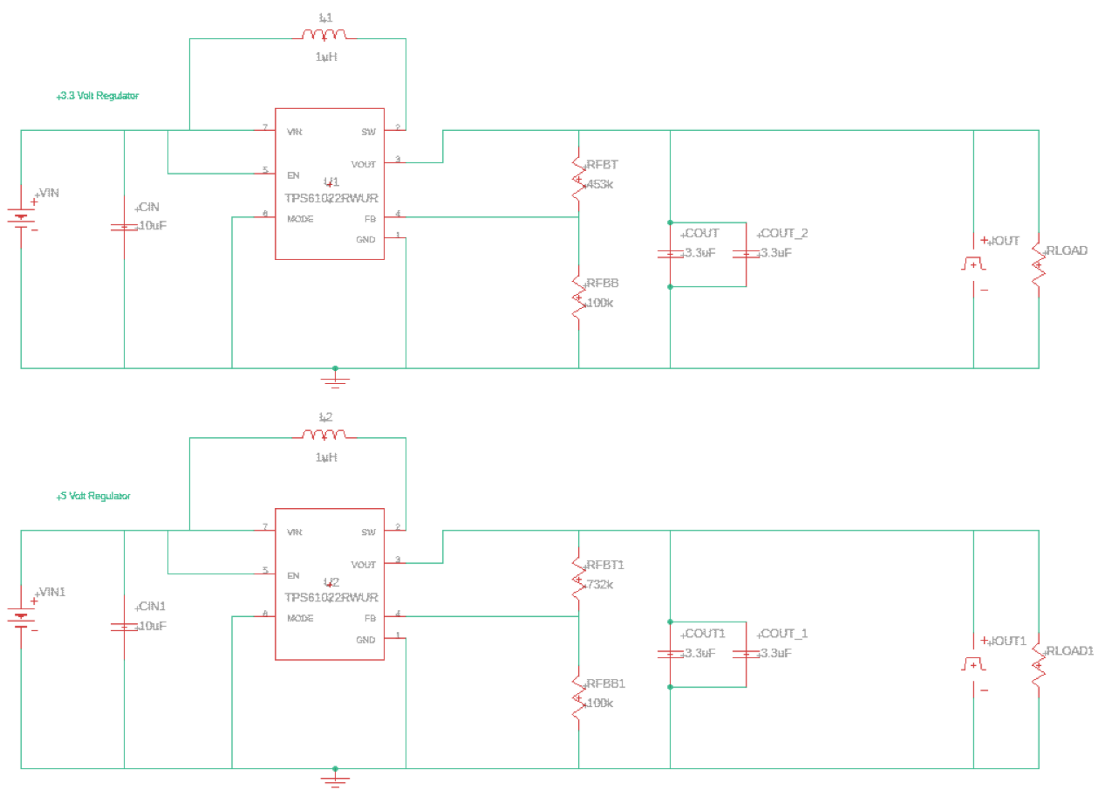

Figure 16 – Receiver Voltage Regulators Schematic

The 3.3-volt regulator that was chosen for the receiver utilizes the Texas Instruments TPS61022RWU boost converter chip and operates in a boost with passthrough mode. Since the converter is operating and a boost converter with passthrough, the output voltage shall be unregulated if the input voltage exceeds the expected output voltage and rather shall be the input voltage with the drop across the FET's on-resistance. This should not be an issue for this application as the maximum value expected from the 2 alkaline AA batteries should not exceed 3.3 volts. In terms of the bill of material (BOM), there are seven components to it and the overall cost comes out to $0.95. The total power dissipated by the converter comes out to approximately 84.626 milliwatts with output power of 990.0 milliwatts, giving the converter a steady state efficiency of 92.125%. The peak-to-peak output ripple voltage is stated to be 37.444 millivolts, which is acceptable for this application.

The 5-volt regulator that was chosen for the receiver, similar to the 3.3-volt regulator, utilizes the Texas Instruments TPS61022RWU boost converter chip and operates in a boost with passthrough mode. Again, the converter operating in passthrough mode should not be an issue for this application as the maximum value expected from the 2 alkaline AA batteries should not exceed 3.3 volts. In terms of the bill of material (BOM), there are seven components to it and the overall cost comes out to $1.13. The total power dissipated by the converter comes out to approximately 150.763 milliwatts with output power of 1.5 watts, giving the converter a steady state efficiency of 90.867%. The peak-to-peak output ripple voltage is stated to be 34.572 millivolts, which is acceptable for this application.

6.3.3 Transmitter Schematics

The main system housed in the floating environment for the Pool-AID has several components. After careful consideration it was decided that the camera module will be included in the receiver module. Therefore, the necessary components to build the schematic are the Parallax 28032 sensor, the LV-MaxSonar-EZ MB1010, Atmega328p chip, the voltage regulators, Wi-Fi module, battery charger, and battery holder.

As mentioned in the PCB layout section, there are 6 sensors for the schematic. The PIR sensors will have one connection each to the Atmega328p chip. One will connect to PB0 at pin 14 and one to PB1 at pin 15 on opposite sides of the board. Next are the connections for the four sonar sensors. The PW pin of the sonar sensor is used to make the connection to the chip. The four necessary connection points are PB2, PD3, PB3, and PD5 corresponding to pins 16, 5, 17 and 11 respectively. The battery holder will have connections to the two voltage regulators inputs. The battery charger will similarly be connected as an input to the battery holder. Finally, the Wi-Fi module must also be connected to the chip. The point selected for connection was PD1 and PD2 or pin 25 and 26 of the ESP module. The next connections to be made were for the battery charging unit. This module has three connections to be made. As the full system is quite large and intricate for a clearer view of how the components are connected reference the hardware testing section for individual schematics.

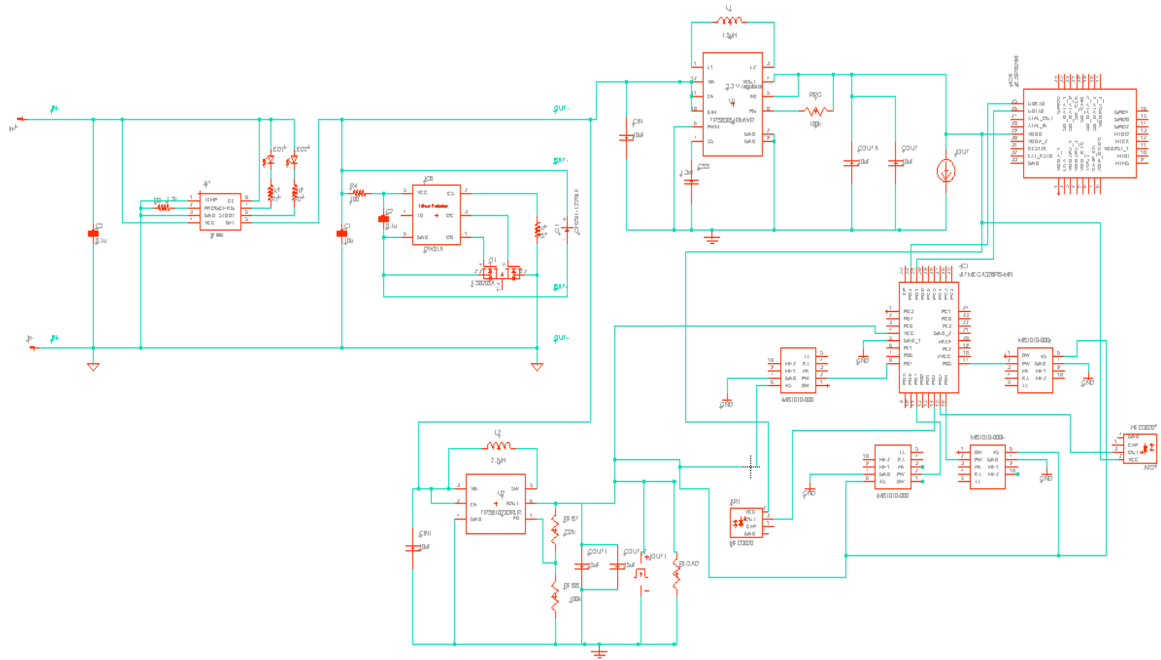

Figure 17 – Main System Schematic

Voltage Regulator Schematics

The design of the transmitter voltage regulators will be examined here to see what values will be selected in WEBENCH to ensure proper operation. First, the input values must be filled out. For the transmitter, a lithium polymer battery will be used which means that the supply type will be DC. According to the LP653042 datasheet, the nominal voltage of the LiPo battery is 3.7 volts with the maximum and minimum voltages being 4.2 and 2.75 volts, respectively. This means the range that shall be imputed into WEBENCH is 4.2 volts for the maximum voltage and 2.75 volts for the minimum voltage. As mentioned before, the output voltages shall be 3.3 and 5 volts respectively for each regulator. The maximum output current can be calculated by summing the maximum current draw of each component on the transmitter, according to their respective datasheets. For the Parallax 28032 PIR sensor, the maximum current draw was found to be 150 microamps and since there will be two, the current draw will be 300 microamps, or 0.3 milliamps. For the Lv-MaxSonar-EZ MB1010 sonar sensor, the maximum current draw was found to be 2 milliamps and since there will be four, the current draw will be 8 milliamps. For the ATMEGA328P microcontroller, the maximum current draw was found to be 200 milliamps. Finally, for the ESP8266, the maximum current draw was found to be 170 milliamps. This means the overall maximum output current for the transmitter should be 378.3 milliamps and with a 5% tolerance to ensure safety of the voltage regulators, 400 milliamps can be used for the maximum output current in WEBENCH. The final two elements of concern for this application are the design consideration and the maximum ambient temperature. The design was determined to be balanced to ensure a mix of efficiency and cost and a maximum ambient temperature of 40°C was chosen (as this is typically the hottest a Florida day can get in the summer). The schematic for the 3.3-volt and 5-volt regulator for the transmitter can be seen in figure 19.

The 3.3-volt regulator that was chosen for the transmitter utilizes the Texas Instruments TPS63051RMW buck-boost converter chip. A buck-boost converter chip was necessary for this application as the lithium polymer battery typically outputs 3.7 volts which is above the 3.3 volts of the converter but can drop to 2.75 volts which is lower than the 3.3 volts of the converter. In terms of the bill of material (BOM), there are seven components to it and the overall cost comes out to $1.09. The total power dissipated by the converter comes out to approximately 138.146 milliwatts with output power of 1.32 watts, giving the converter a steady state efficiency of 90.526%. The peak-to-peak output ripple voltage is stated to be 4.331 millivolts, which is acceptable for this application.

The 5-volt regulator that was chosen for the transmitter utilizes the Texas Instruments TPS61023DRL boost converter chip and operates in a boost with passthrough mode. Again, the converter operating in passthrough mode should not be an issue for this application as the maximum value expected from the lithium polymer battery should not exceed 4.2 volts which is below the 5 volts of the converter. In terms of the bill of material (BOM), there are seven components to it and the overall cost comes out to $0.76. The total power dissipated by the converter comes out to approximately 102.629 milliwatts with output power of 2.0 watts, giving the converter a steady state efficiency of 95.119%. The peak-to-peak output ripple voltage is stated to be 7.707 millivolts, which is acceptable for this application.

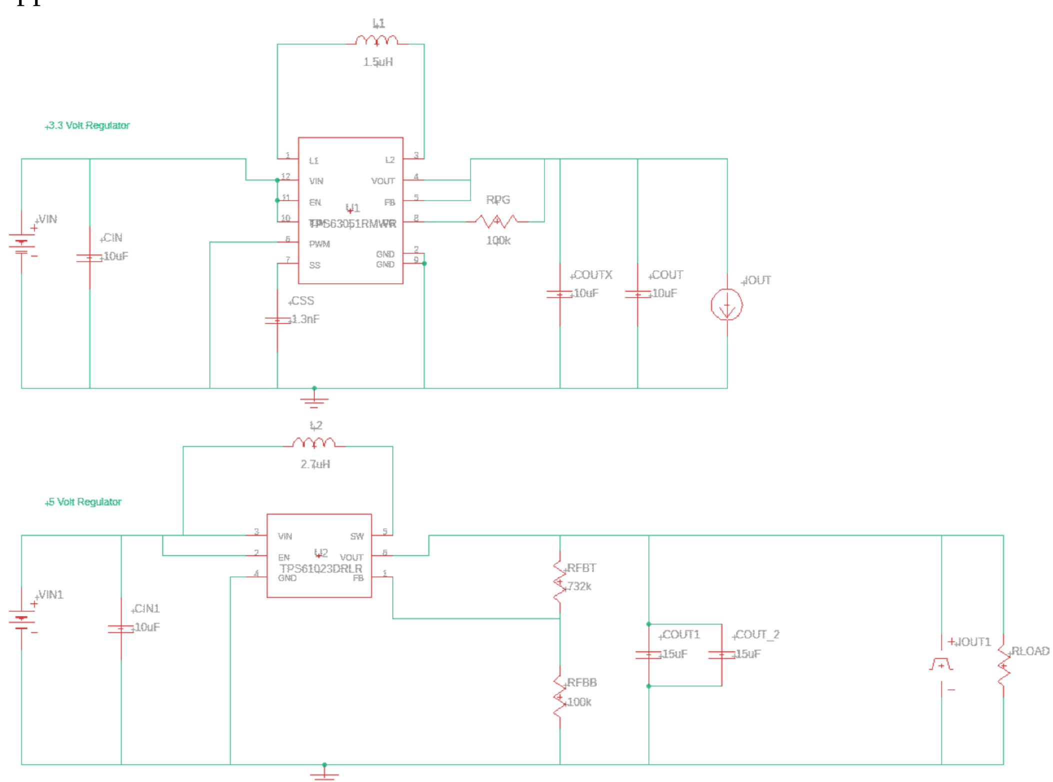

Figure 18 – Transmitter Voltage Regulators Schematics

Battery Charger Schematics

For preliminary testing, a prebuilt battery charger module, the Icstation 03962A, was utilized to gain an early understanding of the principles of lithium polymer battery charging and the ensure that the chosen battery and solar panels could be properly utilized for the circuits power elements. While this method was useful and convenient for testing purposes, it seems necessary to design a battery charging circuit specifically for the Pool-AID to ensure proper satisfaction of all characteristics can be met.

For our purposes, there will be two primary sections that are important to implement into the battery charger circuit: the battery charging element and the lithium polymer protection circuit. While lithium polymer batteries may typically include a protection circuit built in, as does the one chosen for the Pool-AID, it is still important to implement a protection circuit of our own to ensure proper safety is met, as the protection circuit implemented into the battery is unknown and should not be trusted at face value as improper protection for a lithium polymer battery can result in explosion. For the battery charging section of the circuit, the Top Power TP4056 IC was chosen, as it is a typical linear lithium-ion battery charger chosen for this application and supports all of the characteristics that are necessary for out purposes. For the protection circuit the DW01A battery protection IC was chosen as it is designed for lithium polymer battery charging and supports all the features necessary for the protection that is needed for our battery, being overcharge protection, over discharge protection, and overcurrent protection.

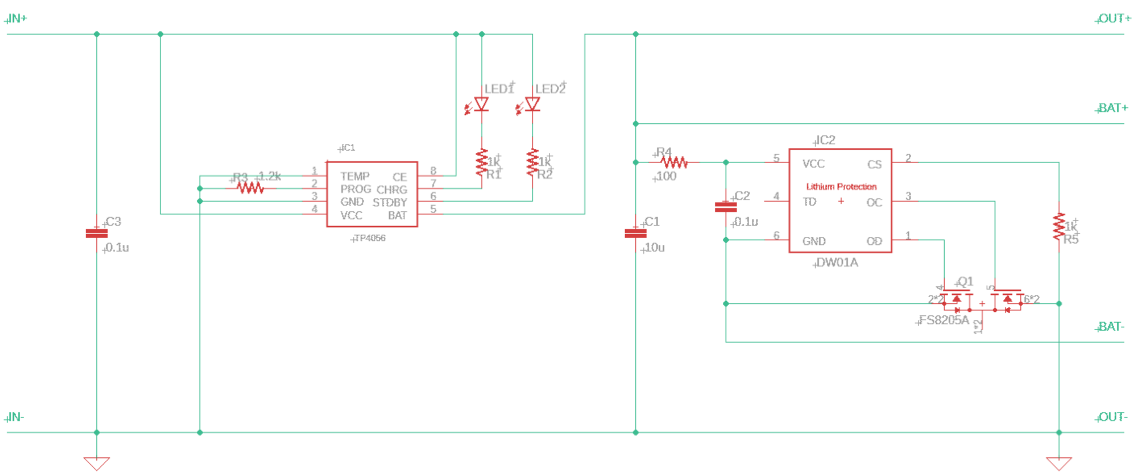

Figure 19 – Battery Charger Schematic

First, the battery charging section of the battery charger circuit can be observed. As stated early, the primary component of this section of the circuit is the battery charger IC, which is the TP4056. This IC is a constant-current/constant-voltage linear charger which is what is necessary for charging single-cell lithium polymer batteries and is package in a SOP-8 package. There are eight pins on the TP4056, and each should be generally understood in order to properly design the charging circuit. Pin 1 is the temperature sense input and can be used to determine the temperature of the battery and shut down the circuit if the temperature becomes too hot. While this feature can be useful for certain protection aspects and may be considered in the future, it will currently be disable by grounding the pin. Pin

2 is the constant charge current settings and charge current monitor pin which can be used to set the maximum charge current for the battery charging. This pin can be programmed through the use of a programming resistor with the calculation for the battery current being

$$I_{BAT} = (V_{PROG}/R_{PROG}) * 1200, \text{ where } V_{PROG} = 1 \text{ volt.}$$

For our purposes the maximum current possible is desired as the time that the solar panels can charge the battery for is limited and no current should be wasted by limiting the battery charge current. For this reason, the selected value of the programming resistor was chosen to be 1.2 kiloohms, which gives the maximum possible charging current of 1000 milliamps. Pin 3 is the ground terminal and should be tied directly to ground, which for this purpose will be the negative terminal of the solar panel. Pin 4 is the positive input supply voltage will be connected to the positive terminal of the solar panel. If this pin receives a voltage within 30 millivolts of pin 5 then the chip will enter a low power sleep mode which will only draw around 2 microamps. Pin 5 is the battery connection pin which is intended to go to the positive terminal of the battery. For our purposes this pin will go to the both the positive terminal of the battery and the positive terminal of the voltage regulators, as well as the V_{CC} pin of the DW01A lithium protection IC. Pin 6 is the open drain charge status output and can be used indicate that the charger is currently in standby mode if connected to an LED, as it will for this circuit. Pin 7, on the other hand, is the open drain charge status output that is responsible for indicating that the battery is charging by being connected to a separate LED, as it will in this circuit. Finally, pin 8 is the chip enable input, which will be connected to V_{CC} to enable the chip. With all of this in mind, a modified version of the typical application circuit provided in the TP4056 datasheet was used for the charging component of the circuit and can be seen in the left-hand section of figure 19.

Next, the lithium-ion battery protection section of the battery charger circuit can be observed. For this section, two chips will be required: the primary chip for protection which is the DW01A (as stated earlier) and the FS8205A which is a dual N-channel enhancement mode MOSFET that is necessary for proper operation of the DW01A. First, the FS8205A can be examined as it is fairly simple. The FS8205A comes in a TSSOP-8 package and has eight pins: two pins for gates (one for each MOSFET), four pins for sources (two for each MOSFET), and two pins for drains (shared between the two MOSFETs). This particular chip was selected as it fits the arrangement indicated in the DW01A's datasheet and is stated to be ideal for lithium-ion battery management applications in its datasheet. Now, the DW01A chip can be examined and discussed. The DW01A has six pins and comes in a SOT-23-6 package. Again, it is important to understand the purpose and application of each pin, so this will now be assessed. Pin 1 is the over discharge control pin and is to be connected directly to the gate of one of the N-channel MOSFETS. Pin 2 is the current sense pin and should be connected through a resistor to the negative terminal of the battery. The purpose of this resistor is to protect against large current if the charger is connected in reverse polarity. Pin 3 is the overcharge control pin and should be connected to the gate of the other N-channel MOSFET, similar to pin 1. Pin 4 is a test pin for reducing time delay and can be ignored for this application. Pin 5 is the power supply pin and should be connected to pin 5 of the TP4056 through a small resistor and to ground through a small capacitor. The purpose of the resistor in this case is ESD protection in the case of power fluctuation and should be relatively small to avoid lowering the accuracy of the overcharge detection. The purpose of the capacitor is for similar reasons with regards to power fluctuation. Finally, pin 6 is the grounding pin and should be connected directly to ground. With all of the pins in mind, this section of the circuit could be designed by utilizing a similar strategy to the battery charging section and using a modified version of the typical application circuit present in the datasheet. This section of the circuit can be seen in the right-hand section of figure 19.

With the two sections of the circuit fully design individually, connecting the sections is as easy as connecting pin5 of the TP4056 to pin 5 of the DW01A. Two bypass capacitors are also included with one being between V_{CC} and GND of the input and the other being between V_{out} and GND. This implementation should give similar results to the prebuilt module that was originally purchased for testing purposes, with the added benefit of being able to utilize the full output current of 1000 milliamps by using the programming resistor for pin 2 of the TP4056. The final prototype schematic can be seen in figure 18 which is then integrated into the overall transmitter schematic.

Battery Capacity Calculations

One aspect of the design that is of important consideration is the capacity of the battery. This will determine how long the device can operate without the support of the solar panels and will also help to determine what battery should be purchased. Battery capacity calculations can be done but using the overall maximum current draw of the circuit and multiplying but the number of hours that the battery should be able to power the circuit. This calculation is most important for the transmitter, as the longevity of the batteries operating time is important since the solar panels can only charge the battery during certain parts of the day. While the calculation is not as crucial for the receiver, the calculations can still be helpful in order to get a sense of how long the device can operate.

First, the maximum current draw of the transmitter circuit needs to be calculated in order to determine, under full operating conditions, what the draw on the battery will be. The maximum output current can be calculated by summing the maximum current draw of each component on the transmitter, according to their respective datasheets. For the Parallax 28032 PIR sensor, the maximum current draw was found to be 150 microamps and since there will be two, the current draw will be 300 microamps, or 0.3 milliamps. For the LV-MaxSonar-EZ MB1010 sonar sensor, the maximum current draw was found to be 2 milliamps and since there will be four, the current draw will be 8 milliamps.

For the ATMEGA328P microcontroller, the maximum current draw was found to be 200 milliamps. Finally, for the ESP8266, the maximum current draw was found to be 170 milliamps. This means the overall maximum output current for the transmitter should be 378.3. It should be noted that this is likely not to be the actual current draw of the circuit at every given moment but rather the maximum current that the circuit could draw. Since, on average, Florida has solar hours for solar panels 6 hours a day, the battery should be able to power the circuit for 18 hours. Therefore, the battery should be able to provide 378.3 milliamps for 18 hours with the capacity calculation being 378.3*18=6809.4 milliamp-hours. This means that the battery should have a capacity of around 6.8 amp-hours (though since the circuit is not likely to operate under this load, it is also feasible to have a slightly lower capacity).

Next, we can determine the minimum battery life of the receiver by comparing the maximum current draw of the circuit with the rated capacity of the AA batteries. It should again be noted that the device is likely to last much longer than this since it will be operating in a low power mode until it is triggered, but it is still helpful to know how long it would last if the circuit was always operating at full capacity. First, the maximum current draw of the circuit much be obtained in order to determine how long the AA batteries could last. The maximum output current can be calculated by summing the maximum current draw of component on the receiver, according to their respective datasheets.

For the ArduCAM-M-2MP, the maximum current draw was found to be 70 milliamps. For the Grove Active Piezo Buzzer, the maximum current draw was found to be 20 milliamps. Finally, for the ESP8266, the maximum current draw was found to be 170 milliamps. Since AA batteries can have a typical capacity of up to 3000 milliamp-hours, the minimum amount of time that the circuit could run can be calculated by dividing the capacity of the batteries by the maximum current draw or 3000/170=17.6 hours. This means that if the receiver were to be running at full capacity, the AA batteries would be able to power the circuit for 17.6 hours. This should be a sufficient time since the receiver is only intended to operate in full capacity for brief time frames and in rare frequency of occurrences. It is also important to note that not all AA batteries will have a capacity as high as 3000 milliamp-hours, so the time may be dependent on the particular battery chosen.

Solar Panel Calculations

Another important element of the transmitter is the solar panel, as it is the primary source of energy and is what will power the battery during the sunlight hours where it is able. Since the solar panel will only have limited time each day to charge the battery, it is important to have adequate characteristics for the solar panel to recharge most of the batteries stored energy while it is able to during the day. To do this, it will be important to factor in the capacity of the battery and the hours during the day in which the solar panel can feasibly power the battery. One characteristic that can affect these calculations is efficiency which is generally achieved through the use of maximum power point tracking systems. As the Pool-AID will not be utilizing a maximum power point tracking system, the amount of time that the solar panels take to charge the battery may be slightly longer than calculated. This discrepancy shouldn’t be of too much concern for this particular application, as maximum power point tracking has a larger effect on larger solar arrays.

First, a calculation will be made to determine what the optimal desired wattage for the solar panel would be in order to be able to charge the battery from empty to full in the average time of day that the solar panel is able to produce. It is important to note that this wattage may not be achievable with a single solar panel and also may not necessarily be achievable at all for this application given the time constraints. However, this should not be of too great concern as it is highly improbable that the battery will be fully drained by the time the solar panel are able to begin providing power. This means that the desired wattage can be lower than what is determined to be the optimal wattage for charging the battery entirely in the span of time given for the solar panels to operate. For this calculation, the watt-hours of the battery must be determined. This can be done by simply multiplying the capacity of the battery in amp-hours by the voltage of the battery which can be done as so: 6.8*3.7=25.16 watt-hours. This means that the battery can provide approximately 25 watts in the span of a single hour (assuming the maximum discharge current is not exceeded). This is effectively the capacity of the battery in terms of power per hour rather than current per hour. So, if it is desired to charge the battery in the 6 hours of average sunlight in the Florida day then we can do the following calculating to determine the number of watts that the solar panel will need to generate in that time: 25/6=4.16 watts.

This means that the solar panels need to generate 4.16 watts per hour which would be a 4.16-watt solar panel. The solar panel used in the preliminary testing was only 0.3 watts, so it would take 4.16/0.3=13.8 or 14 solar panels to achieve this. The solar panel likely to be used in the final design has a wattage of 3.5 watts so it would only take two of these solar panels to accomplish the above feat. However, it is again important to note that this situation would likely never arise, and the number of solar panels could likely be halved, that being seven of the preliminary testing solar panels or one of the final design solar panels.

6.4 Hardware Test Environment

The next section will present the testing results of the components that make up our device. Before going over the results, we must describe the environment in which we will be building Pool-AID. The testing will mostly be done in the senior design lab in Engineering I, which is conveniently located at the University of Central Florida. The lab provides us with the ideal environment for soldering, wiring, and testing parts. It has multiple function generators available to be able to supply a device with a precise waveform and frequency. It also gives us access to useful tools like the oscilloscope for measuring and analyzing the different signal waveforms produced over time. When it is infeasible to go to the lab, the two provide Digilent Analog Discovery 2 kits can be used to perform many of the measurements that ordinarily would only be possible in the lab. The most relevant of these tools for the testing of our equipment is the oscilloscope, variable power supply, waveform generator, and voltmeter. The kit also notably has many different hardware interfaces available, making testing much easier as the tool most suitable for the specific measurement needed is likely included.

6.5 Hardware Specific Testing

The following section is dedicated to all the parts we have acquired and are ready to be tested. This step is crucial for us to complete before moving into the assembly phase of the system. Each sub-section covers in detail the expected results and the actual results obtained for each component. The testing was done in a way where the modules were not all connected to one main controller all at once. Each component was tested and configured independently to ensure that they do function with the right supply. This was also done as a measure to minimize the number of issues that we come across when the components are connected and working together. The more a component is tested and studied, the better the overall design and efficiency of Pool-AID will be.

If proper testing is not realized for each individual component or subsystem, critical failure of the device could be an imminent threat (either due to lack of understanding or the absence of assuring quality of each component). Through various testing procedures, depending on the component being tested, values should be obtained and recorded as to be compared to the expected values. If the values that have been obtained to reasonably match the expected values another instance of the component should be tested to assure quality of the device.

6.5.1 Hardware Components

Testing the hardware components is likely to take up the majority of the testing time for the system as there a many varied components, each with their own miscellany of characteristics to test. It is important that before proper testing begins, it is understood what parameters are of major importance for the component at hand and how said characteristic may be tested to verify its value. These important characteristics can be obtained by looking through the individual datasheets or manuals for the component and marking down what values or attributes are of importance to the operation of the overall system. Once these characteristics are determined, a proper testing procedure can be devised for the component and the values can be obtained and recorded. It is important to note that some values may vary over time, such as battery capacity, so tests should be done with appropriate timing in mind.

6.5.1.1 Microcontroller Testing

There are plenty of programs and resources that make for easy and robust testing of the ATmega328p MCU. Some preliminary tests can be set up to verify various aspects of the controller and ensure that it is working as intended. Having a good understanding of the microcontroller is essential for all members of the project, as it will interface with almost every component of the project.

It is also an invaluable tool in the testing of other components for the system, as these components are to be connected to the MCU in the final design and as such shall be tested appropriately through the use of the board. Once all components are fully understood and tested with the microcontroller, all of the elements can start to come together to create the final product with a specified level of quality and understanding. Some basic testing will be performed to make sure the MCU is working properly.

The first testing we performed on the microcontroller was a voltage analysis on the 5V and 3.3V pins. We used a multimeter in the Senior design lab to measure the voltage of both pins as shown in figure 21. There was no code needed for the voltage testing, but we needed this test since we wanted to make sure it supplies the correct voltage needed for the modules and sensors we are including in our project.

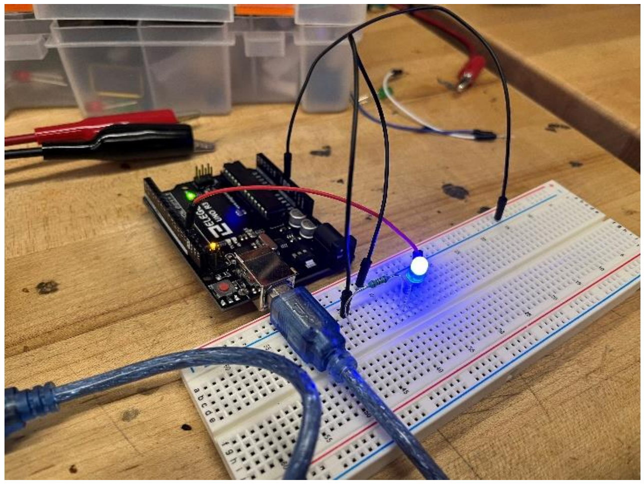

Figure 20 - Light the LED

The next part of the testing was lighting up an LED using the digital pins from the Arduino UNO. For the LED to not get burned, we apply some resistance and consider the current being supplied to the LED; LED only supports around 20mA. The connection is shown in Figure #, the LED is connected to pin 13 on the UNO board. Most of the other testing such as the WI-FI module and the Sonar sensor have their own section but testing the GPIO pins help us test how to make the connections with those.

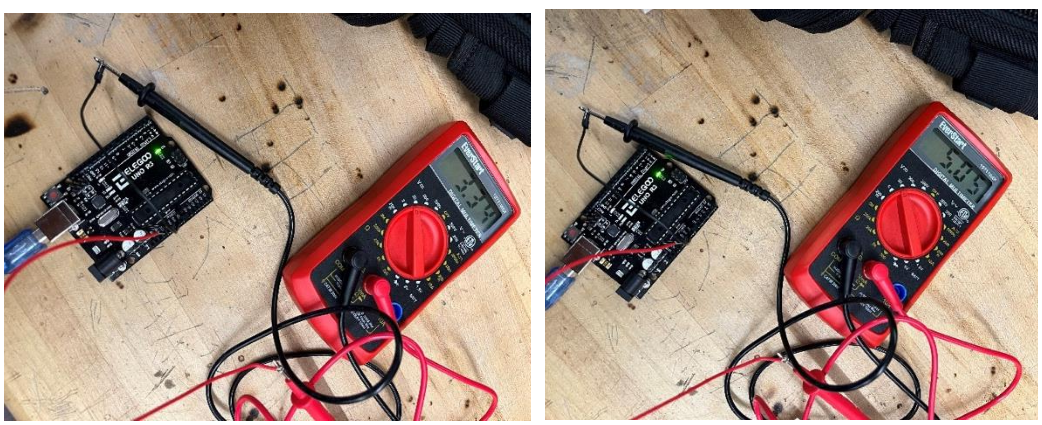

Figure 21 - Voltage Testing from 5V and 3.3V pins

6.5.1.2 Power Circuit Testing

There are many components of the power circuit that require adequate testing. It is paramount that the power circuit is found to be of suitable quality, as if the power circuit fails then the entire device is likely to see fail consequently. For this reason, it is important to not only ensure that each element of the power circuit works as intended isolated, but that they work together adequately as well. The main elements of the power circuit and the elements that are in need of testing here are the battery, battery charger, solar panel, and the voltage regulator. Once all of these elements have been tested, they can then be temporarily integrated together through the use of typical circuit testing methods such as bread board testing. Once this testing has completed, it can be assured, with relative confidence that the power system can suitably supply power to the overall circuit of the device.

6.5.1.2.1 Battery Testing

Battery testing can get quite in depth and complicated but for the purposes of this project only a few characteristics are needed to be tested. Some possible values that may be useful to obtain is the open-circuit voltage (Voc), the internal resistance (Ri), and the state of charge (SoC) (though the state of charge value can be quite difficult to obtain experimentally and may be best untested as it is of more importance when dealing with older batteries). The open-circuit voltage is quite easy to obtain and fairly self-explanatory. Simply reading the voltage of the battery while it is not connected to any load is enough. This value is nice to verify that the voltage is correct, though it is not of particularly great importance because it is a not a significant determinant in battery characteristics and it is likely to be stepped up or down to either 5 volts or 3.3 volts. However, it is useful in the calculation of the next value which is the internal resistance. Finding the internal resistance is not as simple connecting an ohmmeter to the battery as the measurement will have interference due to the batteries generated current. A more appropriate method is to use the open-circuit voltage and the voltage and current of the battery when a load is connected and use Ohm's law to calculate the internal resistance of the battery. This internal resistance is known to grow as a battery's lifetime progresses, causing greater losses and other issues, though this effect has been greatly reduced with the help of modern battery engineering for lithium-ion batteries and is primarily only of great concern at a battery's end of life.

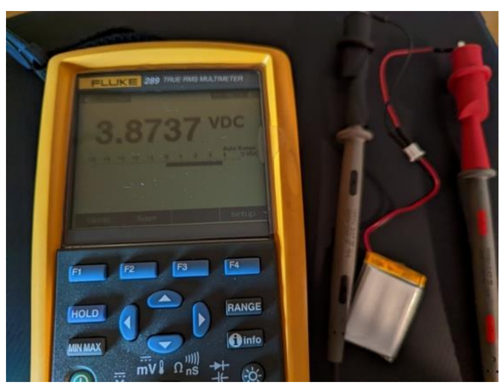

Figure 22 - Battery Open-Circuit Voltage

The open-circuit voltage was the first of these parameters to be tested for accuracy. The expected value for the open-circuit voltage given by the manufacturer is 3.7 volts, which is the typical value for open-circuit voltage of a single lithium polymer cell. The actual open-circuit voltage for the particular, preliminary cell that was to be used for the early prototype of the Pool-AID was observed by connecting the positive and negative ends of a multimeter (in voltmeter mode) to the respective terminals of the battery with no load present. The value that was observed for this particular cell was 3.8737 volts, which can be seen in figure 22.

This value has a percent error of +4.69%, when compared to the expected open-circuit voltage that was provided by the manufacturer, which can be viewed as a tolerable error for this specific application. It should also be noted that the open-circuit voltage can vary slightly depending on various conditions but should stay in a generally consistent range. This test also served to verify that the polarity of the battery was correctly indicated, as reviews for the particular battery tested indicated that there was a tendency for the battery polarity indicators to be reversed, leading to the dangerous situation that is lithium polymer reverse polarity damage. Fortunately, our tests indicated that the battery polarity was correctly indicated.

6.5.1.2.2 Solar Panel Testing

There are a few testing parameters that need to be considered when testing the solar panel, being the open-circuit voltage (Voc), the voltage at maximum power point (Vmp), the short-circuit current (Isc), the current at maximum power point (Imp), and the power at maximum power point also known as the maximum power (Pm). The two simplest parameters to test for are the open-circuit voltage and the short-circuit current. The open-circuit voltage can be tested by measuring the voltage produced by the panel while disconnected from any load. If in full luminosity, the open-circuit voltage should be the maximum voltage of the solar panel, in our case being approximately 6 volts.

The short-circuit current is the maximum current that can be delivered by the solar panel and can be tested by simply measuring the current when the panel supplies to a dead short. In our case this value should be around 50 milliamperes. The maximum power point parameters are the values that are required to generate the maximum possible power for the solar panel and generally occurs at a voltage value below the maximum open-circuit voltage. This value is very difficult to obtain experimentally, as it changes depending on the luminosity of the environment and is usually provided by the manufacturer. In the case of small-scale applications such as that of the Pool-AID, maximum power point values are generally unnecessary and tend to not vary much from the normal operating value of the solar panel and as such the values were not provided by the manufacturer. For these reasons it is not necessary to test for the maximum power point values in this application.

The first of these parameters to be tested was the open-circuit voltage of a single solar panel. This was first done in the lab room, where only florescent light and LED were available to test if the solar panel worked. For this to be accomplished, leads where soldered onto the back of the solar panel and then these leads where connected to a multimeter. Under normal ambient fluorescent light of the room, the voltage output by the solar panel was generally in the range of approximately 2-3 volts. Once an LED was held up close to the solar panel, approximately 4-5 volts were generated by the panel. Finally, the open-circuit voltage in sunlight was to be tested. For this a portable multimeter was chosen and the leads of the solar panel were connected to it. For a sunny day, the solar panel was producing a voltage of approximately 6-7 volts. This is higher than the expected highest voltage producible by the solar panel, though this increase can be explained by the relative luminance of Florida as compared to the region that the solar panels must have been tested in. For the purposes of the Pool-AID, this increase in voltage should not be of significant issue, as the solar panels will power the battery charger which can accept these voltage values, but it should be noted that the higher voltage may make the power production lower as the voltage may be further from the voltage at maximum power point than if it had been in the expected range of values.

Figure 23 - Solar Panel voltage testing

6.5.1.2.3 Voltage Regulator Testing

Voltage regulation will likely be built into the PCB that is to be designed for the project, but some DC-to-DC converters can be used for preliminary testing to allow for some insight into what values should be achieved for various characteristics of the circuit. Some properties that need to be accounted for are input voltage range, output voltage accuracy, and power output efficiency. Maximum values should not be exceeded for the input voltage range but expected input values should be tested to ensure that the range is accurate and that the circuit is able to withstand the voltages that will be received form the power supply. This can be done very simply by connecting the battery or a power supply of near equivalent voltage to a load through the converter and ensuring that no damage occurs to the circuit after an extended period.

Output voltage can be measured in a similar way by connecting a voltmeter to the output terminal of the converter and input a range of voltages that is expected to be received by the power supply. Finally, the power efficiency can be calculated by using voltage and current values at the input and output terminals of the converter and calculating and comparing the power at each end. Ideally there should be minimal loss of power within the converter to allow for as much power as needed to be provided to the systems various circuits and components.

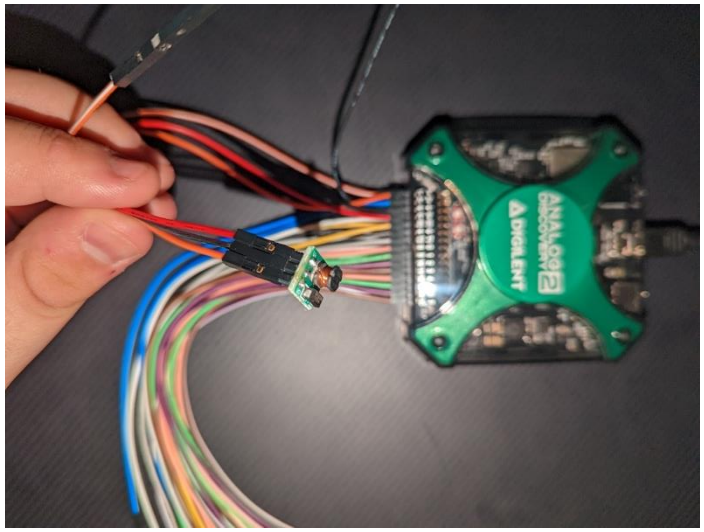

Figure 24 - Boost Converter Oscilloscope connections

All of the aforementioned measurements for the boost converter are the steady state values that are important to the component. There are, however, also the various states that the device experiences, depending on what the current input is and when that input was applied. For the boost converter there are a total of four possible states with two being the steady states and two being the transient states. There is the steady state operation when the device is powered off (which shouldn't be of particular interest due to the fact that it should be a stagnant ambient voltage of insignificant magnitude) and the steady state operation when the device is powered on. When the device is powered on, ideally the output should be a constant voltage. However, due to the way in which the boost converter operates (switching voltage regulation) and the impossibility of a truly completely steady DC voltage, there will be a ripple voltage that can be observed and measured. The two transient states on the other hand are the transient from off to on and the transient from on to off. In an ideal world these two operations would be instantaneous, but due the way in which the converter operates (charging and discharging of an inductor and a capacitor, both time dependent components) the two transients will take some time to reach their steady state operations.

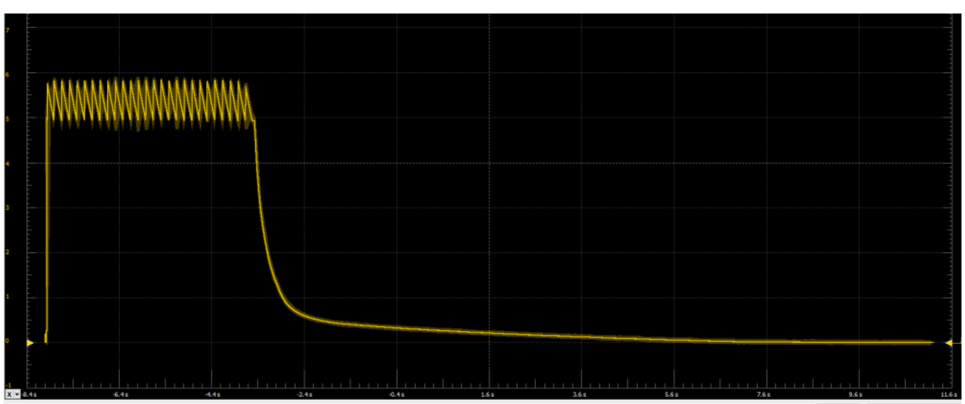

Figure 25 - Transient and Steady-State Operation of Boost Converter

These transients can be observed and measured through the use of an oscilloscope. The oscilloscope's probe can be attached to the output voltage pin of the boost converter and a capture can be set to begin once the voltage begins to rise over a given threshold voltage, ideally something very low as to capture the entire transient.

Once this is done, steady-state operation can be measured for a brief period following powering down the input voltage and capturing the transient voltage until a steady-state off voltage operation is achieved. Once this has been completed, cursors can be used to measure the appropriate values that are necessary to understand the transients and ripple voltage effects. X-cursors can be used to determine the time in which the transients are present, and y-cursors can be used to determine the range of the ripple voltage.

For this set of tests, the Digilent Analog Discovery 2 was utilized to operate as both the power supply for the boost converter and the oscilloscope for capturing and measuring the transients and steady-states behaviors. First the V+ pin, which is used as the positive voltage output for the variable power supply, is connected to the Vi pin of the boost converter, which as expected is the input voltage pin for the converter. Next, one of the four GND pins, which are the ground pins for the Analog Discovery 2, in connected to the GND pin of the boost converter, which again is the ground pin for the converter.

Finally, the 1+ pin, which is the positive input pin for probe 1 of the oscilloscope, is connected to the Vo pin of the boost converter, which is the voltage output pin for the converter, and the 1- pin, which is the negative input pin for probe 1 of the oscilloscope, is connected to another one of the four ground connections of the Analog Discovery 2. All of these connections are depicted in figure 26.

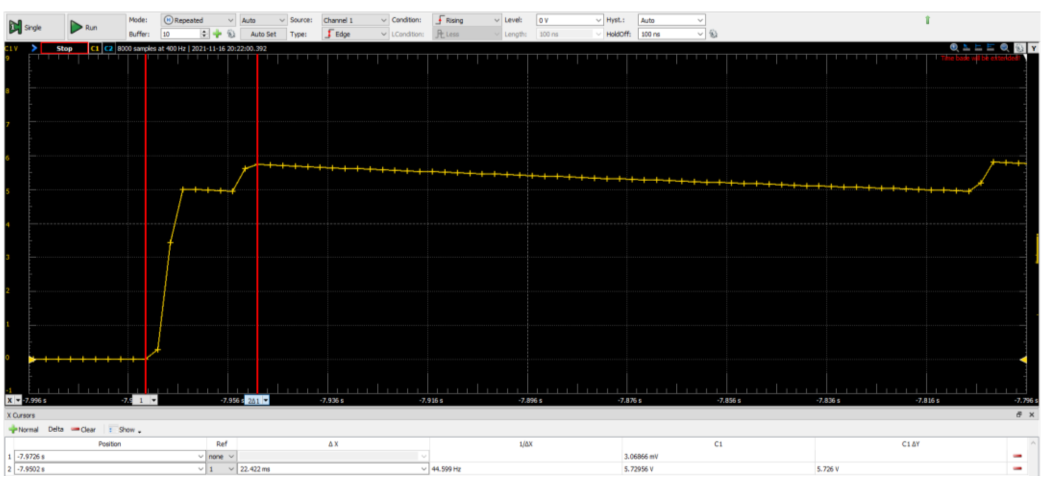

Figure 26 - Powering-on Transient of Boost Converter

Once the appropriate connections described above were made, the capture could begin, and analysis of the output waveform and its features could be observed within the oscilloscope tab of the Digilent Waveforms software. As seen in figure 27, the boost converter has a very rapid charge up to its operational steady-state voltage, a steady-state period with a particular ripple voltage, a relatively long discharge period, and a steady-state ambient period. Each of these states (disregarding the ambient period due to its lack of usefulness) can be observed and measured in closer detail to get a better sense of the overall operation of the boost converter as a whole.

First of these states to be observed is what should generally be the shortest, in terms of time it takes to occur. This is of course the powering on transient that ramps up to the steady-state operating voltage. As can be observed in figure 28, the transient has a quick period of ramping up, followed by a short lull in the ramp, followed by the final stretch up to the maximum voltage achieved by the regulator. This brief lull is likely the switch beginning to operate for the first time in this particular operation of the converter. As can be seen by the cursor values, this boost converter appears to ramp up to its operating steady-state voltage in approximately 22 milliseconds. For our purposes this should be a perfectly acceptable time, as the voltage regulator should generally operate for an indefinite period.

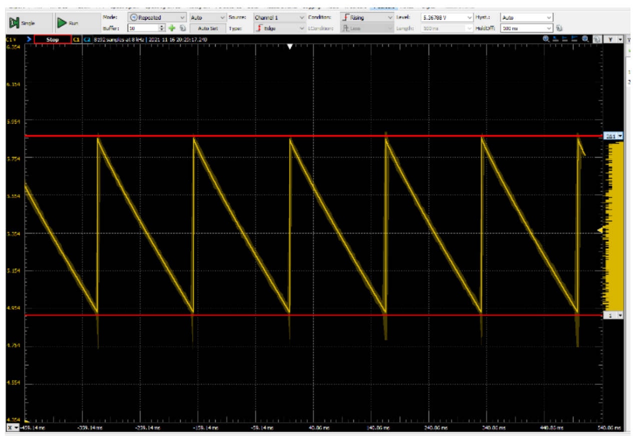

Figure 27 - Steady-State Ripple Voltage of Boost Converter

The next state that can be observed is the steady-state operation when the boost converter is powered on by an input voltage in the range of 0.9 to 5 volts. This state can be observed in figure 28 and can be seen to be approximately represented by a negative ramp function (reverse sawtooth). This is due the way in which a boost converter works in which a switch toggles an inductor from being charged by the input voltage and discharge into a capacitor.

When the inductor is charging, the output capacitor is discharging which is indicative of the falling edge of the ripple voltage. When the inductor is discharging, the capacitor is charging and the output voltage is that of which is present at the inductor, which is indicative of the sudden increase in voltage on the rising edge of the ripple voltage. This ripple voltage generally averages out to the value observed for the output voltage of the boost converter. As can be seen by the cursors, the minimum voltage of the ripple voltage is 4.9178 volts and the maximum voltage is 5.9661 V, which averages out to approximately 5.442 volts which is on par with what is expected. It can also be observed that the delta of the maximum and minimum voltages for the ripple voltage is around 948.28 millivolts. This is nearly a volt and can be somewhat concerning but for the application necessary for the Pool-AID this may be determined to be of tolerable deviation.

The final of states that are of interest to us is the powering-off transient, which can be observed in figure 29. It can be seen that this transient has a relative slow and exponential decay down to steady-state ambient voltage. This can be explained by the fact that the inductor and capacitor must discharge and with no direct discharging mechanism, they simply decay naturally. By observing the cursors, it can be seen that the time it takes for this process to occur to over the course of approximately 10.5 seconds. This time is significantly longer than the powering-on transient. This should still be tolerable however, as there is not generally a significant need for the voltage to suddenly drop down to zero and the overall device should not be powering off very often.

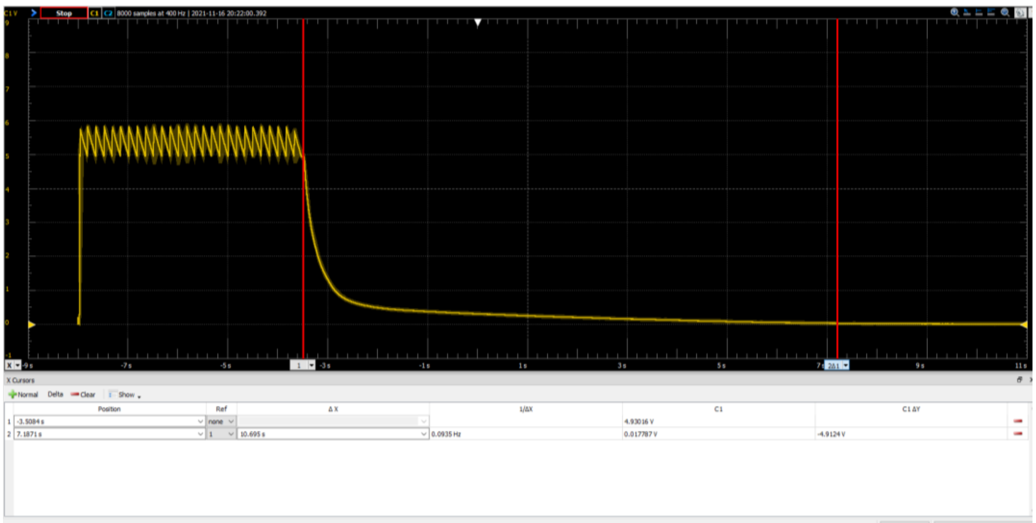

Figure 28 - Powering-off Transient of Boost Converter

6.3.1.2.4 Battery Charger Testing

The battery charger IC is a very important part of the overall design, especially since the use of a lithium-ion battery is anticipated. For lithium polymer base batteries is it very important to charge using a constant current constant voltage (CCCV) method to ensure that no damage is caused to the battery or any other part of the system.

Like the voltage regulator, the final battery charger will likely be integrated into the PCB but for preliminary testing a prebuilt battery charger circuit will be used. Some characteristics that may need to be tested for the battery charger is the is the maximum output current, the input voltage range, and the safety features. The TP4056, which is the IC used for the battery charger, generally operates with an output current of 500 milliamperes to 1,000 milliamperes, depending on a pin that connect to a resister known as the programming resistor (Rprog). This output current will need to be measured with an ammeter while charging the battery to ensure that the appropriate charging time can be achieved. Like with the voltage regulator the input voltage range needs to be tested to ensure that the expected voltages that will be provided to the charger can be handled. These values should not be expected to surpass the maximum rated voltage of 8 volts. Finally, though possibly unnecessary in the final design due to protection circuits built into the LiPo battery, safety features should be tested. Specifically, the over-charge, over-discharge, and over-current features that are provided by the included DW01A protection IC.

Firstly, proper operation of the battery charger IC was to be tested. This was down by soldering leads onto each of the contacts for the battery contacts and the output contacts. Once this was done it would be possible to use a USB cable for input power and test the voltage that is output from the output contacts of the battery charger with not battery attached. This process can be seen in figure 29 where the output voltage is measured to be 4.16754 volts. It is important to note that for this particular IC there are LEDs on the board that indicated certain states. If the blue LED is on that means that either the battery is full or, if no battery is attached, that the circuit is working properly. If there is a red LED on, it means that either the battery is not fully charged, or the circuit is not getting enough power to output. Once the output voltage without a battery has been successfully verified, it is important to connect a battery to the circuit to ensure that it can actually charge the battery. The battery that we used for the test was discharge to some unknown amount and this test did not charge the battery to its full capacity. The intention of this test was to verify that the connections were correct and that the battery would be able to charge while connected to the circuit. For this test, it was found easiest to connect the battery and the battery charger leads to a breadboard and measure the voltage at the terminals of the battery to ensure that the battery was successfully being charged. The results of this test can be viewed in figure 30 where it can be seen that the voltage at the terminals of the battery while charging is 4.19118 volts.

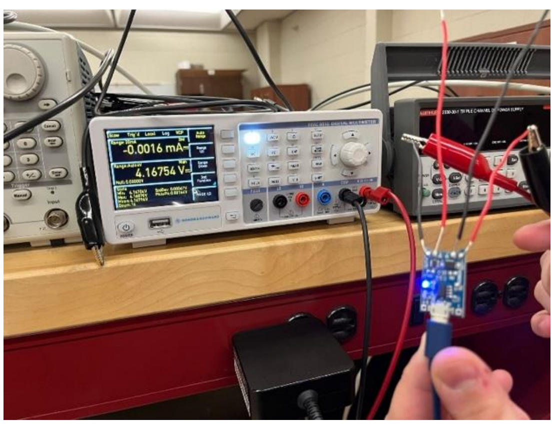

Figure 29 - Battery Charger Output Voltage

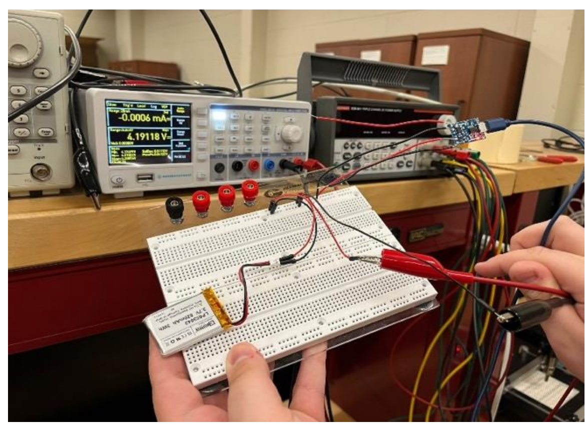

Figure 30 - Battery Charger Battery Terminal Voltage

6.3.1.2.5 Overall Power Circuit Testing

The final step in testing the power circuitry is to test the circuitry when integrated together in an elementary manner. This ensure that all of the components of the power circuit are compatible and able to supply the expected voltage to the exterior circuitry while also being independent of any exterior connections itself. This task can be performed by wiring all of the components together on a breadboard and testing various aspects of the circuitry to ensure that everything is operation as expected.

The first step in performing this task is to wire everything together on the bread board. First the soldered leads of the solar panel are connected to the positive and negative bars on the breadboard. This will be the main driver of exterior power for the entire circuit. Next, this connection will be extended to the input of the battery charger IC. The battery charger then will connect its battery output leads to the battery in need of charging and its output leads to the boost converter. The boost converter is considered to be the interface between the power circuit and the rest of the external circuitry in need of power as it outputs the expected 5-volt output. The connections describe here can be view in figure 28.

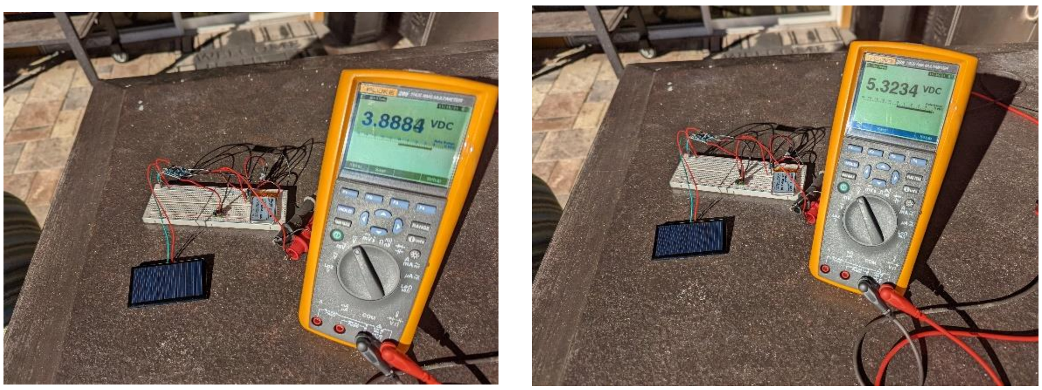

Figure 31 - Overall Power Circuit Test Measurements

Once the connections have been made, the voltage at the battery terminals and the voltage at the output of the boost converter need to be measured. This is as easy as connecting a portable multimeter's leads to the points that need to be measured. These values can be seen in figure 31 and are 3.8884 volts at the battery terminal and 5.3234 volts at the boost converter output. These values make sense with what has been previously measured for each of these components individually.

6.5.1.3 Sonar Testing

For the ultrasonic sensor, the main attribute in need of testing is the maximum and minimum range. This testing can be done quite simply by connecting the ultrasonic sensor to an MCU and placing objects at specified distances away from the sensor and validating that the distance that is computed by the MCU using the values transmitted from the sensor are accurate to the expected values given the distance the object is placed away from the sensor. The beam pattern is also another characteristic that may be tested, although this characteristic may be difficult to accurately test due to its variability and shape. The sensitivity of the sensor is also a trait that may need testing, as it is important that the sensor is in a particular range of sensitivity that does not pick up unnecessary results but also does not miss important events. This may be tested by placing objects of varying sizes in front of the sensor and verifying whether the sensor is capable of detecting it. This test would not be completely rigorous or accurate but would give the general sense for the limitations of the sensor. For the purposes of this application, it should be enough to test the maximum and minimum range and obtain a general understanding of the maximum extents of the beams cone and sensitivity of the sensor. It is also important to test the current draw of the device for confirmation, as this value is important for the battery capacity calculations.

Sonar testing was done on our selected part the LV-MaxSonar-EZ MB1010. The only other component necessary for the testing was the ATmega328p chip selected as our processor. The MB1010 can take input voltage from a range of 3.3 to 5 volts. There are seven total pins for connection on the MB1010 module. As the ATmega238p development board has pins for 3.3 and 5 volts the 5-volt pin was chosen for the Vcc pin of the MB1010. The ground pin 7 of the MB1010 was connected to ground on the development board. The final pin connection was the PW pin of the MB1010 which was connected to pin 8 of the development board. The other 4 pins can and were left unconnected for the testing as pulse width is the desired signal output.

Using the Arduino IDE interface test code was implemented in order to test the accuracy and limitations listed for the MB1010. Using a small object at first testing was done to compare the output distance displayed on the computer with the measured distance done by hand. This first test was designed to test the accuracy of close objects to the sensor as the datasheet cautions that due to acoustic phase effects any reading between 6 to 20 inches can suffer inaccuracies. Below is an image of the hand measurement and physical set up of the test environment.

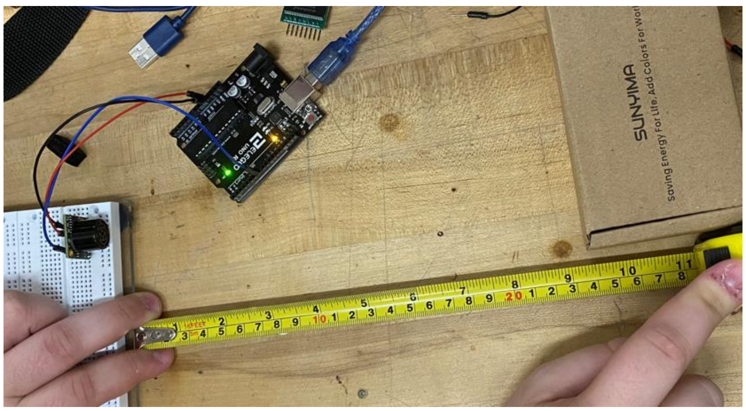

Figure 32 – Sonar Sensor Testing Setup

The hand measurement was 24 centimeters, and the displayed result was 23 centimeters. This level of inaccuracy is within an acceptable margin of error for our device and should not hinder its ability to detect motion inside the pool and alert the user. Next, testing was done of an adult human moving within the range of the sensor. The results of the reading were accurate up to 10 feet. The next test was of the width of the viewing radius of the sensor. The datasheet lists the viewing radius as a beam cone that enlarges the further away from the sensor an object is. For human detection the viewing radius is listed to be about 1 foot wide at the sensor up to 4 feet wide at max distance. This was tested by moving side to side in front of the sensor, and this is shown to be the greatest weakness of the sensor, as anything beyond this range was undetectable. This limitation is the core reason that multiple MB1010 sensors will need to be used in the design in order to have the greatest range of detection possible.

Next the pulse widths of the generated signal were captured in order to compare with the reading of the display in accordance with a measured distance of 14 centimeters. The datasheet specifications list that the range can be calculated as 147 microseconds per inch.

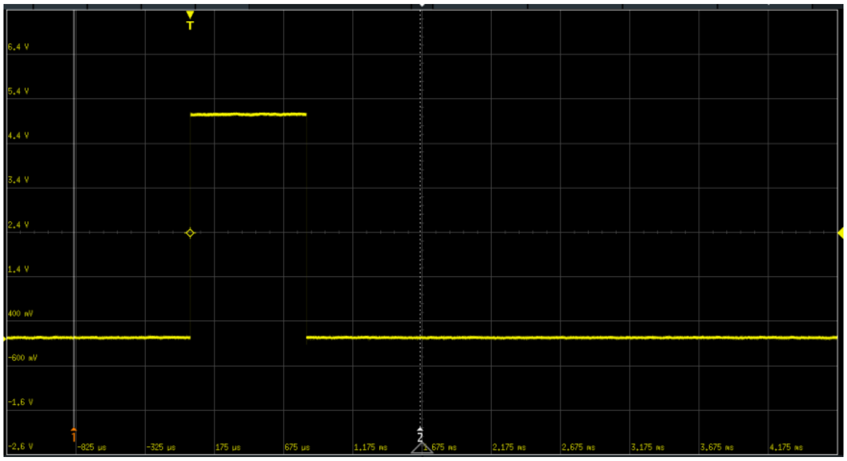

Figure 33 – Pulse Width sonar signal

It can be seen from the image above that the pulse was high for 750 microseconds. Therefore, using the above calculation from the datasheet this reading corresponds to 5.10 inches or 13 centimeters. With testing complete, it is conclusive that this sensor can provide an accurate reading of distance and can be used to detect motion within the distance necessary for adequate functionality of the Pool-AID. The biggest restriction discovered during testing was the limited viewing radius of the MB1010. As this design is dependent on having a 360-degree detection radius at least four of these sensors must be place on the PCB design for adequate viewing coverage.

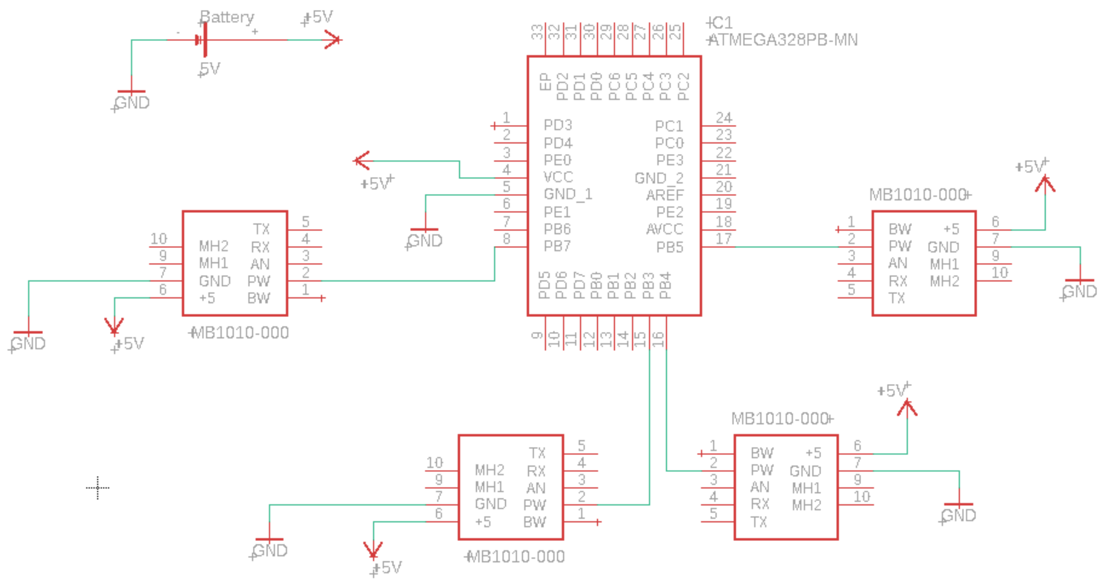

Figure 34 – Potential Sonar schematic

6.5.1.4 PIR Testing

Testing for the passive infrared sensor will generally be very similar to the testing for the ultrasonic sensor. The main characteristics in need of testing is range, spread, sensitivity, and general current draw/power consumption. A difference however is that distance accuracy does not need to be tested as it was with the ultrasonic sensor since the PIR sensor just detects if there is something within the range and not where something is in the range. The maximum and minimum distances can still be tested in the same way, by moving an object away from the sensor until it is no longer able to detect it. The same can be said about the beam spread, though again this is a difficult parameter to test, and even more so in the case of the PIR sensor as beam spread patterns are not readily available

For the initial set up testing of the Parallax PIR sensor four major components were needed. As mentioned previously, this sensor is not meant for exact distance readings like with the sonar sensor so no interface on the computer is necessary to display any kind of readout from the sensor itself. To this effect, the only necessary indicator used during the testing process of the sensor was a red LED. The code compiled for this testing is meant to turn on the LED whenever the PIR sensor detects something in its viewing radius.

The components used for testing were the Parallax 28032 PIR sensor, the Arduino UNO development board containing the ATmega328P processor chip, a red LED, and breadboard for placement. The initial set up for testing is in the figure below.

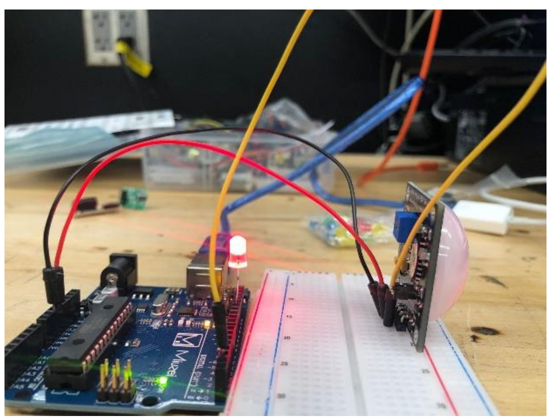

Figure 35 – PIR testing setup

As can be seen from the image, the PIR sensor has four pins to make connections. The Parallax sensor can operate between three to six volts so either the 3.3 or 5 V port can be used for testing. In this case, the 5 Volts output pin was selected to complete the test. Next is the ground pin, a common ground line was created on the breadboard generated from the ground output pin of the Arduino board. The third pin is the output pin, this will generate the signal when detection occurs and is connected to pin 2 on the Arduino UNO development board. The Parallax sensor also has a unique additional fourth pin to its configuration. This pin corresponds to a nighttime enhancement mode.

This enables the sensor for greater detection in lower lighting settings. However, for testing, this pin is unnecessary. This pin is left unconnected as it defaults to high when left unused but could warrant further examination in the future due to its potential uses, as the Pool-AID is meant to be a 24-hour serviceable device upon completion. Now that the PIR sensor is connected the LED is connected directly to the Arduino UNO board via pin 13 and ground. For testing the PIR sensor there are several libraries already available with code that can be used to test the sensor.

As mentioned previously, code was selected to run a simple diagnostic test that will light up an LED when motion is detected. There was a total of three test runs executed each with the goal of checking the three most important specifications of the PIR sensor.
The first test was meant to check if the sensor is only detecting a human being and not inanimate objects. In order to achieve this the code was flipped to flash an LED as long as no human motion is detected. This test was successful and the PIR sensor did not trigger the LED with no human motion in inside its viewing radius, both in distance and range.

The second test was of the viewing radius of the PIR sensor. The data sheet has the Parallax viewing radius graded for a 180-degree spectrum. To test this, we had an individual stand directly to the right and left of the sensor, parallel to the direction the sensor was facing, a full 180-degree test. This test was successful, showing that this sensor can indeed detect at least an adult human moving as much as a 180-degree radius. This is a crucial finding as this reduces the quantity of PIR sensors that will be needed for the Pool-AID design. As few as two sensors can be used for a full 360 degree viewing radius as was desired during part selection.

The third test was of the viewing range of the sensor. The Parallax sensor is graded up to 30 feet for its maximum viewing range. To test this, we had someone stand at the maximum viewing distance from the sensor. This test was also successful, as the LED was lit when entering its maximum viewing distance. The Pool-AID is being designed for pools with dimensions of 10 by 20 feet, so this sensor's testing results meet the criteria desired as well.

At the conclusion of the testing for the Parallax 28032 PIR sensor it has been determined that this sensor will function as intended for the Pool-AID. It can successfully detect human motion at a full 180-degree radius and up to 30 feet. This sensor can therefore serve as an initial trigger for our device as our sonar sensor has a smaller viewing radius but can give more precise readings, the PIR sensor can serve as an initializing process for the sonar sensors on that side of the device. Below is a potential schematic for the two PIR sensors interfaced with the ATmega328P processor.

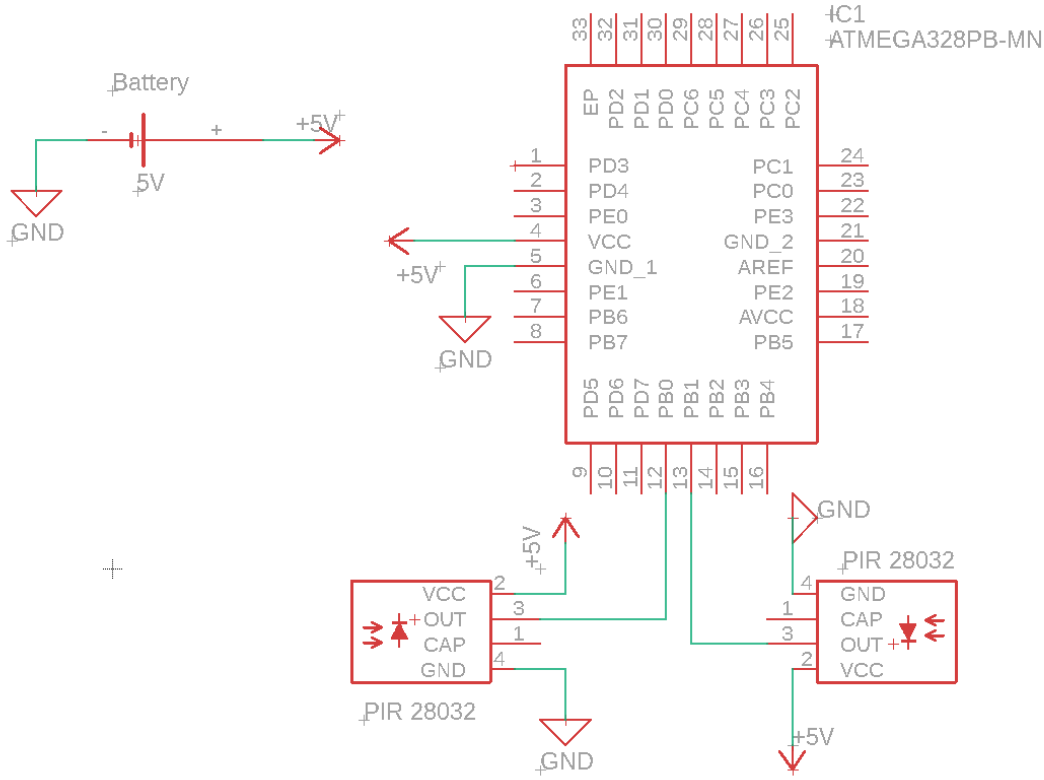

Figure 36 – PIR potential schematic

6.5.1.5 Camera Testing

The camera module will be an important interface for the user to interact with. This will be the only way a user can tell if an alert made by the Pool-AID device warrants action if they are away from the pool and unable to hear the buzzer alarm go off. Testing the camera can be done in two main steps. Once the ArduCAM is successfully connected to the microcontroller, premade testing programs developed for the ArduCAM can be used to ensure that the camera is functioning properly. Once this has been completed, visual confirmation of camera images and videos can be observed to verify that the results are visually satisfactory and give appropriate results.

In order to test the capabilities of the camera we had to interface it with the Arduino UNO development board. The Arducam Shield Mini 2M Plus has a total of 8 pins all of which required connection to function properly. That makes this our most pin demanding module for the Pool-AID design. The Arducam operates at 5V for this testing environment. The pin connections were as follows. The SCL pin is connected to an SCL pin of the Arduino Uno board pin 28 and the SDA is connected next to it at pin 27. The SCK pin goes to pin 13 and the MISO and MOSI pins go to pins 11 and 12 on the Arduino board respectively. The pin connections and an example screen capture are seen in figure 35 below.

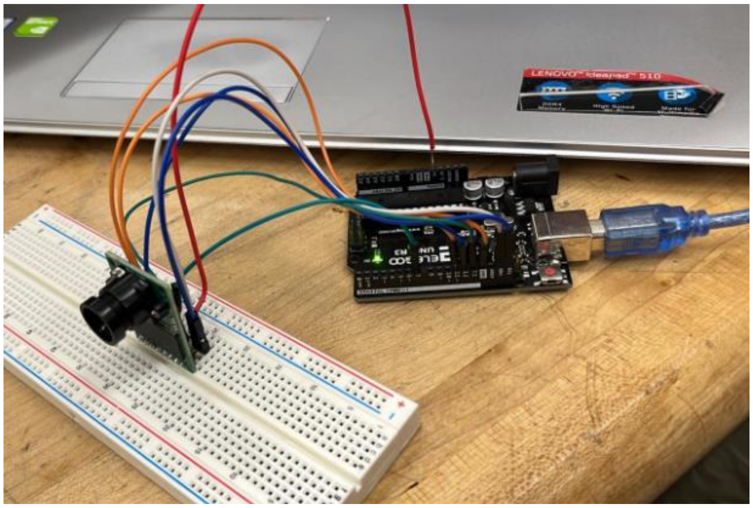

Figure 37 – Camera Testing Setup

As mentioned previously there are three parameters of interest being analyzed with the image capture. First, is the clarity of the picture. This is somewhat subjective, but for the purposes of the Pool-AID the most important aspect when capturing images is that whatever is being captured is distinguishable as either human or not human, as not pictures of inanimate objects should be taken. The image quality view above has been determined as sufficient to meet our specifications.

The second parameter for testing is the viewing range and radius of the camera. The range tested was up to 20 feet which still yielded an image capable of human readability. Therefore, this camera also meets the distance specifications outlined in table 1 of the requirement specifications.

The third parameter tested was the field of view. The data sheet lists this as 60 degrees and from the testing this was shown to be accurate. As with the sensor testing this is the most challenging restriction to overcome in the Pool-AID design. The sensors are small and inexpensive and therefore can be purchased in larger quantities and placed on the PCB layout with relative ease. This is not as easily replicated with the camera module for two main reasons. First, the camera module is expensive at $25.99 and would cost over one hundred dollars to field four modules as will be done with the sonar sensor. Additionally, the pin configuration must be considered.

The ATMega328P chip has a total of 23 I/O pins for configuration. Ignoring the other connections needed for the Pool-AID design, the camera module requires six direct pin connections, so four camera modules would need 24 I/O pins on their own, clearly this is not feasible with the selected chip. Therefore, it was decided that for the most cost-effective means of producing the Pool-AID design the camera module can be connected to a servo motor and programmed to rotate towards the viewed motion to capture images or we can attach the camera module to the receiver module as opposed to the transmitter. This changes several aspects of the design. First, now the location of the receiver module must be attended with greater care. Before, the receiver simply needed to be within a distance in which the transmitter could reliably send data. Now with the camera module as part of the receiver care must be taken to place the receiver module within viewing distance of the pool with the camera module facing it, preferably from an elevated position. With this change to the design plan, it alleviates any further cost constraint on the group from having to purchase additional camera modules or dealing with the complexity of programming the camera with a servo motor. Additionally, the constraints of pin connections for the camera are now addressed as there are fewer components on the receiver end so there will be more than enough available pins to make connections for the camera.

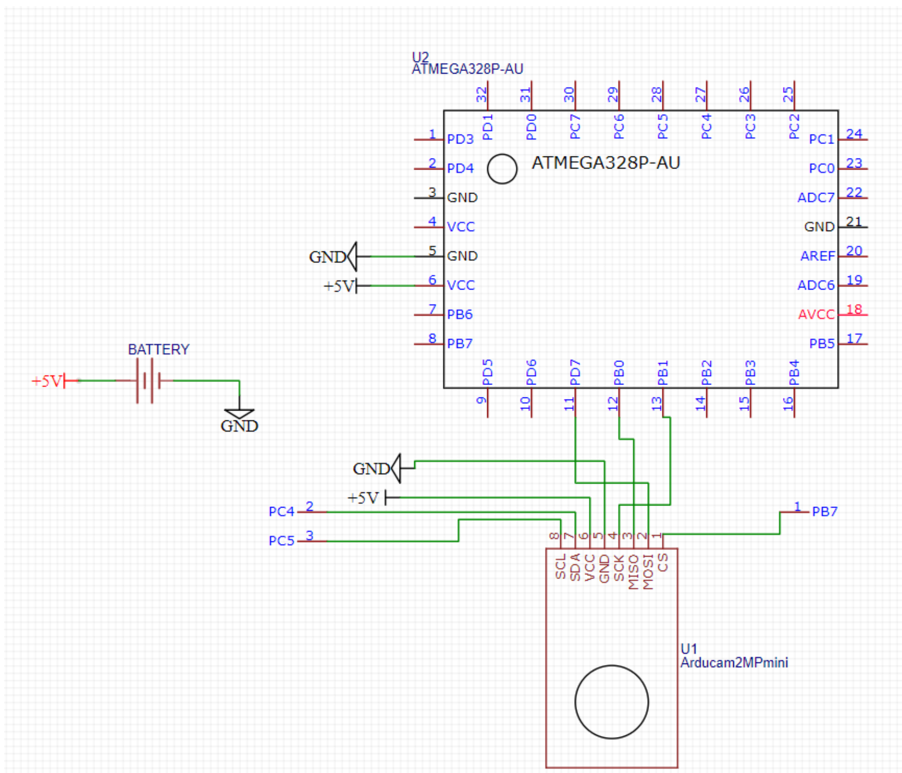

Figure 38 – Camera Module Schematic

6.5.1.6 Buzzer Testing

The buzzer module can be easily verified by simply connecting it to the MCU and running a simple test code to verify that it properly outputs a sound given the appropriate input. This can be done by simply having one member stand at a distance deemed appropriate for a maximum alerting distance and verify if they are able to adequately hear the buzzer's alert.

The buzzer module is a crucial component in the receiving side of the device. As can be seen on the receiver schematics in subsection 6.3.2, the controller on the receiver module is also using the ATMEGA328P unit. We want the buzzer to produce a constant sound as soon as it receives data from the transmitter indicating that some drowning activity has been detected. Note that the buzzer module was tested as an independent module and not connected with the receiver. This was done on purpose to follow through with the idea that we should make sure all our components are functional before moving on to assembling multiple parts and then having a hard time figuring out which part is not working properly.

We first connect the positive terminal of the active-piezo buzzer to the 5 V supply on the launchpad, and then connect a resistor in series with the negative terminal. The resistor is then directly connected to ground on the launchpad. The resistor value is not specified as it is the testing parameter that directly affects how loud or quiet our system was. For this first run, we used 300 Ω.The goal of the initial test phase was to see if the buzzer functions as intended or not, without measuring the actual sound level it produced.

Once we saw that the buzzer was working correctly, we proceeded to the second testing phase where the sound level became our main testing variable. Using an online sound meter, we were able to check if the alarm reached our specified sound level requirement of 95 decibels. The table below highlights the changes we made for each test run, and the direct correlation it had with the sound level of the buzzer.

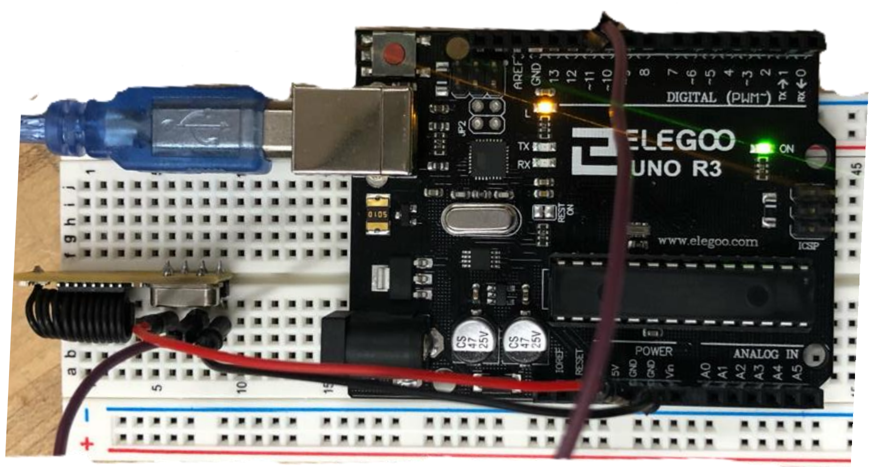

Figure 39 - Receiver Test Layout

	Resistor Value (Ω)	Sound-level (dB)
Test 1	100 Ω	60
Test 2	1000 Ω	42
Test 3	10 Ω	81
Test 4	5 Ω	100
Test 5	3.33 Ω	103

Table 16 - Buzzer Testing Results

As there were no resistors with values less than 10 Ω available, we had to connect two and three resistors in parallel to capture the sound level when the load was very low for tests 4 and 5, respectively. We concluded that the best resistor value we could use for our alarm system would be in the range of 2 to 10 Ω, to provide the user with a sound-level that does not go below 80 dB or exceed the 110 dB safety threshold.

6.5.1.7 Wi-Fi Module Testing

The Wi-Fi module will need to have a few specific characteristics tested. Since the Pool-AID is intended to be able to reach the user at as large a range as possible a 2.4 GHz frequency was selected for the Wi-Fi module. Some testing that will be included for the WI-FI module soldered on the NodeMCU will be a ping test, to see that the ESP8266 was able to connect to WI-FI. If the connection was established successfully, we should receive an IP address, and using the command prompt run the ping command to see if data is being transferred as shown in figure 41.

The first step to establish the WI-FI connection was by enabling a mobile hotspot from any smartphone or a computer. There are 3 important parameters to considered when setting up the mobile hotspot, the SSID or Network name, a password for the network, and the network band. This last one is the most important from the 3. A mobile hotspot was first set with a mobile device to start the connection with the ESP8266. If the ESP8266 connected to WI-FI successfully, the serial terminal from Arduino IDE should return the IP address, but if it doesn't then it keeps waiting for connectivity. The IP address was never returned meaning that connection was not successful, so we tried creating a hotspot using a computer. We figured that there was a third option called network band that allowed you to set the band to 5GHz or 2.4GHz. The ESP8266 uses a 2.4GHz band to work, based on the 802.11 standards, and mobile devices operate with a network band of 5GHz. We not only discovered why our first attempts were not working, but we also had to be careful on how we setup the connection, otherwise the WI-FI module will never connect to the network.

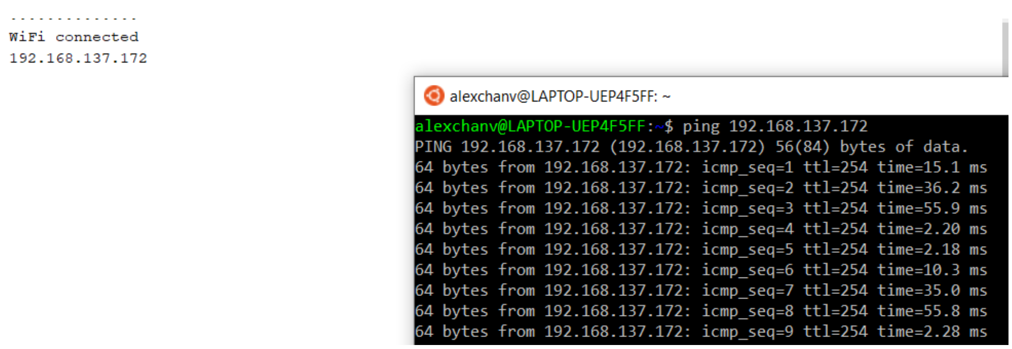

Figure 40 - ESP8266 WI-FI module connection test

Similar to the microcontroller, we performed a basic blinking led test to make sure the GPIO pins are working properly. Additionally, we wanted to test if we can turn off/on a led using the phone, so connectivity with a mobile device can be established. The Blynk app was used to set up the interface to perform this testing.

In subsection 6.5.1.1, we didn't perform any test related to serial communication. Since in our design we want to transfer data that is first handled by the MCU and send it to a cloud database using ESP8266 as the medium for transmitting that data wirelessly, we performed a simple serial communication test that transmits data from the Arduino UNO to the NodeMCU. We need to program first the UNO board as the sender, and then program the NodeMCU as the receiver.

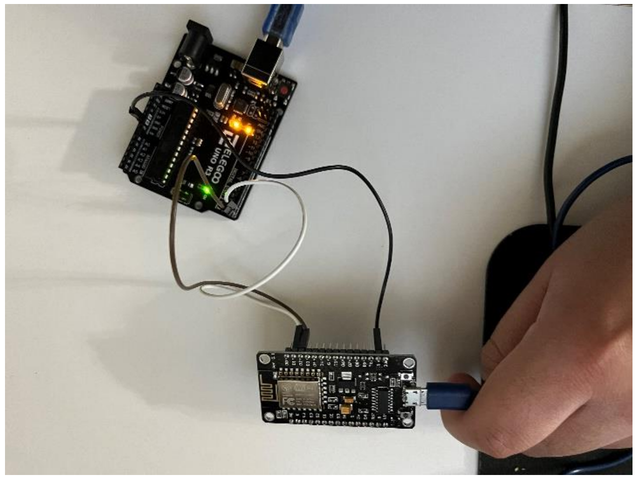

Figure 41 - UNO board and NodeMCU connection

In figure 42, the digital pins D1 and D2 are connected to the Tx and Rx pins from the UNO board. We can program D1 and D2 as the receiver and transmitter using a software library in Arduino IDE for serial communication. For testing serial communication, we just send a string that says "Sending from Arduino Uno" to the NodeMCU. If the communication is successful and the NodeMCU is receiving data, the string should be printed in the serial terminal for port COM9. With this test, we could understand how serial communication works with both development boards, and we could try sending more unstructured data such as sensor readings or images from the camera module.

6.5.1.8 Servo Motor Testing

The servo motor can be a fairly large draw of power when it is operating and specifically when it is stalling so it is important to test some of its attributes, especially those that have to do with current draw. The idle current, running current, and stall current should be tested to verify that they are as specified by the datasheet. The idle current should be approximately 5 milliamperes, the running current (with no load) should be approximately 150 milliamperes, and the stalling current should be approximately 780 milliamperes.

The stalling current is shown to be very large and should be avoided as much as possible to prevent power supply issues and battery lifetime issues. The 200-degree rotation limiting angle should also be visually confirmed to be within 5 degrees of the specified value. This can be done very simply by having a test program setup using the microcontroller that rotates the servo motor to it maximum limits of rotation. The rotation then can be easily observed visually to determine if it seems to be within the intended operation values specified by the datasheet.

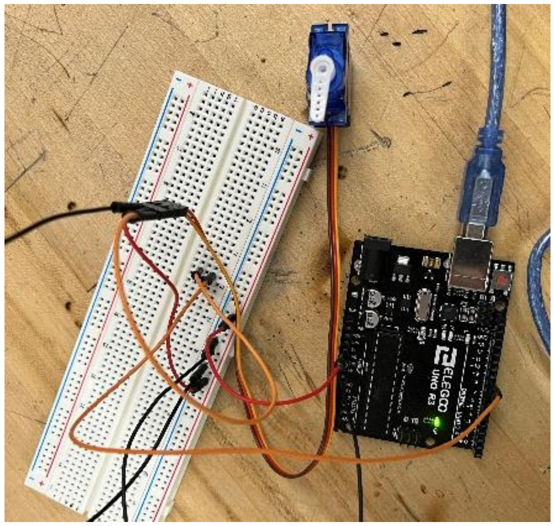

Figure 42 - Servo Motor connection with UNO board

The servo motor was tested with both the Arduino Uno and the NodeMCU. The servo motor will be controlled by the NodeMCU mainly, so it will not only be continuously rotating but also control it using the mobile application. The control testing for the servo motor will be performed using Pulse Width Modulation. For the continuous servo motor, PWM will the determine how fast and in what direction the servo motor will rotate. We can test the rotation of the servo motor, by creating a servo object in our code, and writing the position angle to it. For writing the angle the servo will rotate to, we need to set the pulse duration.

On table 17, there are some approximate values for the pulse durations and the angle the pulse will represent. There can be variation on the angles depending on the quality of the servo motor. This will be different for continuous servo motors, since the signal received by the servo motor will affect the rotation speed and orientation, either clockwise or counterclockwise. In testing we will determine what pulse width we want to keep a descent speed for the servo motor to rotate the camera without making the system to bounce in the pool. The servo motor we have available right now is only able to rotate 180 degrees, so we tested rotation from some angles between 0 and 180 degrees. In the code, we have to configure the position of the servo motor and put an upper bound in a loop that represents how many degrees it will rotate. This code is already available in the IDE, so there was no need to write the code from the scratch. The servo motor requires a library to work with the IDE. We observed that if we modify the delay, it will have an effect on the servo to reach some position; even though we have the servo setup to rotate 180 degrees, it won't exactly reach out that position because of timing. We change the delay to 30ms, the servo motor will be closer to rotate 180 degrees, but with a smaller delay of 10ms, it will only rotate to at least 90 degrees.

Pulse width	Position in degrees
1ms	0
1.5ms	90 degrees or stopped position
2ms	180 degrees

Table 17 - Simple servo-motor position representation

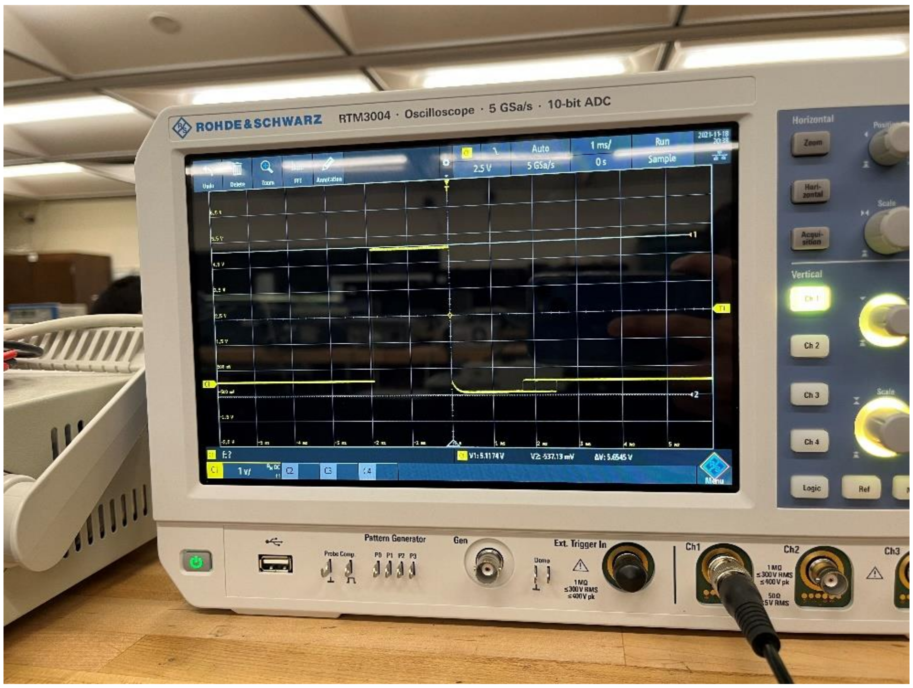

Figure 43 - PWM signal sent from UNO to servo motor

6.5.1.9 Tx & Rx Testing

The Tx and Rx modules have a more intricate design plan and were difficult to set up initially. These are components that will facilitate the communication between our two separate units, the transmitter and receiver. As the receiver will never be sending data to the transmitter, the transmission of data from Tx to Rx will be simplex. The receiver will never have any information to send back to the main unit as it is set up to provide an analog response for the user to hear by triggering the buzzer module tested above.

To make sure the Tx and Rx snap-on parts were functioning correctly, we first connected the transmitter's three pins to the ATmega328P Arduino launchpad. The voltage and ground pins were connected to the 5 V supply and GND pins on the launchpad, respectively. The data pin was connected to pin 12 of the controlling unit to send the data out. The fourth pin on the transmitter is meant for the antenna, as it is a wireless module; however, the antenna is soldered onto the part so that pin was left alone.

Similarly, the receiving module was set up on a second ATmega328P Arduino launchpad and connected accordingly. The data pin on the receiver's end was connected to pin 11 on the board as this was configured to read data in. Since the buzzer was not part of this test, we verified that the data was in fact transferred over and the output was shown on the serial terminal of the receiver's end. The message was a simple string containing 'Hello, World!', and the second test used 'Received data' as the message.

The results from these tests were very helpful in terms of us deciding whether we wanted the alarm to be incorporated within the main unit or on a separate unit. The use of these wireless transmitting modules will support our idea of keeping the alarm in a location that is closer to the home where a parent would be in case of an accident. The next step to test that would give us a quantitative measure would be finding the appropriate distance range between the two modules that would not compromise the efficiency of the receiver's response time and the proximity to the user.

6.6 Software Testing

After talking about the software design, the group needs to develop a test plan for testing the software that will be implemented for the final product. The Pool-AID system make use of various software tools, and testing has to be made to identify possible defects on the software implementation and make some new test for correctness. Since the microcontroller and Wi-Fi module are compatible with Arduino IDE, we will used it as our testing environment for the software implemented to the MCU. For the mobile application development, will be made on Visual Studio Code, and any errors will be identified using a debugger or emulator.

Microcontroller communication

Using Arduino IDE, we will perform some testing to see the interaction of the board with other components. Testing will start with small programs such as blinking the LED, to check the board is answering accordingly to the program we are running. After testing the first program we will start some other components we might want to use for the project such as the servo motor.

The idea of the program implemented is to make the servo motor rotate 360 degrees. In case the servo motor doesn't rotate the desired degrees, that could mean there are some parameters that need to be modified and run another test. There are many built-in programs we can test with the microcontroller, but for testing we will focus on developing a program to work with each module or component we acquired and import the necessary libraries.

ESP8266 Wi-Fi module

Similar to the microcontroller, we will test the WI-FI module to see that connectivity to the device is functional. We can perform a simple ping test on the terminal to check the Wi-Fi module is connected properly. If the ping command is working by passing the IP address of the module, then it is enabled for Wi-Fi.

Once connection is tested, we can perform a similar test with the servo motor and control it using a smartphone. We are still using Arduino IDE to load to program to the chip of the NodeMCU, but we will use BlynkApp to make some basic UI interface for controlling the servo motor. This test will help us later when we get to develop the mobile application, and we can use Blynk for testing specific components using wireless connectivity.

Communication with the database

The database, created in the cloud, we will use should hold the information received by the microcontroller from the camera module and the sensor readings. We will start testing the database by first setting the cloud environment and have some small database with some tables declared. We will store any type of unstructured data first to verify the database was set correctly and that we can access the information once uploaded to the cloud. After checking that the database works, we will try to start sending data from the sensors to the database using the WI-FI module.

This test is actually harder to get on the first attempt since we need to make sure the code is functional, the previous testing processes mentioned must be completed, and that the data represents the expected results. All the results will be documented, so the process of every testing is recorded for all members to keep testing and try to make some correctness. If we received the data we expected and store it to the database, that means the system is communicating correctly with the database cloud service.

Mobile application testing

There are different techniques for testing a mobile application before this one is released to the market. During the development of a web or mobile application there might be some bugs or errors that would affect performance and reliability of the application. Some of the testing techniques we will consider for the development of our Pool-AID mobile application are listed below.

Documentation

Documentation is meant to be the starting phase of every application. It refers to what and how will the application be built, and in what order testing techniques should be applied. This is the test plan the team will follow before starting to build the application. Some test cases must be included to detect possible errors on the application. Some questions such as How can we implement this feature? What information do we require to add this setting? Should we work on this section first before going to another? The members in charge of software testing should plan what the design will be and elaborate some flowcharts and diagrams about the functionality of the application. Detecting errors is not easily visible when development has not started yet, but it will be important to consider some test case at each stage.

Compatibility Testing

The application will be designed to work in android and apple. Compatibility testing will tell us if the application can be adapted to any device, and the application loads according to hardware specifications, screen size and resolution, operating system version. Testing the database working with the app is part of this testing technique.

Usability Testing

Our design will have a friendly user-interface and easy navigation. The Usability test will tell us whether the application satisfy user's experience and what bugs might appear to improve it. Our application would only have what the user needs to communicate with the system such as monitoring, and data storage, so easy access to those features should be provided in the user-interface.

Performance Testing

An efficient mobile application is determined by its performance. Some processes to measure the applications performance is being checking whether the loading time of the user-interface is consistent, what is the storage of the application with and without data being hold, how updates make the application still functional in any device after every update, and minimal crashing of the application.

Functional Testing

During functional testing, we will make sure the application works according to the software specification we list. Some ways we can test functionality in our mobile application could be checking whether we can communicate with the database in real-time, widgets are loaded without interruptions, and what changes to the UI should be made. This is usually one of the last testing techniques apply during the development.

6.6 Software Testing Environment

Most testing regarding the functionality of the microcontroller and how its able to communicate and control the sensors from the system, will be using software tools such as Arduino IDE. Moreover, other tools such as EAGLE were used to design the schematics for the Pool-AID system, as well as the PCB design we will make. Most hardware tools will need to work with a software environment to function. The Discovery Kit provided includes all the hardware we need to run some test in case we don't count with the lab equipment and make some test at home; however, we wouldn't be able to use them if we don't install the Diligent software environment.

Arduino IDE

Similar to Code Composer Studio, Arduino IDE is the platform we will used to test the code that we will write for the system. Arduino IDE comes with some built-in libraries that can be used to test the Arduino boards such as the UNO Rev3. Some information that the Arduino IDE will provide us regarding the program is whether there is a typo in the code, if the program requires some additional libraries, if the program compiled successfully, and what is the size of the program.

There are some libraries that are not installed by default in Arduino IDE. However, the IDE allows you to install external libraries that we can use for our hardware tools such as the ESP8266Wifi library, the RF library, and the BlynkApp library. Arduino made this IDE to work with the board they develop, but other boards can also be added to the software. The NodeMCU development board, which is the board that has the ESP8266 WI-FI module, can also work with Arduino IDE and be added easily to the compiler using the board manager setting. Arduino IDE comes with some examples for every board that is compatible with. This feature is great for testing if the board we are using is being programmed correctly and help us study more about how to write our programs.

Eagle

Eagle is a software tool that will allow us to design the schematics for the main system and the PCB design. The group is already familiar with EAGLE, so we decided to use it as the main platform for hardware design. It provides us with some built-in libraries that can be used to add components for the schematic. The way we are using EAGLE is by making some schematics first for each individual hardware component such as the microcontroller with the RF transmitter, or communication with between the MCU and the ESP8266 WI-FI module.

This will help us first have some mapping on how we want things to be connected and test them physically; if the original connections don't work or if physically the design doesn't look good, we will have to make some adjustments to the wiring in EAGLE first, so we can always redesign some schematics if needed. The PCB design won't be started until the final design for the schematic is completed. We might want to add some external libraries to EAGLE, since the ATmega328p and the ESP8266 footprints are not available by default as well as for other components in our design.

Diligent software for the discovery kit

The discovery kit provides some hardware tools we can use in case some testing is needed to be performed outside the lab. The Discovery Kit counts with a hardware tool called Diligent analog discovery 2 that works with a software called Diligent Waveforms. This full version of the software can only be installed if we count with the kit, so only one member will have access to the software tool. Some information that can be found on the Diligent website about Waveforms is that we can connect the Diligent Analog Discovery 2 to our computer through USB and use it for hardware testing.

Some instruments the Waveform software tool provides are an Oscilloscope, Waveform generator, Power supply, network and spectrum analyzer, logic analyzer, pattern generator, voltmeter, protocol analyzer, impedance analyzer, and many others. We won't use all of them, but we can document our testing without counting with an Oscilloscope or Voltmeter. We could use the Oscilloscope to picture the Pulse width modulation signal sent to the Servo motor and document the value of the duty cycle and pulse duration that works best for our design. We can also configure the power supplies from the Diligent hardware in case we need to power up some specific component from the system, and there is not supplier available.

Visual Studio Code

Visual Studio Code is an open-source code editor specially designed for software developers by Microsoft. Applications such as Full-Stack web applications or Native Mobile applications can be designed in this environment. It doesn't come with the libraries we need by default or packages to work with different frameworks, so we have to install some expansions from the application available in its built-in store.

All software testing regarding the mobile application we are designing for the Pool-AID System will be done here. We should be able to create mobile applications with React Native in Visual Studio Code; however, any extension that is required for the development of the app needs to be installed using the command prompt. Fortunately, VS provides access to the terminal, so we don't need to exit it every time a new plugin or extension is installed.

We can test compatibility and responsiveness of the application using Visual Studio Code. There are some emulators that can be work with VSCode externally and internally. Initially we can use Android IOS emulator by Diemas Michiels to test the responsiveness of the application with Android and IOS devices; this part of the testing will look that all widgets and components were loaded correctly, and if not, we can make the adjustments on Visual Studio Code.

6.8 Prototyping

There are different prototyping requirements for Pool-AID to be the best version of itself by the end of the project term. This section will go over and present all the different prototypes designed by our team. The first prototype we will discuss is that of the exterior look of the device. Next, we will discuss the printed circuit board (PCB) prototype for the receiver and the transmitter.

6.8.1 Exterior Prototype

The housing for the transmitter of the Pool-AID device must meet two basic requirements. It must float, and it must not restrict the ability of our device to perform its various functions. In order to select the proper housing, two design shapes were considered. The first design shape is a rectangular housing. Some advantages of this type of container would be the ease of placement for the PCB within it. With a flat surface no special considerations need to be made in terms of keeping the PCB placement consistent to allow the sensors a reliable and constant view of the pool. Another option would be a spherical housing environment. This could present a more challenging situation for the placement of the PCB. However, the aesthetic of the housing unit is an important aspect to consider. As the housing unit is the main portion of the Pool-AID that the user will see and interact with daily as it floats in their pool, it is important to have an aesthetic design to increase the potential marketability of the device. Therefore, we decided that a sphere like container would provide us with the most efficient and aesthetic look for a tool that will be visible on any pool surface. The sphere container will likely be clear with some sort of sunlight shading to provide protection to the hardware in the interior.

The container will be made of plastic material to provide us with two features, maintaining a waterproof system and not interrupting the visibility scope of the sensors underwater. There might be a small challenge with finding or manufacturing such a specific container, so a 3D printer will be considered in the case where its availability becomes a constraint. It's spherical shape in the bottom will allow us to extend certain features and mobilize certain components so that their range is not limited. For example, having the contained space in the bottom allows us to rotate the camera and sonar-sensor which helps us extend their visibility scope and lower the number of parts we need to cover 360º.

One potential vendor option will be Envision Plastic and Design. This company creates custom plastic enclosures. This option would allow us to craft a specific design tailored to our specifications. Envision, has a variety of customization options such as transparent enclosures, and housing specifically designed for electronic components such as PCB's. One distinct advantage of using Envision to design the housing unit will be the vast quantity of material available to choose from. Envision has 24 different plastic-based materials with various properties. With this in mind, finding a suitable material to house the transmitter won't be as potentially restricted.

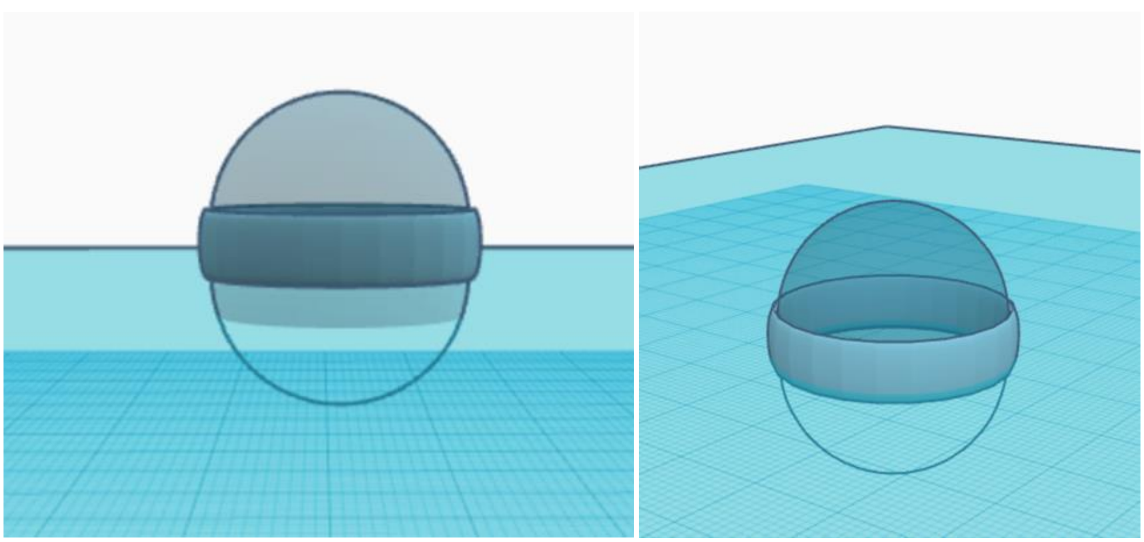

Figure 44 - Side *(left)* & Top-angle *(right)* view of Pool-AID

6.8.2 Significant PCB Design

This design section of the project will present us with the most difficulties that will range from the layout of the components to the troubleshooting of the actual printed board. As we want to minimize the number of snap-on components we will be using for our final product, we must design schematics that take into consideration the power supply, the controller that provides us with the most pins for our components, and a board size that is relatively small to fit within the dimensions specified (*15 x 15 x 15 in*).

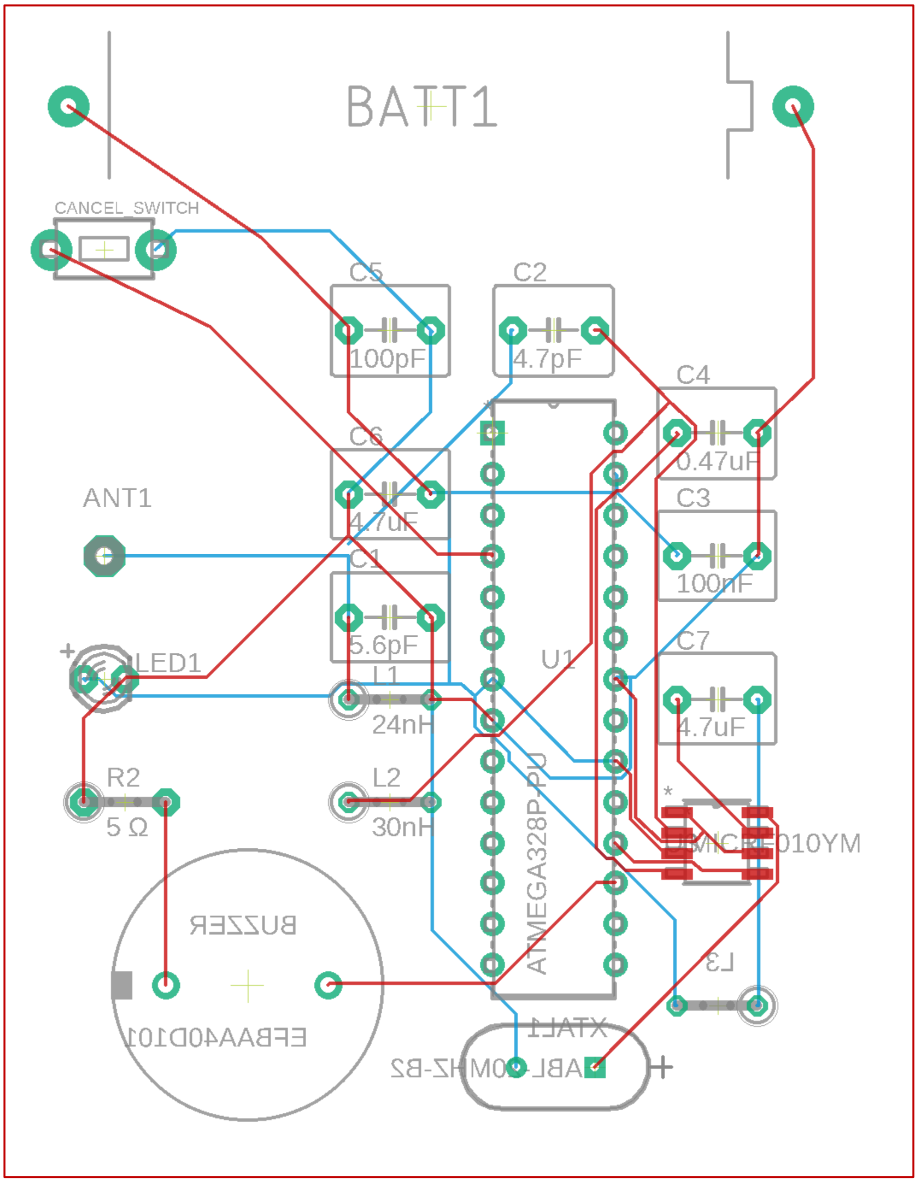

Figure 45 - PCB Design of the Receiver *(Subject to change)*

We will have two PCB designs manufactured, one for the transmitting end and another for the receiving end. The receiver's board is shown on Figure 46**.** It will be the more compact design of the two boards we will be using. It will also be the less intricate design of the two as it does not have any sensor dependencies to function, and only depends on the signal of the transmitter to trigger the camera module embedded within it.

The main PCB design will be the transmitter unit, and that will be attached on our main, active product. This board will have the sensors, Wi-Fi module, solar panel cells, and transmitting module. Our challenge will be making sure that it is not overloaded with components that it affects the functionality of the system. Another thing to keep in mind is that the Wi-Fi module will not be supplying the camera module as mentioned in our original design plan. Figure 46 shows the current board layout generated from the schematics designed and discussed in *sub-section 6.3*.

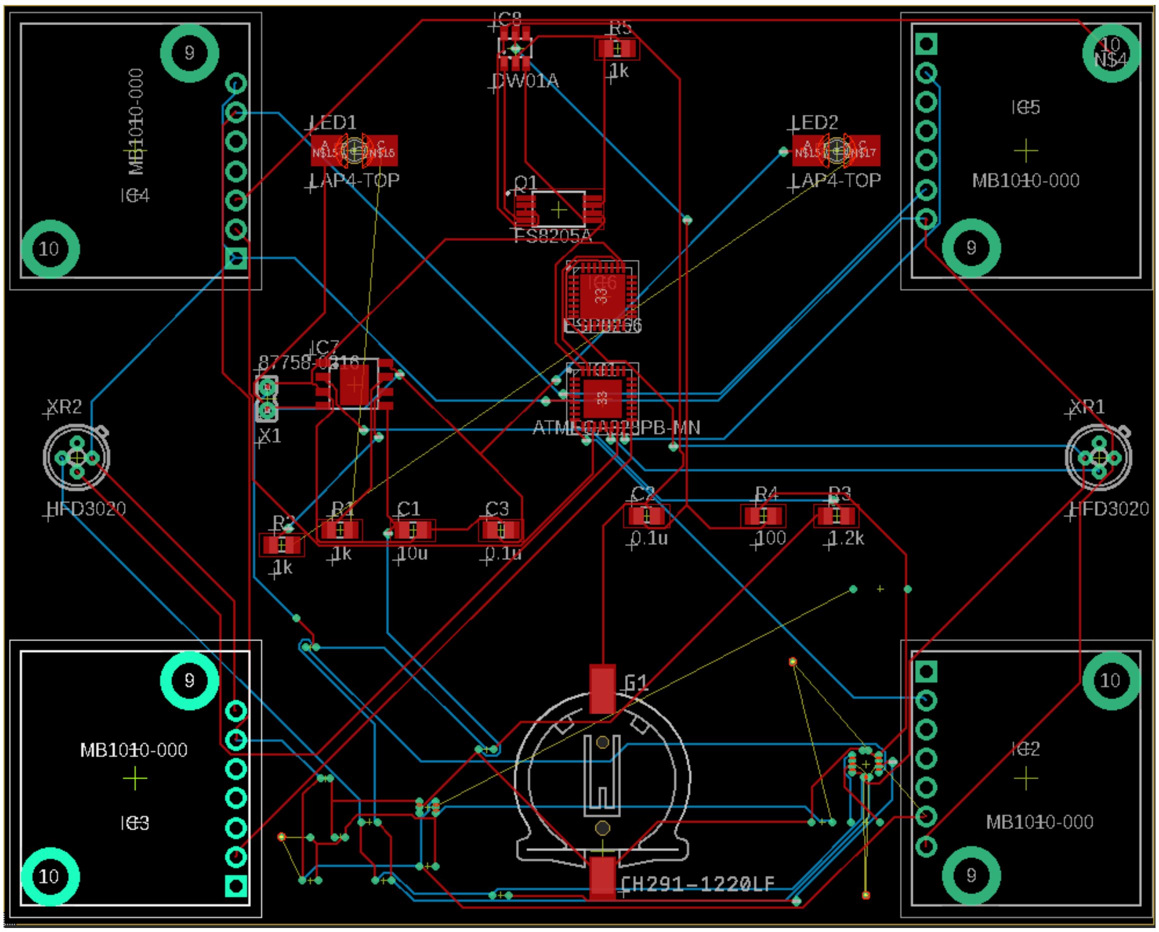

Figure 46 – PCB design of Transmitter

7. Administration

7.1 Milestones

As discussed in section 4, under constraints, Pool-AID has a limited amount of time to realize the device in its entirety. This design project process will begin during the Senior Design I course, which is about 16 weeks long and carry over to a second semester for about the same duration. The project milestones listed below highlight the major deadlines our team will have to work with and most importantly, meet. Since this is a two-term project, the first phase is mostly research and document based with very little prototyping. The second phase of the project will focus on building the device and making sure it is fully functional.

While the table below does not reflect the workload each milestone implies, our team will put in as much effort to present a fully functional device by the end of Senior Design II. The italicized parts mark the milestones that have been successfully met and completed, while the regular cells highlight the milestones that are ahead of us.

Description	Duration	Date
Project Idea	*2 weeks*	*8/23-9/6*
Divide and Conquer 1.0	*1 week*	*9/10-9/17*
Part Research and acquisition	*2 weeks*	*9/18-10/1*
Divide and Conquer 2.0	*2 weeks*	*9/18-10/1*
Interface/test controller with sonar sensor	*1 week*	*10/11-10/15*
Interface/test modules with controller	*1 week*	*10/11-10/15*
Test solar cells	*1 week*	*10/11-10/15*
First Draft Report (60 pages)	6 weeks	10/1-11/5
Further Research and Documentation	4 weeks	11/8-12/6
SDI Final Report Due	**6 weeks**	**7-Dec**
************************** **SD II Begins**	*************	******************
SDII: Begin Building the Device	3 weeks	--
Send PCB Order	2 weeks	--
Testing and Redesigning	4 weeks	--
Finalize Design	3 weeks	--
Presentation	--	--
Final Report	--	--

Table 18 - Senior Design I & II Milestones

7.2 Budget and Financing

There are several considerations to make when considering the budget and financing of the Pool-AID. First is how the project will be financed. As this project has no sponsor, the entire financial burden of the project is being taken on by this Senior Design group. With that in mind the proposed budget of $300 must be strictly adhered to in order to avoid unreasonable financial strain on the members of the group. Second, the budget must also allow for a cost competitive product. If the product were to be placed on the market the Pool-AID needs market for a profitable price margin.

For the Pool-AID to be a competitive product on today's market special consideration must be paid towards the budgeting of the design and creation process. There are several products on the market today that are for the prevention of drowning in residential pools. This product strives to deliver added, improved, and new functionalities when compared to other products on the market. In order for it to be profitable it must remain within the budget constraints of the group and be price competitive with any similar products on the market.

As an example, one of the products discussed previously, the Coral Manta 3000 retails for around $2500 USD while another less advanced product such as the PE23 Pool Alarm retails for $150 USD. With this in mind, there is quite a wide margin in price for the available drowning prevention devices on the market, however these are the extreme ends of the spectrum. Most pool devices retail around $200 and therefore, given the features of the Pool-AID, any marketable price within this range would yield a cost competitive product as long as it exceeds the budget of production.

The proposed budget listed earlier in this document was a maximum of $300 USD. Therefore, any price above $300 would technically yield a profit. This would make the cost of the device marginally higher than the average cost of most products on the market. They key to remaining competitive in the market with a higher price will be the additionally features of the device that its competitors lack such as solar panels, camera, and the user app. The budget thus encompasses the purchase of all parts, PCB fabrication, cloud services, and device housing necessary for the creation of the Pool-AID

7.3 PCB vendors

This following section will be covering Pool-AID 's potential vendors. We will compare their advantages and disadvantages, discuss their pre-order checklist, and the overall costs of having our PCB manufactured with them. Time will be a key factor in selecting the manufacturer. The goal is to test the PCB, make changes accordingly, and manufacture the newer design to allow the team to assemble the device with all the parts in hand. Regardless of how early our team is able to complete the design and submit it, our selected vendor must have a competent shipping record.

7.3.1 PCB-Pool

PCB-Pool is a German company based in Ireland. One of the main advantages they provide to their customers is the kitting service, which would allow us to order the designed PCB along with all the sensors we must solder on the PCB under one vendor. This would also allow us to minimize our shipping costs and track back to one manufacturer in the case where a component is missing or not functioning. Another important feature to note is that they support all of the design software file formats our team would be using. This would allow the team members to migrate from one platform to another without worrying about the vendor file format restrictions.

Ordering from PCB-Pool also comes with its drawbacks. As it is based in Europe, they only accept payments in euros, and that implies that the BOM they would provide us with would also be in the EU's national currency. While paying in a different currency would not be a difficult challenge to overcome, the overhead conversion charges by the banking system here could add up to affect the total cost of our system.

Considering our PCB design requires 2 to 4 layers, PCB-Pool would be able to prototype it with the following specifications [53]:

- FR4 base material
- 1 mm or 1.6 mm material thickness
- 35 µm copper thickness
- Lead-free (hot air leveling) or Chemical Nickel/Gold (ENIG)

7.3.2 OSH Park

OSH Park is a manufacturing company based in the United States. They are known for their purple solder mask on custom boards. The OSH Park website has multiple resources available for us to use when designing our board, selecting footprints, and finalizing our files to send over to the manufacturer. One great advantage about this supplier is the level of detail provided on their guidelines. Using these guidelines, we minimize our chances of having a malfunctioning board before sending it in for manufacturing.

OSH Park is directly compatible with Eagle, which is the design software all of our team members have been exposed to, so the PCB file format (.brd) can be uploaded without any other Gerber files. Another advantage that comes with ordering from this vendor, is that they produce a high-quality board with a relatively low cost compared to other vendors in the market. Not only is the quality guaranteed, but we would also get three copies of the board as long as it is between 2 to 4 layers. More on this will be discussed in the final section of this sub-section.

OSH Park would be able to prototype it with the following specifications:

- FR4 base material
- 1.6 mm board thickness
- ENIG finish

The minimum design rules for 2-layer boards [54]:

- 6 mil (0.1524mm) trace clearance
- 6 mil (0.1524mm) trace width
- 10 mil (0.254mm) drill size
- 5 mil (0.127mm) annular ring

Ordering our prototype from OSH Park would not come with any significant disadvantages that could potentially affect our project. The advantages listed above puts them on top of our list because they do not compromise the quality of the board over its complexity.

7.3.3 4PCB by Advanced Circuits

Advanced Circuits is a manufacturing company with headquarters in Colorado. They are very known for their high production and electrical test first pass yields. Their facility allows them to complete the prototype in-house from start to finish, which helps reduce the turn time significantly. Advanced Circuits will provide us with multiple advantages if we decide to manufacture our board with them.

As their facilities operate 24 hours a day, our 2-layered board prototype could be shipped to us on the same day. They have 24/7 live technical support to help us finalize our board before the board’s assembly process starts. Advanced Circuits also leads a student sponsorship program, which we qualify for as long as we reach out to our local representative through our UCF email. This sponsorship would cut down or cost for a 2-layer PCB quick turn prototype of 60 square inches from $99 to $33 as they would waive the minimum order of 3 [55].

Considering our PCB design is standard and requires 0 to 10 layers, 4PCB would be able to prototype it with the following specifications:

- FR4 base material
- Lead-free (hot air leveling)
- 5 mil trace clearance
- 5 mil trace width

While Advanced Circuits has an excellent reputation in the PCB manufacturing industry, it does come with one minor disadvantage for our purposes. They are too restrictive with their standard design package that we would have no option but to go for their custom one. With the custom package, our cost would double from that of the standard one to $66 for 30 square inches (compared to 60 sq. in.) and our worst-case turn time would grow significantly from 5 days to 4 weeks.

7.3.4 JLCPCB

JLCPCB is one of the largest PCB manufacturers from China. It offers one of the cheapest PCB prices in the market; you can get 5 pieces of 2-layer PCBs for 2 dollars. Additionally, the components that will be soldered in the PCB are also available at JLCPCB, so they can be ordered along with the PCBs. JLCPCB offers a service called SMT Assembly; the service provides the PCB with all the components soldered. The components selected in every PCB order, a Gerber file should be provided with the PCB Design. Delivery is fast compared to other manufacturers; It could take at most a week to get all PCB pieces.

Ordering our PCB in JLCPCB can be cheap; however, there are some limitations and disadvantages. It is compatible with EasyEDA software, so once the PCB is fully designed, it can be ordered directly from the application. However, we are using EAGLE as the main software to design the PCB. We could get the .brd file, but we would need to find if we can get a Gerber file for uploading it to our order. Additionally, we might re-design the PCB if we see that we need to re-route any component or adjust mounting holes, so if we order 5 pieces for the first design and after using one, we need to re-design, we will end up having extra PCBs that are not useful anymore.

There are different options for ordering the PCBs depending on its specifications such as the number of layers. PCBs with 1 to 6 layers cost $2 for five pieces. The cost increases considerably when getting the SMT assembly service starting at $7 extra.

The specifications JLCPCB has for prototyping the PCB are the following:

- FR4 base material
- 0.4/0.6/0.8/1.0/1.2/1.6/2.0mm board thickness
- 0.20mm- 6.30mm drill hole size with a tolerance of +0.13/-0.08mm
- 400x500mm maximum PCB dimensions with tolerance of +-0.2mm

There are no real disadvantages of ordering the PCB on JLCPCB. We would pay a cheap price for more than one piece, and we could use the others in case one of them is not soldered properly or if one piece gets damaged. Disadvantages would come when changes are made to the design, and we end up having extra pieces of PCB that are not useful anymore. JLCPCB is still a good PCB manufacturer; since the PCB we are designing is in between 2 to 4 layers, we can get our layout manufactured for a low price and shipped in a short time.

7.3.5 Selection

Pool-AID will only need the necessary boards for one fully functional device and not multiple devices. This entails that our manufacturer must be able to fulfill an individual order. None of the manufacturers have a minimum PCB order specified for the service we are looking for, so this means this will not be an issue moving on regardless of our selection. As mentioned in the introduction of this chapter, we want to choose a manufacturer that is able to deliver our product on time. With that in mind, to avoid any issues with oversees shipping and constraints, PCB-Pool will not be a suitable manufacturer for what we are looking for. Not only does the location put them at a disadvantage, but they also just recently started accepting Eagle file formats. This is not a good thing because that means the prototype could be flawed since they have not been working with it as long as the other manufacturers have. A similar problem occurs with JLCPCB, the Gerber file needed comes from using EasyEDA and not Eagle, so it might be difficult for the manufacturer to match their specifications with our PCB.

The next thing we are looking at is quality versus cost. We want to find the perfect balance between both and not compromise either constraint. While 4PCB has a great student program that would help minimize our costs, they also have too many restrictions that OSH Park does not on relatively the same prototype package. OSH Park, on the other hand, has great online guidelines and forums, but 4PCB would provide us with live help from licensed professionals 24/7 in case of a question or concern.

The point that determined which manufacturer we were going to pick was the quantity of boards received under one order. Initially, this was not a point we picked on; however, we realized that we are working with a device that is exposed to water. When building and assembling the full device, we might run into an accident where our board gets damaged either with exposure to water or some other factor that we have not yet considered. JLCPCB provide 5 pieces for a small price, so we will have enough time to replace if one gets damaged; however, if we order the pieces without any component soldered it means that we would have to solder everything again. Meaning that if we want to have a replacement if the original gets damaged, it would be beneficial to have the components ready, but ir would increase the cost a lot. Within the OSH Park package, we receive three of the same printed board without an extra charge to the cost listed below. While the delivery time may not be as fast as 4PCB in the best-case scenario, the worst-case delivery time is only a few days later and not weeks. Based on the information and facts provided above, we will be manufacturing our PCB with OSH Park.

	PCB-Pool	**OSH Park**	**4PCB**	**JLCPCB**
Location	Germany	U.S.A	U.S.A	China
Boards	1	3	1	5
Turn Time	6 days + Int'l Shipping	8 – 12 Days	1-5 days 5 days – 4 weeks	2-7 days
Cost	$86 / 12 sq. in	$5 / 1 sq. in.	$33 / 60 sq. in $66 / 30 sq. in	$2 / 5 sq. in

Table 19 – PCB Vendors Comparison

7.4 Bill of Materials

Throughout the acquiring parts process, we have kept track of all the parts purchased, their vendor, and price. The table below highlights all of the mentioned parts and the total cost of the current parts our team has been able to acquire. The starred items under the cost column were previously owned by a member or multiple members and was, therefore, not part of the total cost. These bills of material include parts that will be part of the final design as well as parts used for testing.

Part Name	Part Reference	Cost
LV-MaxSonar-EZ1	MB1010-000	$32.95
RF Link	433 MHz Link Kit	$4.90
Camera Module	OV2640	$25.99
PIR Sensor	Parallax 28032	$12.95
Wi-Fi Module	ESP8266	$13.99
Camera with Wi-Fi	ESP32-CAM	$17.99
Continuous Servo	EAEC100300	$8.97
Buzzer	Piezo-Electric	**
ATmega328P	Arduino Board	$20.00
3.7V LiPo Battery	LP653042	$10.99
5V 1A LiPo Battery Charger (x10)	TP4056 03962A	$8.99
5V 500mA Buck Boost Converter	Pololu S7V7F5	$ 15.31
Solar Panels (10x)	SUNYIMA (N/A)	$16.88
	Total	$189.82

Table 20 - Total Cost of the System

A more accurate BOM table will be provided when the PCBs are finalized and sent in for manufacturing. As of right now, the only financial information we can provide is regarding the parts received and tested.

7.5 Senior Design II Plan

Now that the semester has come to an end the group must look ahead towards the future of the Pool-AID project design. Due to the work and research accomplished this semester we were able to achieve a potential schematic and PCB design and layout for the Pool-AID device. Looking ahead to Senior Design 2 it will be important to finalize the ideal PCB designs by comparing several design ideas in terms of component layout in order to settle on an accurate, complete, and most importantly functional PCB design for the transmitter and receiver. Additionally, the housing unit for the floating board must be purchased and compatible with our designed PCB. The build of the Pool-AID prototype will be the initial focus during the beginning of Senior Design 2. As testing components underwater requires the build to be complete, no testing can begin prior to this setup being accomplished.

Once the Pool-AID prototype has been built then the challenge of implementing the functionality can begin. The testing process will commence with the sensor functionality. This is the most crucial element to a working prototype as the sensors bear the burden for discovering any activity that exists within the pool. Once successful implementation of these core elements is complete then the process of communication between the transmitter and receiver can be established. This element of the design as well as the mobile application can be tested outside of the water. Therefore, any potential delay incurred with regards to the underwater testing from potential order delays or availability of a testing environment will not add significant strain on the process of testing since these elements do no require pool access to be tested. Once successful implementation of the sensor configuration and transmitter receiver communication is established, the final element to integrate into the design will be the triggering of the buzzer alarm and camera image capture. The biggest challenge in this implementation will be in the timing. As a short responses time is a key specification of the Pool-AID design, having short latency between the triggering of the buzzer and camera will be of upmost importance.

8. Conclusion

Moving on to Senior Design II, we will come across two main challenges. The first one is making sure the manufactured PCBs are fully functional, tested, and redesigned if necessary. The second challenge is developing a mobile app that reflects all of Pool-AID's features, data, and configurations. The challenge lies more within the learning curve of the new programming syntax for developing a mobile application. The design will focus a lot more on design and data storage than on data-structures and algorithms.

Looking back at the start of the process, our design plan has evolved significantly based around the ultimate goal of delivering a feasible, efficient, and durable device. By keeping these three marketing specifications, we were able to mold all of four team members' idea of a perfect device and merge them into one realistic and functional life-saving tool. We started off with a single unit device and decided that having two units communicating was more feasible. Instead of overloading the transmitter with modules that were not going to be used for determining whether a child was drowning, we agreed that we would maximize our efficiency by moving the camera and buzzer modules to the receiving end. Finally, the team's initial idea of having a sphere-like container in the pool was modified to cut out about 80% of the submerged half since the camera is now going to capture the activity from the receiver's perspective.

While we may have a series of challenges ahead of us, we believe our team has reached a point where we can go into the next term of the project strong. Each member of the team has a contributed significantly to Pool-AID 's progress since the start of the term. We started with a powerful motivation and took it upon ourselves to address it in the most efficient way we knew and discovered along the way. Partitioning tasks, communicating with one another, and allowing each other to learn and experiment has made the design process very pleasant.

Appendix

A1 References

[1] High Performance Sonar Range Finder – Maxbotix Inc.. https://www.maxbotix.com/documents/LV-MaxSonar-EZ_Datasheet.pdf.

[2] "Motors." *DigiKey*, https://www.digikey.com/en/products/detail/adafruit-industries-llc/2442/5774227?utm_adgroup

[3] "ESP8266-NodeMCU." *components101.*, https://components101.com/sites/default/files/component_datasheet/ESP8266-NodeMCU-Datasheet.pdf.

[4] Cdaviddav, et al. "Esp8266 WEMOS D1 Mini Tutorial." *DIYI0T*, 7 May 2021, https://diyi0t.com/esp8266-wemos-d1-mini-tutorial/.

[5] "W600 Datasheet." *components101.*, https://components101.com/sites/default/files/2020-06/W600-Datasheet.pdf

[6] "ESP32-Wroom Datasheet." *Espressif*, https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.pdf.

[7] *Atmel 7810 Automotive Microcontrollers - Microchip Technology*. https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf.

[8] *Atmel 7810 Automotive Microcontrollers - Microchip Technology*. http://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-2549-8-bit-AVR-Microcontroller-ATmega640-1280-1281-2560-2561_datasheet.pdf

[9] "Noise Infographic - Levels by Decibels." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 6 Feb. 2018, https://www.cdc.gov/niosh/topics/noise/infographic-noiselevels.html.

[10] "Florida Climate Information." *Florida Average Weather, Climate, and Temperature Information*, http://www.worldclimate.com/climate/us/florida.

[11] "IEEE 802.11-2020." *IEEE SA - The IEEE Standards Association - Home*, https://standards.ieee.org/standard/802_11-2020.html.

[12] "What Are IEEE 802.11 Standards?" *SignalBoosters*, https://www.signalboosters.com/blog/ieee-802.11-standards-explained-802.11abgnacax/.

[13] "IEEE 802.11 Wireless Standard | Anixter." *Anixter*, https://www.anixter.com/en_au/resources/literature/technical-references/standards/ieee-802-11-wireless-standard.html.

[14] "What Is WIFI: IEEE 802.11." *Electronics Notes*, https://www.electronics-notes.com/articles/connectivity/Wi-Fi-ieee-802-11/standards.php

[15] "JavaScript brief history and ECMAScript (ES6, ES7, ES8, ES9) features" Madasamy M, https://madasamy.medium.com/javascript-brief-history-and-ecmascript-es6-es7-es8-features-673973394df4

[16] "The Current C Programming Language Standard – ISO/IEC 9899:2018 (C18)" American National Standards Institute, https://blog.ansi.org/2018/11/c-language-standard-iso-iec-9899-2018-c18/#gref

[17] "IEEE/ISO/IEC 29119-2-2013 - ISO/IEC/IEEE International Standard - Software and systems engineering - Software testing -- Part 2:Test processes" IEEE Standards Association, https://standards.ieee.org/standard/29119-2-2013.html

[18] "Overview of Software Testing Standard ISO/IEC/IEEE 29119" Hesham Alaqail, Shakeel Ahmed, Research Gate https://www.researchgate.net/publication/323759544_Overview_of_Software_Testing_Standard_ISOIECIEEE_29119

[19] "How to Test a Mobile Application" testbytes, https://www.testbytes.net/blog/how-to-test-a-mobile-application/

[20] "How well-positioned is IEEE 802.11ax to meet the imt-2020 performance requirements?" IEEE Standards University, https://www.standardsuniversity.org/e-magazine/march-2018-volume-8-issue-1-5g-802-11/how-well-positioned-is-ieee-802-11ax-to-meet-the-imt-2020-performance-requirements/

[21] "Powerful PCB Design Tool." *EasyEDA*, https://easyeda.com/.

[22] "Fusion 360: 3D CAD, CAM, CAE & PCB Cloud-Based Software." *Autodesk*, 20 Sept. 2021, https://www.autodesk.com/products/fusion-360/overview.

[23] "Eagle: PCB Design and Electrical Schematic Software." *Autodesk*, 29 Sept. 2021, https://www.autodesk.in/products/eagle/overview.

[24] "Occupancy Motion Sensors Standard." *NEMA*, https://www.nema.org/Standards/view/Occupancy-Motion-Sensors-Standard.

[25] *Association Connecting Electronics Industries IPC-2221A*. http://www-eng.lbl.gov/~shuman/NEXT/CURRENT_DESIGN/TP/MATERIALS/IPC-2221A(L).pdf.

[26] "FSK Radio Transmitter Module" Radio Controlli, https://www.radiocontrolli.com/media/1327_fb1ea4ae622090c6ba14bde2efd583baa4ff6ea3.pdf/o/RC-TFSK3-868.pdf

[27] "LR series Transmitter Module Data Guide" Linx Technologies, https://linxtechnologies.com/wp/wp-content/uploads/txm-fff-lr.pdf

[28] "Radio Transmitter module with SAW oscillator 433.92MHz - ASK/OOK Modulation" Radio Controlli, https://www.radiocontrolli.com/media/1327_f7054732a631aa97d243f26b8bc746cd6da5a5a3.pdf/o/RC-TX1-434.pdf

[29] "MICRF114 Low-Power Integrated Sub-GHz Wireless RF Transmitter Data Sheet" Microchip, https://ww1.microchip.com/downloads/en/DeviceDoc/50002416A.pdf

[30] "FSK Radio Receiver Module" , Radio Controlli https://www.radiocontrolli.com/media/1327_51f1883815d79ec243795bab57d2d3e4ce03ce99.pdf/o/RC-RFSK3-434.pdf

[31] "AM Superhet Receiver Module" Radio Controlli, https://www.radiocontrolli.com/media/1327_608290cd95f44de98a3c3e207fbea53d3d3a54a3.pdf/o/RCASK2-315.pdf

[32] "AM-RRQ3-433P Super Heterodyne Receiver Module" Mouser, https://www.mouser.com/datasheet/2/975/RFSO_S_A0009835311_1-2576119.pdf

[33] "AM-RX12-433 Super Heterodyne Receiver Module" rfsolutions, https://www.rfsolutions.co.uk/downloads/1623839872DS-AM-RX12-3.pdf

[34] "MSP430FR6989 Product Detail" Mouser, https://www.mouser.com/ProductDetail/Texas-Instruments/MSP-EXP430FR6989?qs=sGAEpiMZZMsKEdP9slC0YfSJOgxsaWp2oxCVcxUBRCQ%3D

[35] "ATmega640/1280/1281/2560/2561 datasheet" Atmel, https://ww1.microchip.com/downloads/en/devicedoc/atmel-2549-8-bit-avr-microcontroller-atmega640-1280-1281-2560-2561_datasheet.pdf

[36] "ATmega328P Datasheet" Atmel, https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf

[37] "ESP8266ex Datasheet" Espressif, https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf

[38] "ESP32-WROOM-32 & ESP32-WROOM-32U Datasheet" Espressif, https://www.mouser.com/ProductDetail/Espressif-Systems/ESP32-WROOM-32D?qs=MLItCLRbWszx2KabkKPu5A==

[39] "W600 Product details", SeedStudio https://www.seeedstudio.com/W600-Module-p-4020.html

[40] "Alarm clock Using Atmega-328 and RTC" ATmega32-AVR, https://atmega32-avr.com/alarm-clock-using-atmega-328-rtc/

[41] *Diagram of the System*. https://www.researchgate.net/figure/Circuit-Diagram-of-the-System_fig1_333796313.

[42] "IPC J-STD-001G Requirements for soldered Electrical and Electronic Assemblies" Institute of Printed Circuits, https://www.ipc.org/TOC/IPC-J-STD-001G.pdf

[43] "What are IPC Standards for PCB" EL-PRO-CUS, https://www.elprocus.com/what-are-ipc-standards-for-pcb/

[44] "IPC-7351: The IPC Standard for PCB Footprint Creation" Tempo, https://www.tempoautomation.com/blog/ipc-7351-the-ipc-standard-for-pcb-footprint-creation/

[45] "IPC-7351 Generic Requirements for Surface mount Design and Land Pattern Standard" Institute of Printed Circuits, https://www.ipc.org/TOC/IPC-7351.pdf

[46] "IPC J-STD-001 Standard Soldering Requirements" Rasika, Sierra Circuits, https://www.protoexpress.com/blog/ipc-j-std-001-standard-soldering-requirements/

[47] “MSP430G2x53, MSP430G2x13 Mixed Signal Microcontroller datasheet” Texas Instruments, https://www.ti.com/lit/ds/symlink/msp430g2553.pdf?ts=1638717348806&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FMSP430G2553
[48] “ESP32 Series Datasheet” Espressif, https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf
[49] “PCB Capabilities” JLCPCB, https://jlcpcb.com/VGB?gclid=CjwKCAiAhreNBhAYEiwAFGGKPDg_UdmnkppZ4oj900wTCTfOgJurVbkPzlMpHRPzGf_GpAZbHWpObRoCBNsQAvD_BwE
[50] “ESP32-CAM Development Board” DFROBOT, https://media.digikey.com/pdf/Data%20Sheets/DFRobot%20PDFs/DFR0602_Web.pdf
[51] “MSP430FR6989 Launchpad User’s Guide” Texas Instruments, https://www.ti.com/lit/ug/slau627a/slau627a.pdf?HQS=dis-mous-null-mousermode-dsf-pf-null-wwe&ts=1638743253298&ref_url=https%253A%252F%252Fwww.mouser.com%252F
[52] “MSP430FR698x(1), MSP430FR598x(1) Mixed-Signal Microcontrollers datasheet” Texas instruments, https://www.ti.com/lit/ds/symlink/msp430fr6989.pdf?ts=1638774290989&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FMSP430FR6989
[53] “PCB & Assembly Services.” *Eurocircuits*, 31 Dec. 2020, https://www.eurocircuits.com/pcb-assembly-standard-pool/.
[54] “OSH Park.” *OSH Park* ~, https://oshpark.com/.
[55] “Advanced Circuits.” *USA PCB Manufacturer & Assembly*, https://www.4pcb.com/.
[56] “Eveready 1215 AA battery datasheet. Document 1215NA0218” Eveready, https://data.energizer.com/pdfs/1215.pdf
[57] “LP653042 specification. Document ZJQM-RD-SPC-H0516”, 2019. EEMB, http://eemb.com/public/Download/Rechargeable-Lithium-Battery/Li-Polymer-Battery/Standard-Version/LP653042.pdf
[58] “TP4056 battery charger datasheet” NanJing Top Power ASIC Corp., https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Prototyping/TP4056.pdf
[59] “DW01A battery protection datasheet” Shenzhen H&M Semiconductor Co.Ltd, http://hmsemi.com/downfile/DW01A.PDF
[60] “FS8205A dual N-channel enhancement mode power MOSFET. Document FS8205A-DS-12_EN, Rev 1.2” 2009. Fortune Semiconductor Corporation, https://www.ic-fortune.com/upload/Download/FS8205A-DS-12_EN.pdf
[61] “Florida Sunlight Hours & Renewable Energy Information.” *TurbineGenerator*, 11 Aug. 2018, https://www.turbinegenerator.org/solar/florida/.

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November 25th, 2021

To whom it may concern:

We are a group of engineering students at the University of Central Florida, who are working on designing and building a pool safety alarm. Part of our process includes some research and documentation, which led us to these particular images of the **Poolguard DAPT-2** and **Poolguard PGRM-2**.

We are writing to request from you permission to use these two images, attached below, in our report.

If you are willing to grant us permission to use the images referenced above, please reply with your official confirmation so that we may have your permission on our records.

Thank you for your consideration of this request.

Sincerely,

Houda El Hajouji,
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Alexander Chan-Vielsis,
Chase Willert

University of Central Florida
Department of Electrical and Computer Engineering

B1.2 PoolEye Permission Pending…

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Department of Electrical and Computer Engineering

B1.4 Pool Patrol PA-30 Permission Pending…

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http://www.poolpatrol.com/swimming-pool-alarm-system/

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Kevin Reim,
Alexander Chan-Vielsis,
Chase Willert

University of Central Florida
Department of Electrical and Computer Engineering

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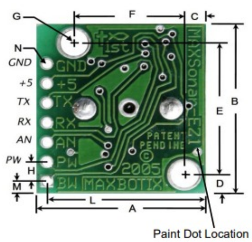
Thank you for your consideration of this request.

Sincerely,

Houda El Hajouji,
Kevin Reim,
Alexander Chan-Vielsis,
Chase Willert

University of Central Florida
Department of Electrical and Computer Engineering



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Thanks.

Joe

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